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**THE PRODUCTIVITY, ECONOMY AND QUALITY OF
WELDING IN THE DIFFERENT GEOGRAPHICAL
AREAS OF CHINA - TODAY AND IN THE FUTURE**

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Abstract

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This master's thesis gives out the real situation of the China welding industry and factories nowadays in different geographical areas, in order to inform the Finnish companies who have the willing to find a Chinese welding subcontractor a proper and correct selection concept by analyzing and supplying the information of different scale and form welding factories in different Chinese areas.

The first section of this thesis gives out the general situation about the co-operation between China and Finland in the welding industry, also includes the general introduction of the Chinese welding industry. The second section gives out the geographical compartmentalization result of Chinese welding industry, which is where and how many areas will be studied in this thesis.

The main body of this thesis is the real information of welding productivity, welding cost, and welding quality in China. All the information was collected from real factories in China by the author. The last section of this thesis is the improvements to the Chinese welding factories that have the willing to become a subcontractor, and the suggestions to the Finnish companies who may find a Chinese welding factory as their subcontractor in future.

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Table of Contents

SYMBOLS AND ABBREVIATIONS

1. INTRODUCTION	8
2. OVERVIEW OF THE CIRCUMSTANCES OF CHINA’S WELDING INDUSTRY	10
2.1. THE STATUS OF THE WELDING INDUSTRIES IN CHINA	10
2.2. THE CIRCUMSTANCES OF THE FINNISH MACHINE COMPANIES BUSINESS IN CHINA – SUBCONTRACTORS, FACTORIES AND THE INTENTIONS	12
2.2.1. The Status of the Chinese Welding Factory as a Subcontractor of Finland Machine Company	12
2.2.2. The Status of Which the Finland Machine Company Intends to Build a Welding Factory in China ...	15
2.3. RESEARCH ITEMS AND METHODS IN THIS THESIS	18
3. THE REGIONAL COMPARTMENTALIZATION OF THE CHINESE WELDING SUBCONTRACTORS AND FACTORIES	20
3.1. THE NATURAL AND INDUSTRIAL REGIONAL COMPARTMENTALIZATION OF CHINESE WELDING INDUSTRY ..	20
3.2. THE RESULT OF THE REGIONAL COMPARTMENTALIZATION OF CHINESE WELDING INDUSTRY	23
4. THE STATUS OF THE NORTH CHINA AREAS’ WELDING FACTORIES	24
4.1. THE PRODUCTIVITY STATUS OF NORTH CHINA AREAS	25
4.1.1. The Productivity Data from Babcock & Wilcox Beijing Company Ltd.....	25
4.1.2. The Productivity Data from Chinacoal Beijing Coal Mining Machinery Co., Ltd	28
4.1.3. The Productivity Data from Shijiazhuang Yulong Machining and Manufacturing Company.....	33
4.1.4. The Productivity Data from Beijing No.2 Machine Tool Works Co., Ltd.....	37
4.1.5. The Productivity Data from Shougang Industrial Equipment Plant	37
4.2. THE COST AND ECONOMY STATUS OF NORTH CHINA AREAS	42
4.2.1. The Cost and Economy Data from Chinacoal Beijing Coal Mining Machinery Co., Ltd.....	42
4.2.2. The Cost and Economy Data from Shijiazhuang Yulong Machining and Manufacturing Company ..	43
4.2.3. The Cost and Economy Data from Shougang Industrial Equipment Plant	44
4.3. THE QUALITY CONTROL INFORMATION OF NORTH CHINA AREAS	46
4.3.1. The Quality Control Information from Babcock & Wilcox Beijing Company Ltd.....	46
4.3.2 The Quality Control Information from Chinacoal Beijing Coal Mining Machinery Co., Ltd	50
4.3.3. The Quality Control Information from Shijiazhuang Yulong Machining and Manufacturing Company	53
4.3.4. The Quality Control Information from Shougang Industrial Equipment Plant	56
4.4. OVERVIEW OF THE WELDING INDUSTRY IN NORTH CHINA AREA.....	60
5. THE STATUS OF THE EASTERN AND COASTAL AREAS’ WELDING FACTORIES.....	63
5.1. THE PRODUCTIVITY STATUES OF EASTERN AND COASTAL AREAS	64
5.1.1. The Productivity Data from Xuzhou Construction Machinery Group	64
5.1.2. The Productivity Data from Zhejiang Shipbuilding Co., Ltd.	67
5.1.3. The Productivity Data from Qingdao Qiyao Wärtsilä MHI Linshan Marine Diesel Co., Ltd. (QMD)71	
5.2. THE COST AND ECONOMY STATUES OF EASTERN AND COASTAL AREAS	77
5.2.1. The Cost and Economy Data from Xuzhou Construction Machinery Group.....	77

5.2.2. The Cost and Economy Data from Zhejiang Shipbuilding Co., Ltd.	80
5.2.3. The Cost and Economy Data from Qingdao Qiyao Wärtsilä MHI Linshan Marine Diesel Co., Ltd. (QMD).....	81
5.3. THE QUALITY CONTROL STATUES OF EASTERN AND COASTAL AREAS	83
5.3.1. The Quality Control Information from Xuzhou Construction Machinery Group	84
5.3.2. The Quality Control Information from Zhejiang Shipbuilding Co., Ltd.	86
5.3.3. The Quality Control Information from Qingdao Qiyao Wärtsilä MHI Linshan Marine Diesel Co., Ltd. (QMD).....	89
5.4. OVERVIEW OF THE WELDING INDUSTRY IN EASTERN AND COASTAL AREAS	95
6. THE STATUS OF THE SOUTHWEST AND INLAND AREAS' WELDING FACTORIES	97
6.1. THE PRODUCTIVITY STATUS OF SOUTHWEST AND INLAND AREAS	98
6.1.1. The Productivity Data from Yunnan Yunmeng Steel Structure Manufacture Factory	98
6.1.2. The Productivity Data from Mechanical Repair Factory of Yunnan Copper Corporation	104
6.1.3. The Productivity Data from Chengdu Zhongling Radio Communication Cable Co., Ltd	106
6.1.4. The Productivity Data from Sichuan Tungtay New Material Technology Co., Ltd	110
6.2. THE COST AND ECONOMY STATUS OF SOUTHWEST AND INLAND AREAS	115
6.2.1. The Cost and Economy Data from Yunnan Yunmeng Steel Structure Manufacture Factory	115
6.2.2. The Cost and Economy Data from Mechanical Repair Factory of Yunnan Copper Corporation.....	116
6.2.3. The Cost and Economy Data from Chengdu Zhongling Radio Communication Cable Co., Ltd.....	117
6.3. THE WELDING QUALITY STATUS OF SOUTHWEST AND INLAND AREAS	118
6.3.1. The Quality Control Information from Yunnan Yunmeng Steel Structure Manufacture Factory	118
6.3.2. The Quality Control Information from Mechanical Repair Factory of Yunnan Copper Corporation	121
6.3.3. The Quality Control Information from Chengdu Zhongling Radio Communication Cable Co., Ltd	123
6.4. OVERVIEW OF THE WELDING INDUSTRY IN SOUTHWEST AND INLAND AREAS	125
7. THE FUTURE PROSPECT OF THE FINLAND COMPANIES' INVESTMENT IN CHINA AND SUGGESTIONS TO THE CHINESE SUBCONTRACTORS	129
7.1. THE ADVANTAGES AND DISADVANTAGES IN THREE AREAS AND DIFFERENT SCALE FACTORIES IN CHINA	129
7.2. THE IMPROVEMENT SUGGESTIONS TO THE CHINESE WELDING SUBCONTRACTORS AND FACTORIES	132
7.2.1. Total Welding Management.....	132
7.2.2. The PDCA Theory.....	134
7.2.3. The 5S Methodology	136
7.2.4. The Six Sigma Business Management Strategy	137
7.2.5. The Implement of GB and EN-ISO Welding Standards	139
7.3. THE OPTIMAL CHOICE SUGGESTION FOR THE FINNISH COMPANIES.....	140
7.3.1. The Optimal Choice of Chinese Welding Subcontractors	140
7.3.2. The Future Suggestion of China Business to the Finnish Companies	141
8. CONCLUSION.....	143

REFERENCES

APPENDIX

Symbols and Abbreviations

€	The Euro symbol
°C	The symbol of Celsius degree
kN	Mechanical units (SI units), kilo-Newton
kWh	Energy unit, kilowatt
m	Length unit (SI units), meter
m²	Area unit (SI units), square meter
m³	Volume unit (SI units), cubic meter
5S	Abbreviation of Seiri, Seiton, Seiso, Seiketsu and Shitsuke. The name of a workplace organization methodology
ABS	American Bureau of Shipping
ASME	American Society of Mechanical Engineers
CO₂	Carbon dioxide
DMADV	A project methodology. Define, Measure, Analyze, Design, and Verify
DMAIC	A project methodology. Define, Measure, Analyze, Improve, and Control
DNV	Det Norske Veritas.
DVS	German welding society
EN	European committee for standardization
ERP	Enterprise Resourcing Planning
FCL	Full Container Load
FINCHI	Abbreviation of Finland-China innovation center
FINPRO	A globally operating organization that helps Finnish companies to grow internationally and successfully.

GB Chinese national standards

GL Germanischer Lloyd

GRC Governance, Risk, and Compliance

ISO International Organization for Standardization

ISO 9000 An ISO standard is related to the quality management systems and is designed to help organizations ensure they meet the needs of customers and other stakeholders

ISO 14000 An ISO environmental management standard

ISO 18000 International standards for occupational healthy and safety management system, a Chinese enterprise formulation

IWE International Welding Engineer

MAG Metal Active Gas welding

MIG Metal Inert Gas welding

MMA Manual Metal Arc welding

MT Magnetic Test

NDT Non-Destruction Test

O₂ Oxygen

PDCA Plan-Do-Check-Act, a four-step problem solving working process

PT Penetration Test

pWPS preliminary Welding Procedure Specification

Q235 A type of carbon structure steel. Chinese steel type series

QHSE Quality, Health, Safety and Environment management system

RMB The name of Chinese currency, 1 RMB = 0.1077 € (18.7.2011)

S235 A type of alloyed structure steel.

SAP Systems Applications and products in data Processing

SAW Submerged Arc Welding

Six Sigma A business management strategy

TEKES The Finnish Funding Agency for Technology and Innovation

TIG Tungsten Inert Gas arc welding

UT Ultrasonic Test

VT Visual Test

WPQR Welding Procedure Qualification Record

WPS Welding Procedure Specification

X-ray The abbreviation of X-radiation. A form of electromagnetic radiation.

1. Introduction

The background of this thesis is the HitNetGlobal project. HitNetGlobal project is a LUT Metal Technology and laser processing laboratory project cooperated with Savonia polytechnic. It is paid mainly from TEKES and little part from other aboard companies. One aim of this project is to understand the real situation of the Chinese welding industry exactly. The information about Chinese welding industry will be collected from Chinese welding institute, Chinese welding factories and some of the Chinese universities. The information includes the welding productivity, the welding cost, and the quality control situation in China.

The study processes of this topic is to find real and latest information form any possible channels, like the website of the Chinese factories, the promotional materials of the welding factories, and the field visits of the Chinese factories. Because of this, a three months itinerary to China has been made. The destination cities in China cover a large range from north China areas to the southwest Chinese areas. More than 15 professional welding factories or factories which have the welding workshop were visited, and from the conversation and investigation in those factories, a group of detailed and reliable information was collected. By using and analyzing that information, a general profile of nowadays Chinese welding factories situation was discovered. Moreover, the suggestions to those Finnish companies who intend to find a Chinese subcontractor were given out.

The information about productivity, cost, and quality control is divided into several information points. The welder amount, customer situation, welder skill, plant situation, manufacturing machines and equipments, processing materials, and environment and climates are using to measure the level of the productivity. The worker's wage, materials cost, logistics and transportation cost, and turnover are using to measure the cost of welding work activities in China. The processing steps, WPS standards, culture and human factors, personal training methods, inspection methods, maintains of machines, material storage condition, and the environment and climate conditions are using to measure the quality control level of the

welding factories.

After the survey period, many problems were found in the welding processes in Chinese welding factories. How to balance the low cost and unsatisfactory quality of Chinese products nowadays becomes the top significant issue does not only exist in the welding industry. A more better and reliable regulatory approach or a more proper qualification system of Chinese welding factories should be studied in future as quickly as possible. Moreover, the mutual understanding of cultural, living, and habits between eastern and western in future also play an important role in the co-operation.

2. Overview of the Circumstances of China's Welding Industry

2.1. The Status of the Welding Industries in China

China nowadays becomes the world's biggest machining product export center and one of the biggest trade markets all over the world. The welding industry is one of the most important branches in the Chinese machining industry. From the report of one of the world's two largest welding fair, Beijing Essen Welding and Cutting Fair, 2009 edition and 2010 edition, the number of exhibitors increases from 866 to 973, meanwhile the number of professional visitors increases from 42852 to 62486, the exhibition space increases from 69354 m² to 92400 m². [1][2] This growth trends illustrates that more and more people in China were interested with this industry, more and more foreign companies regard China as their significant cooperative targets and their present and future markets.

The Chinese welding industry have two interdependence and meanwhile independent research fields: the research of welding machine and new welding technologies, and the application of welding methods. The former branch's research will carry out in professional institute, like Harbin Welding Institute, the professional national welding research agencies, department in the universities and other research institutes, and certain research center inside large enterprises. The latter branch will conduct almost at every corner inside Chinese territory, which are covering and including steel structure manufacturing, ship building industry, construction machine fabrication, high pressure vessels assembly, and chemical metallurgical industry.

The research and innovation work will be done in some institute and universities, such as China Welding Institute (Harbin), welding department in Kunming University of science and technology, welding institute in Xi'an Jiaotong University, institute of high energy physics

Chinese academy of sciences, and China iron & steel research institute group. Those department and institutes above, but not only them, will responsible for the research and promotion for the new technologies and welding machines. The different applications and using ways by welding techniques will responsible for each industry association in China. Meanwhile, the real information of economical, quality, and productivity situation for each Chinese factory must be collected from the each factory's person, like factory director, management staff, technical officer, or section managers.

The visiting to China welding institute was made on 21.2.2011 and the institute director Mr. Shi He gives out the overview of the research status quo of Chinese welding technology and welding machine. This institute only care about technology development but not the welding application situation to each industry region.

The visiting to China iron & steel research institute group was made on 5.3.2011 and the senior researcher Mr. Yiying Li gives out the comments and suggestions about this topic. He recommended that the steel structure factories, the shipbuilding factories, and boiler manufacturing factories should be the paramount visiting factories. Those factories above represent the application level of Chinese welding technologies.

The visiting to Kunming University of science and technology was made on 8.4.2011 and the Doctor Ruibo Yuan and Professor He Pang give out the welding technology application statues quo in China southwest areas.

The welding processing workshops in China is all kinds; even small private workshops can have the ability, but usually not good quality, to carry out the welding works. The private small workshops and middle scale factories occupy a large market share in China. Some large factories nowadays close out their welding workshop and move their welding works to the small or middle scale factories, which are professional factories just focusing on the welding and machining works. The large factories, such like the Beijing 2nd lathe factory, just need keep their assembly plant only. This kind of cooperation pattern are becoming the prosperity

development mode not only between foreign companies and Chinese subcontractors, but also between the state-owned enterprises and small private factories after the reform and opening up period in China. In this thesis, 14 factories related with welding processing works in China's different areas will be researched. (see in the appendix I)

2.2. The Circumstances of the Finnish Machine Companies Business in China – Subcontractors, Factories and the Intentions

The Finnish companies also make a lot of commercial activities in China, but they choose different cooperation patterns between their Chinese partners. Like Junttan or Normet, they choose the Chinese welding factories as their subcontractors, the final assembly work of their product will also finished in their own factories in Finland. Some other companies like Wärtsilä, KOMAS, or Metso, they choose the way to build their own or joint venture factories in China, the total work from welding, machining, to assembly works will all done inside China domain. Most of other Finnish companies also utilize those two kinds of cooperation pattern with Chinese companies; this is the general business methods between the two countries.

The different global market, company size and understanding level of China will determine the different cooperation model to those Finland companies. But the targets to all the Finnish companies are same: higher productivity, lower cost, and reliable quality. Some of the Finnish government agencies like TEKES, FINPRO, or FINCHI, will help the newcomer Finnish companies to build their offices and handle Chinese legal and tax issues. Moreover, some Finnish intermediary agencies can help (should be paid) the Finland companies to find out their appropriate subcontractors in China, like Eastwork agency.

2.2.1. The Status of the Chinese Welding Factory as a Subcontractor of Finland Machine Company

Three Finland or Europe companies' cooperation model with Chinese subcontractor will be

introduced in this section. The three companies will be Junttan, Normet, and ABB. They use identical way to find their partner but the details may vary.

Junttan is a Finnish company that is specialized in the design, manufacture, and service of hydraulic piling equipment in Kuopio, Finland. Junttan's piling equipment now is being used in 45 different countries. [3] In Kuopio, Junttan built its new assembly workshop (see in figure 1), the machine parts will be assembled in every single working cell, like cleaning cell, hydraulic parts assembly cell, engine assembly cell, electronic equipment assembly cell, driving cab assembly cell, and crane and hammer assembly cell.



Fig1. The Junttan's assembly workshop in Kuopio

There are no machining and welding workshops in Junttan's factory, all the machine parts manufacture work will assigned to their subcontractors all over the world. Junttan make their cooperation with specific Finnish agency, like Eastwork company (see in figure 2). The agency will be in charge of the contact with Chinese factories, the quality control, machine parts transport, and bargain with Chinese factories. Junttan just need to deal business with Finnish people, and without doubt, this kind of cooperation will reduce the communication difficulty to a Finnish machine manufacture company who even know almost nothing detail

about China.

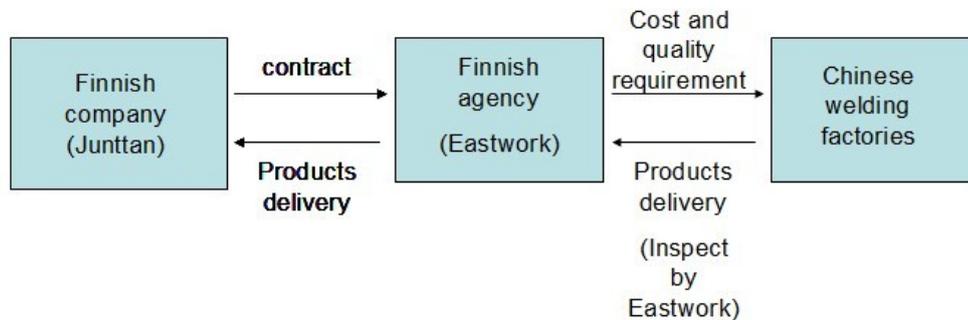


Fig2. The cooperation model between Junttan and Chinese factories

But the disadvantages are: Junttan will pay to the agency company, which will increase the cost; Junttan do not know anything about China's tax, transportation fee, labor cost, or the differences between middle and small scale Chinese factories ultimately. Those disadvantages will influence the future strategic decision in dealing with the issue of Chinese subcontractors to some extent.

Normet choose the same cooperation like Junttan, but they have different working style. Normet is specialized in the development, production, and sales of equipment and vehicles for underground mining and tunnel construction in Iisalmi, Finland. [4] They have assembly workshops in, not only, but most of, Finland. Machine parts will be manufactured, including welding works, in other subcontractors and themselves. At Iisalmi, the Normet factory has machining, welding, painting, assembly, and reassembly workshops. This circumstances determined that Normet do not have very strong needs to the Chinese subcontractors. Normet ask Chinese factories manufacture some welding parts recently, but the quality problem should not be underestimated (see in figure 3).



Fig3. The less penetration problem from Chinese welding factories (Normet specimen)

Those irresponsible welding fabrication works will lead to several problems. The reputation of Chinese factories will be destroyed, and over time, the Finnish companies' trust and confidence in their Chinese partner will be lost, like the example of Ponsse.

Like ABB company, their co-operation way is to find suitable OEM subcontractor by itself, and control the quality problems also by itself, in Shanghai, China. There are more than two welding workshops in Shanghai that have become the subcontractors of ABB company. The problem is also the quality control, Mr. Ming Sun in LUT did an investigation and research work last year in order to improve the poor quality of those welding factories. [5]

2.2.2. The Status of Which the Finland Machine Company Intends to Build a Welding Factory in China

The other collaboration model between Finnish companies and their Chinese partners will be much different compared with the previous way. Like Wärtsilä, KOMAS, or Metso, they have their own or joint venture factories in China. All the manufacturing and assembly works will be done in China. In this section, those three companies will be examples in order to illustrate this collaboration model.

Wärtsilä is the world leader in complete lifecycle power solutions for the marine diesel engine

markets. [6] Wärtsilä nowadays is one of the leaders in the ship machinery, propulsion, and maneuvering industries. The headquarter of this company is in Vaasa, Finland, and their design center located in Switzerland. In the end of 2006, Wärtsilä built their joint venture marine diesel engine factories (for short title: QMD) with China and Japan capital in Qingdao, Shandong province, China. This huge factory has three complete processing plants, the welding plants (including a painting workshop) (see in figure 4), the machining plants, and the assembly plants.



Fig4. The welding plant of QMD

Although the QMD factory established in China, all the management, production, and quality control tasks will be all in strict accordance with an excellent model. Therefore, in this factory, not only the low labor and material cost requirements can be reached, but also the high quality products can be manufactured. The management concepts and quality control methods should be the most significant experiences that those small or private Chinese welding factories must be learned in future.



Fig5. The assembly plant of QMD

Because Wärtsilä's large scales of production and their big global market, they decide to build not only welding and machining factories, but also the assembly plant, just like the picture above depicted (see in figure 5). The quality will also be guaranteed by their efficient management pattern; meanwhile, the ocean transportation cost will also decrease. One thing should be noticed is that the broad global market, which is the key point, decided that Wärtsilä build their assembly plant in China.

Metso is a global supplier of services and technologies on mining, paper and pulp, power plant, construction, gas and oil, and recycling industries. [7] Mr. Jarmo Heinonen in TEKES Shanghai, and Mr. Kari Hiltunen in TEKES Beijing give out a brief introduction of the Metso's business and factories in China. Metso build their own factories and find appropriate Chinese subcontractors, including welding factories, all around China, even in the northwest

inland areas. Metso has offices and factories in Beijing, Shanghai, Tianjin, Shaanxi, Jiangsu, and Guangdong. This cooperation strategy ensures that Metso does not only can obtain their concessions in terms of production and processing, but also has great benefit to further development of Chinese market.

KOMAS is an engineering industry system supplier, and their services contain manufacturing of machined components, ready-fitted hydraulic unit, welded steel structures, and mechanical and sub assemblies. [8] KOMAS has leased a production factory in Suzhou, Jiangsu province. This new factories will renovation and reconstruction according to the requirements of KOMAS. KOMAS is not a large company like those two companies were introduced above, the expansion capacity determined the development approach in China. Those small and medium enterprises in Finland and Europe ought to consider the KOMAS' experiences in future.

2.3. Research Items and Methods in This Thesis

In this thesis, all the Chinese welding factories or the welding plant inside huge enterprises will be studies into three aspects: the productivity, the economy and cost, and the quality control system.

The influence factors of productivity will be: the number of workers (welders), the customers' case, the level of the workers' skill, the plant situation, the processing equipments and machines, the auxiliary materials and gases, the environment and climate conditions, and other factors.

The influence factors of economy and cost will be: the wages of staffs (workers and management staffs), the cost of all the materials (main material and auxiliary materials), the cost of processing, the cost of logistics, the margin and turnover of the factories or welding shops, and other factors.

The influence factors of quality and quality control will be: the processing crafts, the WPQR and WPS, the human and culture factors, the assessment of welders and welders' skill level, the inspection methods and steps, the maintains and repair conditions of equipments and machines, the storage conditions of materials, and environment and climate conditions.

By using the research items mentioned above, the final objective is to find out the most suitable and appropriate subcontractors in China, in order to give out the suggestions to the Finnish companies who have the willing to conduct the commission processing works. At the conclusion of this thesis, a relative optimized result will be given out.

The selection principles of the Chinese welding companies are: a) covering more range of different areas, like north China area, eastern and coastal areas, and southwest and inland areas, b) covering more range of different scales, like state-owned large scale factories, state-owned or private middle scale factories, and private small scale factories, c) covering more range of industries, like the shipbuilding industry, the boiler and pressure vessel industry, the steel structure industry, the metallurgical industry, the machine manufacturing industry, and electronics industry. These selection principles ensure the more intuitive and comprehensive research result of this thesis.

3. The Regional Compartmentalization of the Chinese Welding Subcontractors and Factories

The reasons for regional compartmentalization of Chinese welding industry are based on the influence factors to the welding processing. The temperature and humidity are two key influence factors to the welding processing works in terms of natural zoning, meanwhile, the human factor, market, and materials are the most significant influence factors to the welding works in terms of industrial zoning. The natural and industrial regional compartmentalization should be considered simultaneously in this thesis.

3.1. The Natural and Industrial Regional Compartmentalization of Chinese Welding Industry

The natural geographical compartmentalization is based on the commonality of natural geographical environment and composition, the similarity of natural geographical structure, and the unity of natural geographical processing. The aim of natural geographical compartmentalization is the certain levels division of a geographical region. [9] The region differences of temperature, humidity, soil, and vegetation are the four key factors may influence the natural geographical compartmentalization (see in figure 6). Considering about the welding industry, the only first two factors, temperature and humidity, will be researched in this thesis.



Fig6. The natural geographical compartmentalization of China

The final natural geographical compartmentalization of China is shown on the figure 6, the north China can be divided into two areas: north China and northeast China; the south China can be divided into two areas: eastern and coastal area, and southwest and inland area; the Tibet and Qinghai area do not have developed industry because of the protection of excellent natural environment; the northwest area have some industry but do not include in the research of this thesis.[10] The north China areas located in the temperateness areas, the cold winter temperature (the average temperature is -2.6°C in south, -12.2°C in north) will influence the welding works.[11][12] The south China areas located in the sub-tropical area, the heavy humidity in summer (average relative humidity is 63.3% to 73.2%) will influence the welding works.[11][13] (see in appendix II)

Considering about the requirements of the economical division and industrial division of Chinese region, the distribution of materials, markets, fuel, and labor factors, and economical,

society and ecology factors are combined influence to the industrial geographical compartmentalization.[14][15] For the researching of welding industry in China, the labor factors, the markets, the society factors and materials are the most significant elements. Dr. Meie Ren gave out the Chinese industrial zoning plan indicates that there are six grand industrials in China: the northeast area, the north China area, the northwest area, the center China area, the southeast area, and the southwest area.[16] The figure 7 gives out the latest division plan of Chinese economical zoning which is published by the Chinese government.



Fig7. The industrial and economical geographical compartmentalization of China

The seven Chinese economical zones are: 1) the Bohai economic zone, 2) the northeast economic zone, 3) the Yangzi river economic zone, 4) the center China economic zone, 5) the southeast and coastal economic zone, 6) great southwest economic zone, and 7) northwest economic zone.

3.2. The Result of the Regional Compartmentalization of Chinese Welding Industry

Considering about the natural geographical compartmentalization, the industrial compartmentalization, and the welding factories which were included in this research, there are three different areas of Chinese welding industry: the north China area, the eastern and coastal area, and the southwest and inland area. Five welding factories in Beijing city and Hebei province are studied in this thesis as the representation of north China area. Five welding factories in Shandong province, Jiangsu province, and Zhejiang province are studied in this thesis as the representation of eastern and coastal area. Four welding factories in Yunnan province and Sichuan province are studied in this thesis as the representation of southwest and inland areas (see in appendix I). In appendix I, other three welding research institute in China, and the location of TEKES offices in China are also marked.

The human factors will to some extent influence the working attitude. Different geographical environment and climate will determine the different people characters. The catholic people characters of each China area will be listed here. The advantages of people character in north China area are honest, kindness, loyalty, practical, and warmhearted; meanwhile the disadvantages are flabby and lazy. The advantages of people character in eastern and coastal China areas are hardship bearing, competent, pragmatic, flexibility and pioneering spirit; meanwhile the disadvantages are shrewd and cowardly. The advantages of people character in southwest and inland China areas are smart, clever, and unsophisticated; meanwhile the disadvantages are undisciplined and short-sighted. [17]

4. The Status of the North China Areas' Welding Factories

In this section, five north China area's factories, which has big amount of welding applicant works, will be introduced according to the visiting sequence. This expedition was made by Xiaochen Yang from 30.12.2010 to 6.5.2011 in China. Focus on the north China area; there are totally five visiting to Beijing, Shijiazhuang, and Qian'an cities respectively.

The first expedition was made on 30.12.2010, and the target company is Babcock & Wilcox Beijing company ltd. This factory is used to be the biggest boiler manufacturer in north China, and now partly turned to be a joint venture with USA, partly kept as a small independent state-owned enterprise. The factory is located at the west side of Beijing city, not far away from the downtown. The products of this factory are: Radiant Boiler-Carolina type, W type fire boiler, Supercritical boiler U-1, and Ultra Supercritical boiler.

The second expedition was made on 10.3.2011; the target company is Chinacoal Beijing coal mining machinery co., ltd. This is an affiliated factory of the China National Coal Group Corp. This factory is located at the Fangshan district, 44 kilometers southwest away from Beijing city. This factory was established at 1958, from 1972, the main product of this factory is hydraulic support for the coalmine. The height of their products is around 0.6 m to 5 m, and the working resistance of their products is around 1800 kN to 10000 kN.

The third expedition was made on 19.4.2011; the target company is Shijiazhuang Yulong machining and manufacturing company (for short title: Yulong). This factory was established in the year 2000, which has the background of Shijiazhuang airplane manufacturing and design factory. The main business of this factory is machining for steel structures, which are including every kind of manufacturing ways as well as welding. This factory located at northwest suburb area of Shijiazhuang city, the capital of Hebei province. This is a middle

scale factory in north China area, having some significant representative.

The fourth expedition was made on 25.4.2011; the target company is Beijing No.2 machine tool works co. ltd. This company, formerly known as Beijing No.2 lath factory, was established in the year 1953, located at Fengtai district, southwest suburb area of Beijing city. This company's key products are CNC cylindrical grinder, universal cylindrical grinder, polishing machine, and special machine tools. This company uses outsourcing form to produce their welding parts, so there do not have any welding plants in this factory now.

The fifth expedition was made on 6.5.2011; the target company is Shougang (the Capital iron and steel work) industrial equipment plant (for short title: SIEP), Qian'an city, Hebei province. This factory is affiliated with Shougang Group Corporation of mechanical and electronic products. It is one of the biggest and most professional manufactures of such equipment in China north. The main products of this factory are 'A' heat-enduring boilers with smoke hood, the steel forging equipment, the heat converters, the pressure boilers, and bridge lifting machines. The other products are tunnel boring machine, and tower for wind power plant.

4.1. The Productivity Status of North China Areas

All the five factories are willing to give out their information regarding with the welding productivity. All the pictures displayed in this section were shooting in their real working plants.

4.1.1. The Productivity Data from Babcock & Wilcox Beijing Company Ltd

Overall, this factory could be defined as a well-equipped welding factory. The most important processing work in power plant boiler manufacturing is the welding processes. So this factory represents the best and most technology welding manufacture skill level in north China.

The products of this factory are boiler for power plant. The basic manufacture processing in the factory is to produce the parts of the boilers. Every workshop has their own duty, such as the tube workshop, the membrane wall workshop, and the cauldron workshop. The main customers of the factory come from worldwide, such as African countries, Southeast Asia countries, Australia, USA, and all around China. This factory has very good working experience in welding product manufacture, and even the best one in Beijing.

These figures 8 and 9 illustrate the working conditions and environment of the most two significant workshops in Babcock & Wilcox Beijing company ltd. The MPM (Membrane Processing Machine) welding processing center ensured that the high productivity of the membrane wall welding works.



Fig8. The tube structure manufacture workshop



Fig9. The membrane wall workshop

The welding method in this factory is MAG (CO₂ as shielded active gas) welding. The welding machines were produced by Panasonic (KR11-500, 505FL4, and SS400) (see in figure 10).



Fig10. The welding machines using in B&W Beijing

4.1.2. The Productivity Data from Chinacoal Beijing Coal Mining Machinery Co., Ltd

Numbers of workers:

There are 6 welding workshops, almost 1000 welding workers.

Customers nowadays:

The main customers of this company are SHENHUA Group Corporation Ltd., SHENHUA Ningxia Coal Industry Group, and Shanxi Pingsu Coal Industry Corporation.

Worker skills:

Every welding worker in this factory has the welding technician certificate which means they

have the skills for the professional welding operations. 1/4 of the welding workers are senior welding technician, and 3/4 of them are intermediate welding technician. In China, the assessments of welders are different, and the different skill level welders will acquire different skill level certifications by passing variety difficulty assessments. The general welders need to obtain the welding operation certification in order to acquire the working permit; in pace with the increasing of the working experiences, the intermediate welding technician will become the welding technician or senior welding technician. This difference in most extent shows the welders' working time. The special welders need to acquire the welding certification of boiler and pressure vessel in order to acquire the working permit in a professional working place. This certification in most extent shows the working skills level of a welder.

Plant situations:

This is the main workshop in this factory for welding works (see in figure 11). The environment of this large scale factory is acceptable comparing with the most of small and medium enterprises.



Fig11. The welding workshop

The next working plant is the cutting processing workshop. Dust removal facilities are inadequate in this cutting processing workshop (see in figure 12). Strengthening the protection of workers will increase the productivity obviously.



Fig12. The cutting workshop's environment

Workers in this workshop do not have sufficient protect for their eyes and respiratory system (see in figure 13). The material placing and waste material treatment are not under a reasonable arrangement.



Fig13. The cold machining workshop

Manufacturing tools & machines:

The only two welding methods in this company were MAG (CO₂ as shielded active gas) welding and MMA welding. The welding machines are CO₂ inverter welding machines (produced by Hunan Tianyi welding equipment corporation Ltd.) (see in figure 14)



Fig14. The CO₂ inverter welding machine of this factory

Materials:

Main material: Steel board, steel type: Q550, Q460, Q690 (based on GB221-79, the China national standards);

Welding wire: flux-cored welding wire: type 77, 78, 702; solid welding wires: JL-80M (produced by Beijing Lijiali welding material co. ltd.);

Environments and climates:

No special temperature and humidity control method expect the ceiling fun in this factory.

4.1.3. The Productivity Data from Shijiazhuang Yulong Machining and Manufacturing Company

Numbers of workers:

There are 50 workers in Yulong Company, 10 of them are welders. Every worker in this factory do not only predominate one manufacture skills, such as welding, machining, milling, drilling, grinding, and bending works. This means the workers' flexibility is good, which will lead the increasing of productivity.

Customers nowadays:

Royal Boon Edam (Beijing), Taihang machining factory, Hongtai Machine. Customer also includes some small scale or private factory. The customers supply their engineering drawing and Yulong will conduct the manufacturing works.

Worker skills:

2 of the welders are senior technicians. 5 of the welders are technicians. All other workers are senior technicians. Young workers are all enroll from professional technical school.

Plants' situations:

2 workshops, the total area for welding is 2650 m². The courtyard area for store and truck parking is 1200 m².

The welding area located at the southeast corner of the plant (see in figure 15). The working area is clean and neat comparing with most of the small and middle scale Chinese factories. The dust removal equipment is insufficient in this area.



Fig15. The welding work area

The machining area is neater than the welding place (see in figure 16). The protection of the workers needs to be strengthened here.



Fig16. The machining area of the plant

Manufacturing tools & machines:

MIG (Argon as shielded inert gas) welding machine×1;

MAG (CO₂ as shielded active gas) welding machine×2 (Chengdu Gaoxin KH-350) (see in figure 17);



Fig17. The MAG (CO₂ as shielded active gas) welding machine

AC MMA welding machine×5 (Hebei welding machine factory BX3 500J and BX1 500) (see in figure 18);



Fig18. AC MMA welding machine

This factory also has other machining tools such as lathe, milling machine, bending machine, grinder, and boring machine.

Materials:

Almost all the metal materials can be manufactured (welding, machining, small parts assembly and painting) in this factory. The basic manufacturing materials are stainless steel, aluminum, carbon steel, plastic, nylon, copper, and plexiglass. The welding process will not conduct with plastic, nylon, and plexiglass.

Environments and climates:

The temperature in north China area is very stable, so there do not have significant influence to the welding processing. All the welding works are certified by China national environment assessment. Noise, waste gas and water emission are all reaching the standards.

4.1.4. The Productivity Data from Beijing No.2 Machine Tool Works Co., Ltd

The Beijing No.2 machine tool works co. ltd do not have there own welding plants after the enterprise restructuring. The productivity will be guaranteed by this factories' subcontractor, a professional welding factory located in Gaobeidian city, Hebei province. Like the Finnish companies, the only kind of plants there in Beijing No.2 machine tool works co. ltd is only assembly workshops. The risk related with productivity will easily avoid.

4.1.5. The Productivity Data from Shougang Industrial Equipment Plant

Numbers of workers:

There are 3 plants in this company. The pressure boiler plant has 20 senior welding technicians (with national welder certification). The total number of welders for three plants is 80.

Customers nowadays:

The customers of this factory are almost all the steel factories in China, and some of foreign companies from Italy, India, and Zimbabwe. This factory has become a subcontractor to those foreign companies above.

Worker skills:

Almost all of the workers in this factory are senior welding technicians, with boiler and pressure vessel national welder certification, which is the compulsory document for boiler welding works in China. The Shougang industrial equipment plant has the national welder training and certificate qualification, and this will guarantee the welder's skill level for this factory.

Plants' situations:

The occupied area is about 140 million mm², and 82000 mm² of them are manufacturing work shops. The manufacturing capacity is 40000 ton per year. The three workshops are: pressure vessel workshop, the heavy machinery workshop, and the thermal equipment workshop.

In the pressure vessel workshop now, the steel structure and small welding works will be done here (see in figure 19).



Fig19. The pressure vessel workshop

The heavy machinery workshop is the main workshop for Shougang industrial equipment plant (see in figure 20). All the main products will be manufactured here. Like the most Chinese old state-owned factories, the neat and arrangement requirement is insufficient.



Fig20. The heavy machinery workshop

The thermal equipment workshop is the second biggest workshop in this plant (see in figure 21). The main welding methods here are MAG welding and MMA welding for the tube's joint work.



Fig21. The thermal equipment workshop

Manufacturing tools & machines:

MIG (Argon as shielded inert gas) welding machine;

Almost 100 MAG (CO₂ as shielded active gas) welding machines (NBC-500 and NB7-500, Tangshan Greatwall welding machine factory) (see in figure 22);

Welding wire: ER50-6

Welding rod: GB 506, 507, 5016, 4303, and 426



Fig22. The MAG (CO₂ as shielded active gas) welding machines

AC MMA welding machine;

SAW machine×1, for the outside cylindrical welding seams (see in figure 23).



Fig23. The Submerged arc welding machine

Materials:

Almost all the steel materials can be manufactured in this factory. The basic manufacturing materials are K235, Q345, Cr-Mo steel, heat-resistance steel, and low alloy steel. This plant also can process the Europe standard materials.

Environments and climates:

The winter temperature in north China area is very low, so there will be a pre-heating works for thick steel boards before the welding processing in winter. Because all the welding works will be done under the roof, the raining and windy days can also conduct the manufacturing.

Other factors:

The management system, the rewards and the penalties, the market, and the workers loss strongly influence the productivity of this plant. The workers loss is the most serious problem for this plant, especially to the young and well trained workers.

4.2. The Cost and Economy Status of North China Areas

Three of the factories give out their operation situation, and the cost or economy information. The other two factories including Babcock & Wilcox Beijing company ltd. and Beijing No.2 machine tool works co. ltd. refuse to reveal that information about cost and economy.

In this thesis, the currency unit is RMB (CNY) using in China. The exchange rate between Euro and RMB is fluctuation not severe recently (in year 2011), the exchange rate is 1 RMB = 0.1077 Euro (the exchange rate is checked on 18/7/2011)

4.2.1. The Cost and Economy Data from Chinacoal Beijing Coal

Mining Machinery Co., Ltd

Workers salary:

Average salary for welders is 4000 RMB per month in this factory. No information about the proportion of welders' salary of the total processing cost.

Materials cost:

All the price of steel board, welding wire, and welding rod is according to the market prices. The steel price in China in recently years is fluctuate very frequently. The price of steel will be decided by both sides involved before the contract signs, and after the contract signed, the price of the material will be fixed at the current prices.

Logistics cost:

In this factory, the logistic cost will be the highway cost, the railway cost, and the shipping cost. No detail information about the specific price here.

Processing cost:

The processing cost will be including the water cost, the plant transport, the propane gas cost, the oxygen gas cost, and the electricity cost. All the cost for consumables will be consistent

with market prices.

Other cost:

There also have other cost, which are equipment depreciation, warranty service, and rework cost for the defective products. There is no detail information about that cost.

Turnover:

The turnover is 30 billion RMB for the whole factory last year.

4.2.2. The Cost and Economy Data from Shijiazhuang Yulong Machining and Manufacturing Company

Workers salary:

The average wage for welders in this factory is 2500 to 3000 RMB per month, which is including the five insurances and one fund. The workshop director, dispatcher, and group leaders will provide work records of workers to the factory in order to decide the salary award for workers. The defective products will lead the deduction of worker wages according to the proportion. If the defective products were caused by the material cutting workers, the wages will deduct by the proportion of material price. If the defective products were caused by the machine operator, the wages will deduct by the proportion of material price and working hour's fee. All the wage deduction will determine by inspection group. If the defect could be repaired, there will do not have wage deduction. The workers' wages will account the 1/3 of the total cost in the factory. The latest trend of the workers' wages is increasing annually.

Materials cost:

The cost of the materials is about 1/3 of the total cost. The price of 5mm thick steel board is about 5000 RMB per ton, and this price is only about 2000 RMB per ton two years before.

Logistics cost:

The logistic cost, processing cost, and other cost is about 1/3 of the total cost, and the logistic

cost is about 10% of the total cost itself. The logistic cost in this factory constitute by truck cost, labor cost, petrol cost, and highway fee, and management fee to the government. This factory do not have huge amount of transportation so the road transportation is the only logistic method.

Processing cost:

Processing costs are including the water (4 to 6 RMB per ton, general industrial water price for the year 2011 in north China), argon, oxygen, acetylene, carbon dioxide, hydrogen, electricity (1 RMB per KWh, general industrial electricity price for the year 2011 in north China) and every type of welding rods.

Other cost:

Depreciation cost for manufacturing machines and cost of equipment loss. For the tax, nowadays the middle scale welding and machining factories in north China areas have a 10% margin. The tax cost is about 17%, but 12-13% will be paid by the customers. The taxes are including: 1/4 of the profit, channel environment charge, income tax of workers, disabled worker tax, and environment management tax.

Turnover:

The turnover for this company is 500 to 600 million RMB per year.

4.2.3. The Cost and Economy Data from Shougang Industrial Equipment Plant

Workers salary:

The average wage for welders in this factory is 1200 RMB per month, which is including the five insurances and one fund. The journeyman welders' wage is 2000 RMB per month. The trend for welders' wage is increasing continuously in recent years.

Materials cost:

The cost of the main material will be the 60% - 70% of the total cost. The price of main material, the steel board, is fluctuations in recent year in China. The price for the steel board without any additional requirements is 5000 RMB per ton before May 2011. If the customer proposed that the ultrasonic test should be made, the prices will be increasing to 5100 RMB per ton. The thickness of steel board is the key influence point to the price, the different thickness steel board (same components) price will in a interval of 5000 to 10000 RMB per ton. The flaw detection and heat treatment are another two indicators that will influence the price. If all the flaw detection and heat treatment are required, the steel board price per ton will increase from 5400 RMB to 12000 RMB. Special requirement, for example the special component steel, or the special testing methods and heat treatment methods, will also lead to the price rise.

Logistics cost:

The logistic cost is about 10% of the total cost in this factory. 90% of the transportation methods are highway transport. The transport price for ultra wide and ultrahigh products is more than one thousand RMB per ton.

Processing cost:

In this factory, the processing cost will be the cost of welding wire, welding rod, carbon dioxide, argon, oxygen, diesel oil, water, and electricity. Those costs will be the 5% to 10% of the total cost. The price for welding wire ER50-6 is 8200 – 8300 RMB per ton. The price for special welding wire is about 6000 RMB per ton. The price for carbon dioxide gas is 700 – 800 RMB per ton. The price for oxygen gas is 1200 – 1300 RMB per ton. The industrial water and electricity price is according to the national standards.

Other cost:

The worker's wage and depreciation cost for manufacturing machines and cost of equipment loss is 10% of the total cost. The margin of this factory is about 10%. For the tax, the 23% of the margin will be the sales tax. The value-added tax for the material purchase is 17%. Other

tax like income tax for the welders also should be considered as a kind of cost.

Turnover:

The turnover for this company is 2.1 billion RMB for year 2010. The average turnover for recent five year is 2 billion RMB.

4.3. The Quality Control Information of North China Areas

All the factories will comply with the China national standards to conduct their production. The welding classes in China is different but similar from B, C, and D levels in Europe, the national standard GB/T12469-90 provides the defect classes of welding seams. The weld classes are I, II, III, and IV, the most stringent level is level I.

The quality control methods and qualification of each factory will include in this paragraph. The welding quality control method for Beijing No.2 machine tool works co. ltd will guaranteed by their subcontractor, so the details do not include in this section.

4.3.1. The Quality Control Information from Babcock & Wilcox

Beijing Company Ltd

The factory have ISO9001:2008 certification in manufacturing, and even have the “S”, “PP”, and “U” seal of ASME certificate in USA.

The quality control sections, all the tubes after welding should be checked through the quality control group (see in figure 24).



Fig24. The welding structure testing lab

In the testing lab, all the welding seams will be checked here (see in figure 25). The welding defect and the metallographic analysis will be done here. The testing methods is the business secret of this factory, no information about the testing methods. The only information about testing is the lab will check microstructure of the joints for each tube.



Fig25. The inside situation of the testing lab

The professional quality control personal in the Babcock & Wilcox Beijing Company Co. Ltd., is in charge of the inspection of every welding seam (see in figure 26 and 27). The welding quality of thick tube is acceptable; the appearance check of the tube shown in figure 26 is qualified. The quality control personal firstly using visual check of the welding seams, after this, the ND test will be utilized.



Fig26. The welding appearance of the thick tube

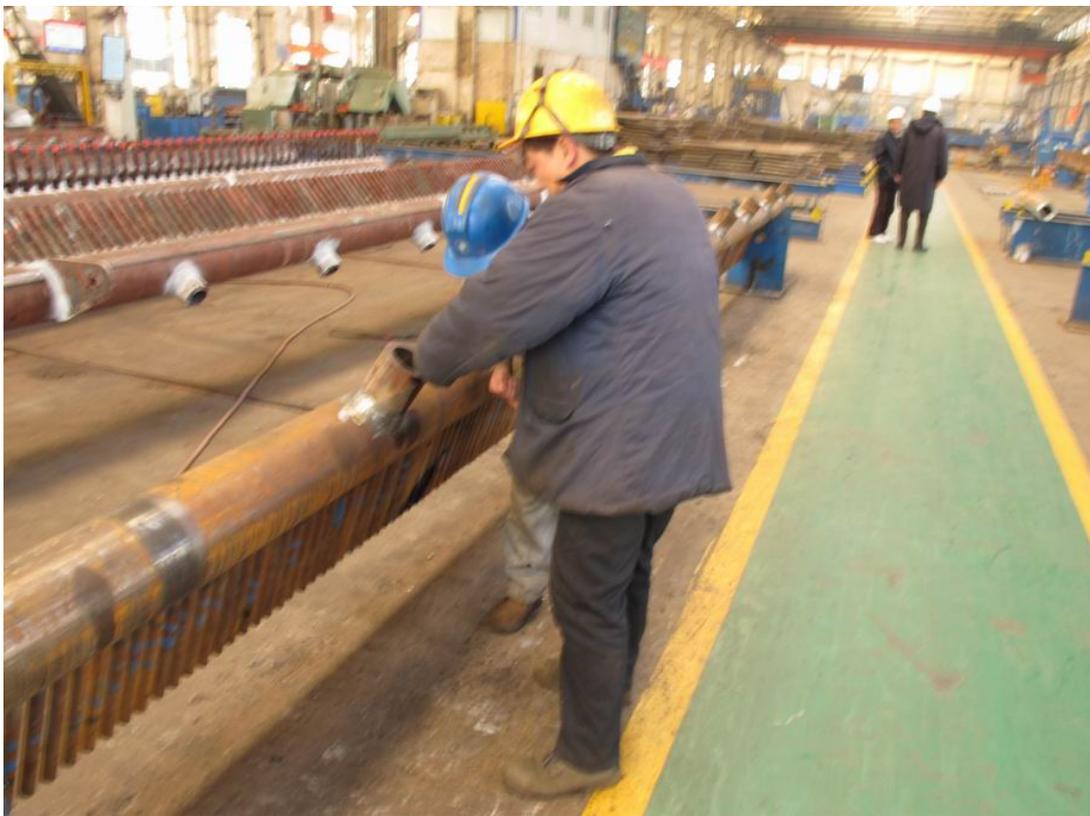


Fig27. Inspection of the welding seam

4.3.2 The Quality Control Information from Chinacoal Beijing Coal Mining Machinery Co., Ltd

Processing steps of the welding and machining workshops:

In this factory, the manufacture processes are: raw material cutting → cold machining (some parts) → heat treatment → riveting and welding (spot welding and assembly) → aging process (some parts) → seam filling welding → cold machining (some parts) → assembly

Culture and human factors:

All the workers in this factory are coming from Zhangjiakou city (Hebei province), Huludao city (Liaoning province), and Shijiazhuang city (Hebei province). Those two provinces are situated in north and northeast China areas.

Worker skills and personal training methods:

The assessment method is based on the national standards, which are including security assessment and skill assessment. The security assessment is more important in this factory. Before the welding workers become a regular staff, there has a one month internship. At the end of the internship period, one final test will be organized in order to decide if the welding worker could be a regular staff. The regular staffs still have some classes and trainings every year.

Inspect methods:

Inspection will be done by the professional personals from the quality assurance office. At the delivery period of the materials, the steel board hardness and material defect should be inspected. Every part should be inspected by the professional quality control personals after the welding process. The main inspection methods are appearance of the welding seam, the size of the part, the welding slag inspection, stoma inspection, the oil pollution inspection, and the quality of the welding seam. For the welding current and other parameters, the computer

control system will start the alarm when danger situation happens. The quality criteria using in this factory is not strict and common.

The appearance of the welding seam is not perfect sometimes (see in figure 28). The weld reinforcements are much higher than the standards. The clean up for the welding seam is insufficient.



Fig28. The welding seam quality appearance

Machine and equipment maintenance:

Everyday there will be a basic cleaning and maintenance of the equipment after work. Every week the professional personals from the equipment office will do the maintenance for every machine and repair the broken ones.

Material storage and treatment:

Steel board and welding wire were storage in the special warehouse. Before manufacture and welding, the steel board will be pretreatment in order to remove the rust.

The welding wire is storage inside the workshop, in order to proof the moisture (see in figure 29).



Fig29. The storage of the welding wire

The storage areas have a tidier and clean environment than the processing areas (see in figure 30). The storage of steel board inside will proof the corrosion.



Fig30. The storage of the steel board

Environment and climate:

Hot temperature in summer may cause the inattention of the welders. The only way for cooling is fan and water in summer. Dry and cold winter needs preheating of the materials. The warm method (heating system inside the workshop) for welders is enough in this factory.

4.3.3. The Quality Control Information from Shijiazhuang Yulong Machining and Manufacturing Company

Processing steps of the welding and machining workshops:

The working steps in this factory are: Engineering drawing reading and review → processing design → manufacturing plan → materials preparation → processing steps (heating treatment) → manufacturing (machining and welding) → inspection (every processing steps) → packaging → products ready.

Culture and human factors:

All the welders are coming from Shijiazhuang city, Hebei province (north China areas).

Worker skills and personal training methods:

The new enrolling workers will be trained by the older workers and technical staff. The basic training content is safety teaching and working skill education. The group leasers of the workshop will guide the new workers about the manufacturing steps. The trial period is about 1 month; the very first testing is safety test. After one month training period, there will be a working skill testing. All the regular staff must pass this testing, and then draw up the wage standards. All the welders in this factory are holding the welding certification.

Inspect methods:

The inspection group will do inspection after the welding works (see in figure 31). The welding size, flatness of welding seams, and cracks will be the inspection items (see in figure 32). The entire NDT test will conduct only by the customers' request.



Fig31. The inspection team and testing area

The appearance of the welding seam is acceptable. Rely on the working experiment but not the WPS or quality control criteria is the commonly circumstances in this scale factories in China.



Fig32. The welding seam quality of this factory

Machine and equipment maintenance:

Every Saturday there will be machine maintenance in this factory. Every year all the machines will do a major maintenance.

Material storage and treatment:

Steel board and materials were storage at indoor environment in the workshop (see in figure 33). The welding wire and welding rods were storage in the special warehouse. The oxygen will store in an isolated warehouse.



Fig33. Material storage area inside the workshop

Environment and climate:

All the protection equipment will hand out to the welders, which is including overalls, special masks, welding glasses, and welder groves. In the summer time, the fan will be the only way to control the temperature.

4.3.4. The Quality Control Information from Shougang Industrial Equipment Plant

Processing steps of the welding and machining workshops:

The processing steps are: material re-examination → material cutting (CNC flame cutting) → coiling and drilling → assembly (spot welding) → seam welding → NDT → heat treatment → painting → pressure testing (for boilers and containers) → products delivery.

Culture and human factors:

All the elder or experienced welders are coming from the army, because the predecessor of this factory is a munition factory. The young welders are recruiting from Tangshan, or Qian'an city, Hebei province. The young worker turnover and aging of the experienced welder are two problems of this factory.

Worker skills and personal training methods:

The basic standard for welders is safety education qualified. There are three months internship period, and after the welder obtain the certification, who can be the regular staff. Most of the welders are recruiting from the technical school. The mandatory examination for the welders will be held when the certification's matureness.

Inspect methods:

For the material delivery test, there will be ultrasonic detection, the chemical component test, the tensile strength test and the yield strength test. For the welding seam test, there will be the ultrasonic detection, the radiation detection, the magnetic particle detection, and the penetration detection as the customers' requirement (see in figure 34).



Fig34. The welding seam after ultrasonic detection

If there are no requirements from the customer, there will be only size checking, the appearance inspection, and hardness testing. All the special requirement and national standard on the engineer drawing will be finished. In this factory, total quality control method will be utilized. The quality control methods are including self inspection (check by the welder themselves), mutual inspection (check by other welders), and professional inspections. The professional inspection will be conduct with quality control department.

The quality of SAW welding seam is good. (see in figure 35) The semi-automation welding method will to some extent increase the welding quality.



Fig35. Appearances for the SAW seam

Those white color Chinese characters on the product are the name of the welder (see in figure 36). This is the method to differentiate the welding defects.



Fig36. Appearance for the MAG (CO_2 as shielded active gas) welding seams

Machine and equipment maintenance:

The maintenance and repair procedure is formulated by the maintenance department, which are including the everyday maintenance and clean standard, the lubricating oil use method, and overhaul standards.

Material storage and treatment:

The steel board will be storied outside at the storage square. The welding wire and rod will be storied inside the warehouse according to the national standard. The rapid turnover material will be storied inside the workshops.

Environment and climate:

Cold weather in winter will strongly influence the welding process in this factory. The very thick steel board need preheating and continued heating level when the welding process is carrying out. Otherwise, the physical properties of the microstructure will be changed. The

insulation method is heating system.

Welders in this factory have sufficient protection suit (see in figure 37). The mask, gloves, flame retardant overalls, and worker's boots are all providing to the welders.



Fig37. The welders on working

4.4. Overview of the Welding Industry in North China Area

There are not many large scale professional welding factories in China, especially in north China areas. The Shougang industrial equipment plant (steel-making equipment) and CFHI Tianjin heavy industrial co., ltd. (tower for wind power plant) are two master enterprises focusing on the welding process. Often the large scale factories will find the small or medium welding factories as their subcontractors; the large factories only need to concern the quality with fine finishing works. The welding parts will be only handled as a blank piece to the large scale factories in north China areas.

The welding plants in heavy industry in north China are usually the supporting factories of metallurgical industry. The sophisticated technologies of welding do not use in production. Because the heavy industry is the most significant industry in north China, the technology content is not good as the eastern and coastal areas, but much better than the southwest or northwest areas.

For the willingness to cooperate with foreign companies, the large enterprises like Babcock & Wilcox Beijing company ltd., Chinacoal Beijing coal mining machinery co., ltd., or Beijing No.2 machine tool works co. ltd., do not have any willingness about the cooperate. Often the small or medium factories like Shijiazhuang Yulong machining and manufacturing company have strong willingness to find proper foreign partners. The Shougang industrial equipment plant have different attitude towards the cooperation compared with other large enterprises, they have the willingness to be a subcontractor or partner with foreign companies, because the introduction of new technologies, and the advanced management system are deeply interested with this plant.

In Chinacoal Beijing coal mining machinery co., ltd., the products cost will be calculated in the cost accounting office. Different size, material, manufacture process and working hours will leads to different cost. It is not possible to ask them to calculate Junttan's parts cost because this cost calculation will only start when the contract is ready or both sides assured have the intention to sign the contract.

In Shijiazhuang Yulong machining and manufacturing company, the signing process for commission processing contract in this factory is: situation understanding to each other → engineering drawing prepare and sending → engineering drawing audit → technical and economical consultation and discussion → inspection methods agreed → signing of the order contract (quality, transportation, earnest money, processing cycle, and packaging methods) → earnest money paying → procurement of the materials → machining and manufacturing → packaging → customer inspection → payment (90% of the total price, other 10% for the warranty shall) → products delivery → at the end of the warranty, pay

the last 10% price.

In Shougang industrial equipment plant, the usually cooperation pattern is: the bid inquiry → the price quote (technical program, processing equipment, and quality control methods will be included) → third party plant inspection (production capacity and welder skills) → sign the contract → production. The Tianjin port is the usually export dock of this factory, but the customers can propose their special requirement.

5. The Status of the Eastern and Coastal Areas' Welding Factories

In this section, five factories located at eastern and coastal areas of China will be introduced according to the visiting sequences. This expedition was made by Xiaochen Yang from 18.3.2011 to 9.5.2011 in China. Those factories are built in Jiangsu province, Zhejiang province, and Shandong province respectively.

The first expedition was made on 18.3.2011, and the target company is Xuzhou construction machinery group (XCMG). There are three single factories have welding workshops. They are Xuzhou Xugong road construction machinery co., ltd, XCMG branch factory of construction machine, and Xuzhou Rothe Erde slewing bearing co., ltd. These three factories used to be attached with the XCMG group, but nowadays the Rothe Erde Company changed to be a joint venture with the ThyssenKrupp Company, the other two factories are still the wholly-owned subsidiary of the XCMG group. The products of these three factories are soil stabilizer, cold mining machine, soil stabilizer mixing plant, maintenance machine, crawler crane, concrete pump car, and antifriction bearings. All the companies were established before 1989, and they are all time-honored factories in China. These three factories are all not allowed to take photos, the statement of the workshops are all based on the visiting. All the factories in XCMG factories are certified by the ISO 9000, ISO 14000, OSAS 18000, DNV certifications, and GRC (Governance, Risk, and Compliance) assessment.

The second expedition was made on 24.3.2011, and the target company is Zhejiang shipbuilding co., ltd. This factory has long history and vitality. Zhejiang shipbuilding co., ltd covers a total area of about 1.36 million square meters. It has 5 production lines and 3 of the production lines focuses on offshore service vessels. 2 out of the 3 production lines are for indoor slipway production lines equipped with a floating dock which specializes in the production of world's high-end offshore vessels, such as PX105, SX130 and GPA696 with

world advanced level. The third production line is an outdoor slipway line producing series offshore vessels. Its current annual output is 30-36 offshore vessels. Featured products are SAP80, SPP17, SPP35, SPU1000 which are designed by themselves and GPA254L, GPA696, PX105, and SX130 which are jointly designed by SINOPACIFIC and world class design companies like Ulstein, and GPA. The factory is implanting the QHSE management system, which means this factory will comply with the ISO 9001, ISO 14000, and ISO 18000 standards.

The last expedition was made on 9.5.2011, and the target company is Qingdao Qiyao Wärtsilä MHI Linshan marine diesel co., ltd. (QMD). QMD was established in the end of 2006 by Qingdao Qiyao Linshan power development company (invested by SMDERI and YMD, two Chinese shipbuilding factories) and Panda ShinCo holding B.V. (invested by Wärtsilä and MHI). QMD, owning large scale NC machining equipment and test facilities, is licensed to use Wärtsilä and MHI product designs and technologies to produce, assemble, and test marine diesel engines of RT-flex and UE series, with cylinder bore of 500 mm to 960 mm.

5.1. The Productivity Statues of Eastern and Coastal Areas

The eastern and coastal areas of China have the best productivity, technology, and management system comparing with other Chinese industrial areas because of the longer open period to the whole world. High productivity brings up the excellent market all over the world. All the information in this section was investigated from the factory director, welder, section manager, or management staffs from those factories respectively.

5.1.1. The Productivity Data from Xuzhou Construction Machinery Group

Numbers of workers:

XCMG branch factory of construction machine: There are 400 workers in one workshop, and 200 of them are welders.

XUZHOU Rothe Erde slewing bearing Co., Ltd: Labor productivity is 300000 RMB per one worker per one year. Industry net value added is 20% now. Another labor productivity information for the small scale factories in eastern China is 100000 RMB per one worker per one year. There is no information for the *XUZHOU XUGONG road construction machinery Co., Ltd*.

Customers nowadays:

The biggest amounts of the customers are individual enterprises. Almost half of the customers of cranes and road rollers are individual enterprises in XCMG group. The other big customers are China state construction engineering corporation, China railway Engineering Corporation, China national nuclear corporation, China Huadian Corporation, and Shanghai metro.

Worker skills:

All the workers in these three factories are skilled workers. The basic education background is high school graduated (the 5 or 6 years primary education, and 6 years secondary education). After their graduation from high school, all the workers should be educated in the professional technician institute. 95% of the workers are post-secondary technical school students, 70% of them are college students. In the key positions, 10% of the workers are undergraduate students, and normally this number will not less than 5%. For the whole XCMG group, 50% of the workers are college students nowadays. The SAP (Systems applications and products in data processing) and ERP (Enterprise resourcing planning) systems will be used in the management teams in the three factories.

Plants' situations:

All the plant structures of the factories are built by light steel; the basic form of the workshop is truss modes, which are based on the Europe standard. Noise reduction materials and strong exhaust fan were used in the buildings. Heating system, soundproof room, rest areas were set up for the workers' health. Waste water treatment system, and solid waste recycle system were set up for the environment protect.

XCMG branch factory of construction machine: The area of all the factory is 2666 acre, the area of steel structure workshop is 200 meter × 150 meter.

Manufacturing tools:

XCMG branch factory of construction machine: MAG (CO₂ as shielded active gas) welding, MAG inverter welding machine (PANASONIC), Automation liner welding machine × 2, welding robot × 1.

XUZHOU XUGONG road construction machinery Co., Ltd.: MAG (CO₂ as shielded active gas) welding, MAG inverter welding machine (PANASONIC: KRII 500 or LINCOLN welding machine) × 20. Welding wire: MAG WELDING CHW-50C6 (Shanghai Atlantic welding consumables Co., Ltd.)

XUZHOU Rothe Erde slewing bearing Co., Ltd: Gas plasma cutting, contour cutting, MAG (CO₂ as shielded active gas) welding, laser welding, and robotic welding. For machining, 90% of the small parts are manufactured by CNC machining and flexible manufacturing, 80% of the manufacture machines are import from Germany and USA.

Materials:

XCMG branch factory of construction machine: Steel board, steel type: 70 steel.

XUZHOU Rothe Erde slewing bearing Co., Ltd: Steel board, steel type: medium carbon steel, and Q235. Some of the products will be manufactured by special steel.

Environments and climates:

The machine noises inside the workshops are not allowed over 85 Decibel. The entire plants basement is covered with a whole sealed steel board in order to prevent the leakage of the petroleum. All the workers should be protected by special protective gear and educated by professional institutions.

5.1.2. The Productivity Data from Zhejiang Shipbuilding Co., Ltd.

Numbers of workers:

There are 2 welding workshops (one is for ship body section welding, one is for small parts welding) in this factory, and other welding works will be finished in outside environment on the berth (see in figure 38, 39, and 40).



Fig38. The working environment of welding workshops



Fig39. The ship under construction

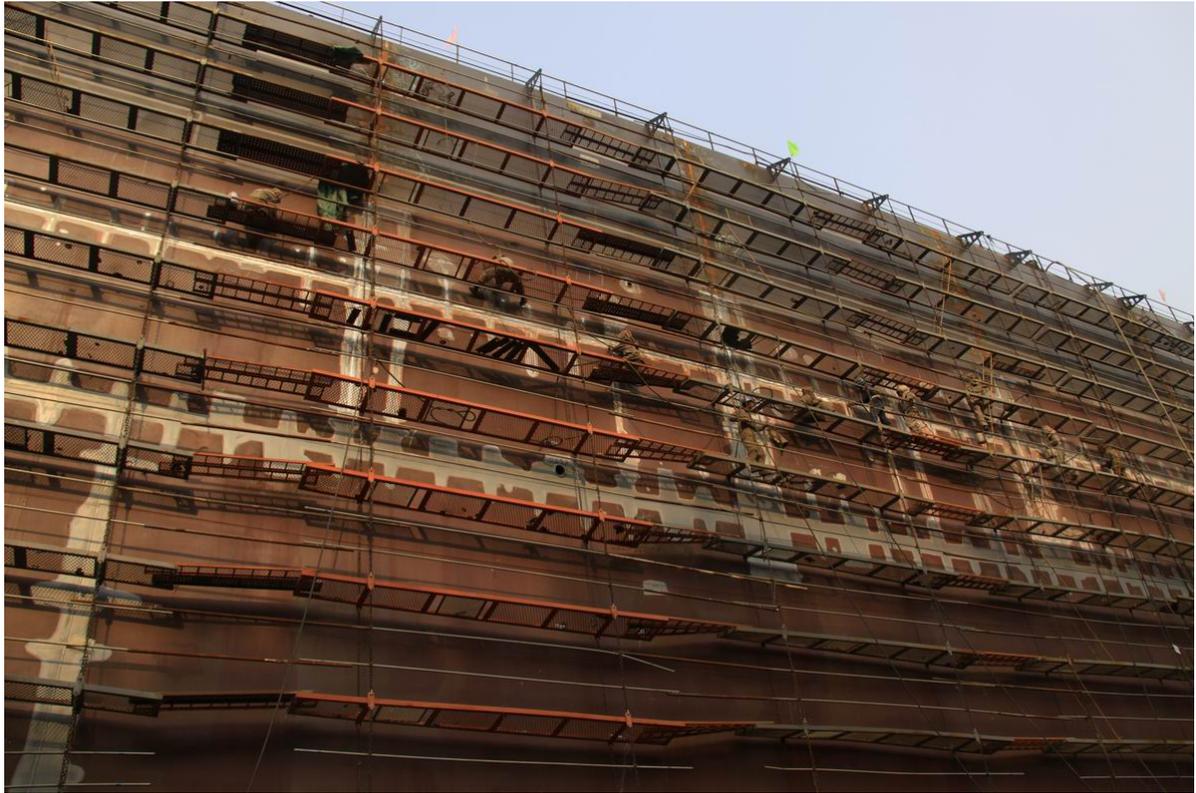


Fig40. The welders working on the berth

Almost 1300 - 1400 welding workers from outsourcing labor force companies. 70 – 80 welders are responsible for the welding work's management and working in the key positions. Those management workers are regular staff from the Zhejiang shipbuilding company itself.

Customers nowadays:

Customers are foreign companies from France and Australia. The biggest customer is Bourbon from France. The manufacturing method is 'working with order', not working in mass production. The main production is marine engineering ship, petrol platform supply vessel, and cargo ship.

Worker skills:

Every welding worker has the technician certificate in this factory. 1000 welders are intermediate technicians. 300 of them are apprentice welders.

Manufacturing tools:

90% of the welding works were finished by MAG (CO₂ as shielded active gas) welding, using MAG inverter welding machine (OTC: XD 500S; PANASONIC: KR II 350; Zhoushan Donghai electrical welder manufacturing co. ltd.: MR3151) (see in figure 41 and 42).



Fig41. Welder is working by using the MAG welding

10% of the welding works are submerged arc welding (Zhoushan Donghai electrical welder manufacturing co. ltd.: MZ-1250-2) and MMA welding (Zhoushan Donghai electrical welder manufacturing co. ltd.: ZXE 1-500).



Fig42. Welding machines in the workshops

Beside these welding methods, TIG welding and fillet welding are using for patch, repair, tube welding or fine welding.

All the welding facilities are lending to the outsourcing labor force companies, because this kind of corporation will leads to high machine usage rate and decrease the management cost.

Materials:

The main processing material is steel board, the steel type are: carbon steel board and stainless steel welding (according to the A to E levels). The welding wire types are: 3Y level welding wire, Antai QJ 501 and Jintai 712C.

Environments and climates:

In the raining environment, all the welding works will be stopped. In the strong windy days, the MAG (CO₂ as shielded active gas) welding will be stopped. In the small windy days, the MAG (CO₂ as shielded active gas) welding work will be conducting under the anti-wind

shield. In the humid environment, special steel and high strength steel should be treated by heating before welding. Before the manual welding, the welding material also should be treated by heating over 1 to 2 hours under 350° C. In cold winter environment, the welding material also needs some thermal insulation methods before welding works.

5.1.3. The Productivity Data from Qingdao Qiyao Wärtsilä MHI Linshan Marine Diesel Co., Ltd. (QMD)

Numbers of workers:

There are 123 welders in the Wärtsilä companies' welding workshop. All the welding personals in this factory must be qualified according to strict and explicit conditions. The welding and operating personal qualification level must be directly related to the type of producing welding and documented with a valid welder performance qualification based on EN 287 for welding workers and EN 1418 for welding operators. Each welder or operator qualification must to be approved by the classification society and must be freely available for review on request by the classification society or WCH (Wärtsilä Switzerland ltd.). Mr. Frank Wang, the section manager of welding workshop and the welding coordinator, who had obtained the IWE certification.

Customers nowadays:

Almost all the customers are specific requirement companies for Wärtsilä marine diesel engines, including domestic and foreign clientele. Other customers are the companies who have large steel structure projects, the welding work also can be accepted by QMD, like the Schuler from Germany.

Worker skills:

88 workers from total welding personal are specified welders. All of the welders are qualified by DNV (Det Norske Veritas), GL (Germanischer Lloyd), BV (Bureau Veritas), or ABS (American Bureau of Shipping), conforming to the welding and quality instruction of QMD. The welder who only held the Chinese welder qualification or certification is not acceptable in

QMD.

Plants' situations:

QMD has one welding workshop, one machining workshop, and one assemble workshop in Huangdao, Qingdao city, Shandong province. The total area of welding workshop is 380m×40m (see in figure 43).



Fig43. The welding workshop in QMD

Manufacturing tools:

QMD welders are mastering the submerged arc welding, (see in figure 44 and 45)



Fig44. Working with the SAW



Fig45. The SAW welding machine in QMD, manufactured by ESAB

MAG (CO₂ as shielded active gas) welding (see in figure 46 and 47),



Fig46. Working with MAG welding



Fig47. The MAG welding machines from ESAB

MMA welding, Stud welding (see in figure 48),



Fig48. The stud welding machine in QMD, manufactured by Nelweld and TIG welding machine (see in figure 49).



Fig49. The TIG welding machine in QMD

The stud welding are using for the processing of screw bolt on the engine case. Some of the commission processing works will employ the MIG (Argon as shielded inert gas) welding, as the Schuler Company.

Materials:

The most common processing material is S235 steel board. All the special requirements from customers will be satisfied in QMD.

Environments and climates:

Wärtsilä have well constructed workshops with well constant temperature and humidity conditions. In the welding workshop, the dust exhaust machines were set up well in order to avoid the detrimental of welders' health (see in figure 50).



Fig50. The dust exhausts equipment in QMD

All the conditions ensure not only the welders' health, but also the stable welding quality (see

in figure 51).



Fig51. Clean and neat working conditions in QMD

5.2. The Cost and Economy Statues of Eastern and Coastal Areas

A significant features considering about the cost and economy statues of eastern and costal areas in China is the higher labor cost than other industrial areas in China. Because of the higher living cost for citizens in this area, low working salary can not ensure the workers normal life. Meanwhile, the fast-paced working method and higher efficiency management system in this area are also interested attentions of investors.

5.2.1. The Cost and Economy Data from Xuzhou Construction Machinery Group

Workers salary:

Wages for operators and real wages for workers means that the workers wage will related with

their working attitude. In *XUZHOU Rothe Erde slewing bearing Co., Ltd*, the average wage is 60000 RMB per year (workers and middle managers). In the *XCMG branch factory of construction machine*, average wage is 4500 – 4700 RMB and 1500 RMB housing provident fund per month for welders.

In China, the wages for workers is divided into six parts: medical insurance, pension insurance, unemployment insurance, security insurance, maternity insurance, and housing provident fund.

For the payroll, there are some differences between workers, middle managers, and professional technical personals. For the workers, the wages should be calculated by the working hours and piece numbers, and the salary deducting should be considered with the working safety status. The overtime salary in the holidays should be doubled and the most overtime is not more than 36 hours per month. The statutory working days for workers are 21 days per month, 8 hours per day. The 2 days weekend and every national statutory holiday are common holidays for worker. For the different length of service, the workers will obtain different days of annual leave. For the middle manager (section manager, factory director, and operators), the wages should be paid by annual salary system. For the professional technical personals, the wages should be paid by monthly basic salary, and the salary deducting is calculated by the quarterly assessment. Especially for the technical staffs, the monthly allowance and projects awards are other two ways for their wages.

Materials cost:

The price of steel board for different size of factories is same in the eastern and coastal China areas. For the XCMG group, the raw material costs are about 40% of the total cost (not including the fittings). In the eastern China area, the gross profit margin of the mechanical industry is about 20%, so the more big the factory is, the more better the digests of the cure cost.

Logistics cost:

Logistic cost is a kind of selling cost. The sale cost is divided by staff salary, selling expenses, and logistic cost. The selling expense is 3% of the selling cost. The logistic cost is 1% of the total cost. In the XCMG group, the most logistic method is road transport and the railway transport is not very often. The Lianyungang port is used for the export. In the customs, the tariff and port ship tax should be paid.

Processing cost:

Labor cost is the 20% of the processing cost. Other processing costs are: depreciation of fixed assets, the cost of the operation of the fixed assets, maintenance cost, and material consumptions. The depreciation of fixed assets was calculated by the financial standards monthly. The cost of the operation of the fixed assets are including heating, gases, water, electricity (350 million RMB last year for *XUZHOU Rothe Erde slewing bearing Co., Ltd*), coal, and petroleum. This cost is about 10% of the processing cost. Material consumptions are including the using of welding wire and machining tools. The total processing cost is about 10% of the total cost. All the processing costs are secret information for the factories, so the details could not be acquired.

Other cost:

Other cost is including the office supplies, shuttle bus for workers, business travel cost, hospitality, canteen cost, maintenance for other assets, R & D expenses, experimental cost, and quality difference cost. Although there are many items of the other cost, i.e. management cost, the percentage in the total cost is very small.

Turnover:

XUZHOU Rothe Erde slewing bearing Co., Ltd: 22 billion RMB for the whole factory last year.

XCMG branch factory of construction machine: 9.8 billion RMB for the year before last, 20 billion RMB for last year, and prospective turnover for this year is 45 billion RMB.

5.2.2. The Cost and Economy Data from Zhejiang Shipbuilding Co., Ltd.

Workers salary:

The management team, that means the 70 to 80 welders from the company itself, will be paid by wages, insurance and funds. The 1300 to 1400 welders from outsourcing labor force companies will be paid by their contractors. The wages for intermediate technician is about 3000 RMB per month, and if the welder violates the safety or quality rules, the factory will give the ticket and reduce the wage in that month.

Materials cost:

The price of the steel board is according to the market price. The welding wire will be purchased by outsourcing specialized procurement companies.

Logistics cost:

Highway transport cost is the biggest one inside the logistic cost. Railway transport will be used for the welding wire, and ship transport is used for the steel boards.

Processing cost:

All the processing cost will be estimated before manufacturing. Processing costs include the water, plant transport, argon, oxygen, carbon dioxide, acetylene, machine maintenance cost, workshop building repair cost and electricity.

Other cost:

Inventory cost is zero because all the warehouse or storage cost will be burdened by the outsourcing storage companies. Other costs also may include the cost of stationary or office appliances.

Turnover:

The turnover is 42 billion RMB for the whole factory last year. Before the financial crisis is about 100 billion RMB per year. In 2009, the turnover is about 50 billion RMB.

5.2.3. The Cost and Economy Data from Qingdao Qiyao Wärtsilä MHI Linshan Marine Diesel Co., Ltd. (QMD)

In QMD, every welding seam cost is well calculating and planning by their staffs. The welding cost is divided to processing cost, consumption cost, NDT cost, and post treatment cost. The total processing cost considers every working step, like the figure 52 shown. In the figure 52, the welding work will be divided into several steps, and each step has their working time and cost.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB			
13																															
14	Welding work																														
15	Weld Type																		K	K	SV	SV					SV	SV	K		
16	Quality Level																		C	C	C	C					C	D	C		
17	Weld Thickness [mm]																		60	60	28	28					25	12	40		
18	Gap [mm]																		3	3	3	3					3	0	3		
19	Weld Length [mm]																		4130	3175	3500	3060					4134	4134	3175		
20	Quantity of welds																		2	2	4	4					4	4	2		
21	Preparation angle [°]																		40	40	40	40					40	45	40		
22	Weld seam volume [cm3]																		7725	5938	5781	5054					5576	1191	2893		
23	Root run grinding																		Yes	Yes	No	No					No	No	Yes		
24	Time for grinding [cm/h]																		1000	1000	0	0					0	0	1000		
25	Time effort [h]																		0.41	0.32	0.00	0.00					0.00	0.00	0.32		
26	Additional weld volume [cm3]																		41	32	0	0					0	0	32		
27	Total weld seam volume [cm3]																		7766	5970	5781	5054					5576	1191	2925		
28	Filler material weight [kg]																		60.96	46.87	45.38	39.68					43.77	9.35	22.96		
29	Amount of Layers																														
30	Welding Process																		136	136	136	136					136	136	136		
31	Deposition rate [kg/h]																		9	9	9	9					9	9	9		
32	Welding speed [cm/min]																		45	45	45	45					45	45	45		
33	Duty cycle [%]																		60	60	60	60					60	60	60		
34	Welding time [min]																		677	521	504	441					486	104	255		
35	Man hours																														
36	Cost welding																														
37	general [¥/h]																		35.00	35.00	35.00	35.00					35.00	35.00	35.00		
38	specific [¥]																		409.58	314.87	294.13	257.16	866.17				283.72	60.58	159.94	504.23	

Fig52. The cost of welding work

In the figure 53, welding wire consumption for each welding seam will be calculated, and the NDT time effort for each welding seam will also consider as a kind of processing cost.

40	Consumable consumption								
41	Wire consumption [kg]	60.96	46.87	45.38	39.68		43.77	9.35	22.96
42	Cost wire								
43	general [¥/kg]	30.00	30.00	30.00	30.00		30.00	30.00	30.00
44	specific [¥]	2.03	1.56	1.51	1.32	4.40	1.46	0.31	0.77
45									2.54
46	Shield gas consumption [l]	16934	13018	12606	11021		12159	2596	6378
47	Cost shield gas								
48	general [¥/l]	1.7	1.7	1.7	1.7		1.7	1.7	1.7
49	specific [¥]	28,788.01	22,131.22	21,429.77	18,735.74	62,296.72	20,670.84	4,413.46	10,843.05
50									35,927.34
51	NDT: Time effort								
52	VT inspection speed [min/m]	1	1	1	1		1	1	1
53	VT time effort [h]	0.07	0.05	0.06	0.05		0.07	0.07	0.05
54	Cost VT								
55	general [¥/h]	30	30	30	30		30	30	30
56	specific [¥]	2.07	1.59	1.75	1.53	4.87	2.07	2.07	1.59
57	MT inspection speed [min/m]	5	5	5	5		5	5	5
58	MT time effort [h]	0.34	0.26	0.00	0.00		0.34	0.00	0.26
59	Cost MT								
60	general [¥/h]	40	40	40	40		40	40	40
61	specific [¥]	13.77	10.58	0.00	0.00	10.58	13.78	0.00	10.58
62	UT inspection speed [min/m]	5	5	5	5		5	5	5
63	UT time effort [h]	0.34	0.26	0.00	0.00		0.34	0.00	0.26
64	Cost UT								
65	general [¥/h]	50	50	50	50		50	50	50
66	specific [¥]	17.21	13.23	0.00	0.00	13.23	17.23	0.00	13.23
									30.45

Fig53. The cost of consumable consumption and NDT test

The post treatment cost for each welding seam will also be calculated (see in figure 54). After several single cost calculations, a summary will be counted and give out the total final processing cost for those welding seams.

68	Post treatment								
69	Grinding [min]	0	10	40	40		0	0	10
70	Cost Grinding								
71	general [¥/h]	35	35	35	35		35	35	35
72	specific [¥]	0.00	5.83	23.33	23.33	52.50	0.00	0.00	5.83
73	Stress relieving [h]			1.75				0	
74	Cost Stress relieving								
75	general [¥/h]			3,250.00				3,250.00	
76	specific [¥]			5,687.50		5,687.50		0	0.00
77									
78	SUM Material and Preparation					89,336.12			79,848.10
79	SUM Welding					866.17			504.23
80	SUM Consumables					62,301.12			35,929.88
81	SUM NDT					28.68			60.54
82	SUM Post treatment					5,740.00			5.83
83									
84	SUM General [¥]					158,272.08			116,348.59

Fig54. The cost for post treatment and summary

Workers salary:

The wages for welders in QMD is 3000 RMB per month. The overtime work pay in workdays is 1.5 times than usual. The overtime work pay in holidays and weekend is 2 times than usual.

Materials cost:

QMD purchase steel board and other raw material are according to the market price in China. The steel board price for now is 6000 RMB per ton.

Logistics cost:

QMD uses the specific logistic company to manage the transportation matters. Some of the logistic cost may include in the purchasing contract of raw materials, other logistic cost may pay for the logistic company. The transportation cost is divided by two: the highway transport, and the ocean shipping. For the highway transport, the price is calculated by the unit of ton per kilometer. For the ocean shipping, there are three ways to calculate the price: the 20 cubic feet container for FCL (full container load), the 40 cubic feet container for FCL, and weight counting or bulk counting (cubic meter).

Processing cost:

The processing cost in QMD includes shielded gas cost (CO₂, or 82% Argon + 12% CO₂), propane, welding wire, welding rod, welding flux, water and electricity. The total processing cost is 20% of the total cost. The welding wire cost is 30 RMB per kilo. The shielding gas cost is 1.7 RMB per liter.

Other cost:

The inspection team cost in QMD is: UT test is costing 50 RMB per hour, VT test is costing 30 RMB per hour, and MT test is costing 40 RMB per hour.

Turnover:

The turnover is 6 billion RMB for the whole factory last year. The margin for welding workshop is 20% to 30%.

5.3. The Quality Control Statues of Eastern and Coastal Areas

Like all the five factories in this paper, the welding factories in eastern and coastal areas in China always pay mach attentions on the quality control matters. Because of the application of the latest management system, the quality control of the product has been planned in well order. Each inspection or testing step is reasoning and the quality control departments always have a well training.

5.3.1. The Quality Control Information from Xuzhou Construction Machinery Group

The quality rules of the three factories are meet customer requirements and continuous improvement in quality, price, and services.

Working steps of the welding and machining workshops:

In XCMG branch factory of construction machine and XUZHOU XUGONG road construction machinery Co., Ltd.:

The manufacture processes are: incoming inspection (Chemical elements: carbon, manganese, silicon, sulfur, and other alloying elements. Physical inspection: yield strength, tensile strength, and bending strength. Metallographic analysis: hardness) → raw material cutting → pretreatment (shot treatment) → cold machining (some parts) → heat treatment → riveting and welding (spot welding and assembly) → aging process (some parts) → seam filling welding → cold machining (some parts) → assembly. The cutting processes are laser cutting, plasma cutting, and gas cutting.

In XUZHOU Rothe Erde slewing bearing Co., Ltd:

The manufacture processes are: incoming inspection (Chemical elements: carbon, manganese, silicon, sulfur, and other alloying elements. Physical inspection: yield strength, tensile strength, and bending strength. Metallographic analysis: hardness) → pretreatment → cutting → riveting and welding → painting

Culture and human factors:

Workers are mostly coming from Xuzhou city, or other cities in Jiangsu province. For the management method, the PDCA (Plan-Do-Check-Act) system, total management system, 5S (Sort, Set, Shine, Sustain, Standardize), and 6 σ (Six Sigma) were used in the three factories. The lean method is not mentioned in this factory.

Worker skills and personal training methods:

The assessment method is based on the national standards and Europe standard system. All the workers are recruiting by the third part corporations. Before the welding workers become a regular staff, there has daily training, weekly training, and one monthly examination. The failure workers should not be a regular staff. The regular staffs still have some classes and training every year teaching by the experts from institutes, professors from universities, and engineers from other companies. Training is a kind of benefits inside the XCMG group. The managers, technical personals, selling teams, and manufacture teams have regular training and contest every year. The assessment criteria for welders are working hours, the rejection principle for welders are quality, security, equipment maintenance, and labor discipline. Most of the workers will be training in the XCMG technical school.

Inspect methods:

Inspection will be done by the professional personals (200 people team and 10 of them are quality engineers) from the quality assurance office. At the inbound period of the materials, the steel board hardness and material defect should be inspected. Every part should be inspecting by the professional personals after the welding process. The main inspection methods are appearance of the welding seam, the size of the part, the welding slag inspection, gas stoma inspection, the oil pollution inspection, and the quality of the welding seam. For the welding current and other parameters, the computer control system will start the alarm when danger situation happens.

Ultrasonic testing, magnetic particle testing, and turbine testing are using in the welding quality inspections. The quality control department of *XUZHOU Rothe Erde slewing bearing Co., Ltd* has Metallographic, chemical, and physical labs. *XCMG branch factory of construction machine* have a system of inspector responsibility, every work step will have their inspection process. All the products will have a total factory inspection before send to the customers.

Machine and equipment maintenance:

Everyday there will be a basic cleaning and maintenance of the equipment after work. Every month the professional personals from the equipment office will do the maintenance for every machine and repair the broken ones. The machine starting rate is a kind of examination indicators for the workers. The statement of the equipment will be inspected by the DNV or other certification regularly.

Material storage and treatment:

Satisfaction for the design requirement: the chemical element content (based on the US, Europe, Japan, and China standards), Metallographic microstructure, and the working conditions (desert, sea environment, or temperature requirements). The requirement of customers is more important than the standards.

Environment and climate:

Air condition workshops, constant temperature condition satisfaction, and constant humidity condition will meet for the welding processes. Also some other methods for the welding processes, which are dehumidifier, strong ventilation equipment, drying equipment, aging equipment, and carbide processing equipment.

5.3.2. The Quality Control Information from Zhejiang Shipbuilding Co., Ltd.

Working steps of the welding and machining workshops:

In this shipbuilding factory, the manufacture processes are: raw material cutting → small part welding or assembly (inside the workshops) → middle parts welding or assembly (partly inside the workshops, partly outside) → final assembly on the berth.

Every the welding seams, such as continuous welding, welding height, or welding positions, should be controlled by the WPS. The details of WPS are the business secrets of the factory.

Culture and human factors:

Workers form every part of China in this factory. The most amounts of welders are coming from Nantong city, Jiangsu province (Southeast areas of China).

Worker skills and personal training methods:

The assessment method is based on the national standards, which are including security assessment and skill assessment. The security assessment is more important in this factory. 50% of the welders in the factory have the welder certification. Nearly all the welding works will be finished by the outsourcing labor force companies, and the worker skills will be monitored along with the manufacturing process. The unqualified welders will expel immediately.

Inspect methods:

Inspection will be done by the professional personals from the quality assurance office. The total quality control processes are listed below:

Material incoming inspection: The basic inspections in this step are experiment for welding materials, technology assessment for the materials, and the authentication for the new type welding materials. All the experiment and authentication should be conducted under the instruction of welding process guide. For the inspection of steel boards, the board thickness and the shipping register certification are two important items. If needed, the physical or chemical experiment for steel board will also carry out.

Before welding inspection: The items for this step are groove, assembly trace, ribs, and board thickness differences.

Welding process inspection: the inspection personal should supervise the welders if they are working under the welding processing guide. There are tow kinds of inspections: patrol inspection and sample inspection. The total steps of welding process inspection are: welding finished (self inspection by welders, visual inspect, size of welding seams) → inspection of

boss (re-examination by boss, visual inspect, size of welding seams) → inspection of quality control personal (professional testing, visual inspect and machine inspect, size and quality of welding seams) → ship owner test (inspection by surveyor). Every steps should have the signature on the inspection file by every inspect person. Every welding seam will be recorded including the name of the welders.

Non-destruction test: After the quality control personal inspection, there should be some NDT test for the welding seams. The X-ray inspection and Ultrasonic inspection are using for internal testing. The magnetic particle testing and penetration testing are using for the surface cracks and stomas. All the NDT methods should be conducted under the NDT location graphs which are certified by the ship register.

After all the works, the production will be final inspected by the ship register and the X-ray film will include the signature from the ship register.

Machine and equipment maintenance:

Everyday there will be a basic cleaning and maintenance of the equipment after work. The welding machine, welding wire and cable should be put in a storage position after daily works.

Every week the professional personals from the equipment office will do the maintenance for every machine and repair the broken ones. The maintenance records will be kept as a file in the archives room.

Material storage and treatment:

Steel board and welding wire were storage in the special warehouse. Before manufacture and welding, the steel board will be pretreatment in order to remove the rust. The welding wire should be storied in a dry and ventilation environment, put away from wall over 30 cm, and paving by anti-damp materials. The factory also has their special standards for welding wire storage.

Environment and climate:

In the welding processes, if the welders are working in the confined spaces, the ventilation and lighting conditions should be guaranteed. When the welders are in working, all the labor protection devices such as masks or earplug should be used.

5.3.3. The Quality Control Information from Qingdao Qiyao Wärtsilä MHI Linshan Marine Diesel Co., Ltd. (QMD)

The quality control department of QMD is responsible for the welding quality to each welding seam according to the Welding and Quality Instruction of this factory. The operational sequence for planning and execution of welding activities, testing, and repair work of welded joints are including in the instruction. Not only the welders should obey those rules, but also the inspectors need pay their attentions on every working step.

Working steps of the welding and machining workshops:

Pre-treatment for materials → material cutting → parts assemble and welding → painting → machining → assembly for whole product → testing → product delivery.

For the welding steps and parameters, the first planning is pWPS based on EN 15609-1. In pWPS, the name of the company, WPQR number, materials, welding position, welding process in EN standards, consumables in EN standards, gas and flux, current, voltage, travel speed, energy input, heat treatment, and groove type is estimated. The next step is WPQR; the qualification of WPQR is according to ISO 15614-1. All the welding and testing must be witnessed by classification society. Then the next step is generation of WPS according to EN 15609-1, based on the qualified WPQR. After the production, NDT test will be conducted.

Culture and human factors:

The QMD welders are usually coming from other factories in Qingdao, and graduate students from technician schools of Qingdao.

Worker skills and personal training methods:

There is one specific welding training school inside the welding workshop (see in figure 55). The purpose of this place is helping the freshman to familiar with the daily welding works, especially focusing on the welding methods using in this factory.



Fig55. The work stations inside the training center

In this training center, also some simple material property testing will be conducted here. The testing will include fatigue testing, hardness testing, micro metallographic testing, and bending testing (see in figure 56).



Fig56. Testing specimens in the training center

Inspect methods:

In QMD, all the NDT test, like UT, VT, or MT test, will conduct accompanying the whole welding process (see in figure 57). All the testing activities will follow the standards listed in table 1.

Table 1: The EN standards for NDT using in QMD

EN Standard Number:	EN Standard Name:
EN 473	NDT-Personal
EN 12062	NDT-test scope
EN 970	Non-destructive examination of fusion welds/ Visual examination
EN 1290	Non-destructive examination of fusion welds/ Magnetic particle examinations

EN 1714	Non-destructive examination of fusion welds/ Ultrasonic examination
EN 571-1	Non-destructive examination of fusion welds/ Penetrate inspection



Fig57. The inspector is working with the UT test for welding seam

In QMD welding workshop, every welding cell will allocate several inspection staffs in order to ensure the welding seam quality (see in figure 58 and 59).



Fig58. Welding quality (MAG) for very thick steel boards in QMD



Fig59. The welding quality for stud welding in QMD

Machine and equipment maintenance:

In QMD, the maintenance and calibration will be followed the standards listed in table 2.

Table 2: The standards for machine maintenance and calibration

EN Standard Number:	EN Standard Name:
EN ISO 9001/9002	Quality management system
EN ISO 3834-2	Quality requirements for welding- fusion welding of metallic materials --- Part 2: comprehensive quality requirements
EN ISO 17662	Welding-Calibration, verification and validation of equipment used for welding, including ancillary activities
DVS techn. Bulletin 3009	Calibration of welding power sources
DVS techn. Bulletin 0714	Manufacturer requirements for the calibration of welding equipment manufactures

The welders will charge for the daily machine clean and maintenance, the professional team will charge for the disassemble maintenance every month.

Material storage and treatment:

The standards and recommendations of welding consumable storage which was explained in those materials below (see in figure 60) will be utilized in QMD.

- a) Welding consumable Handbook from Thyssen Schweisstechnik – 1999 Edition
- b) Welding consumable Handbook from Böhler Schweisstechnik – 2003 Edition
- c) Recommendation for storage, re-drying and handling of ESAB consumables
- d) FILARC product catalog – international edition 1999/2000

Fig60. The storage standards are using in QMD

The material storage and treatment rules cover every welding material. Handling and storage

of covered welding electrodes, solid and cored welding wire, and welding flux have a significant influence on the weld quality.

Environment and climate:

All the protection equipment will hand out to the welders, which is including overalls, special masks, welding glasses, and welder groves. Because all the welding works will be done inside workshop, the climate change will not influence the weld quality in QMD.

5.4. Overview of the Welding Industry in Eastern and Coastal Areas

The factories locate at China eastern and coastal areas have the most advanced management system, latest processing technologies, but the most expensive labor and management costs. In the eastern and coastal China area nowadays, the welding processes are usually finished by some middle and small scale factories. Because of the low margin and badly working environment, big scale companies often do not consider the welding work contract with the foreign companies. Nowadays, middle and small companies in the eastern and coastal China areas will also utilize the welding robot and automation welding systems in their welding works.

For the cooperation with foreign companies, like the north China areas, state-owned large scale welding factories or welding workshop in large scale factories do not have intentions to be a subcontractor, because the domestic cooperation with other state-owned factories or production for the government have already satisfied their production capacities.

The welding workshops in XCMG do not have any intentions about the cooperation. Zhejiang Shipbuilding Co., Ltd has the ability to process the construction machine parts, but there still do not have any contract is related without ship parts manufacture work. Small scale welding factories are the largest group who have strong willing to receive orders from foreign companies, just like the two welding factories become the ABB's subcontractor in Shanghai.

For QMD, this factory does not refuse any kind of cooperation with foreign companies, especially for Finnish companies. The QMD welding workshop section manager Mr. Frank Wang gives out the information about the ongoing manufacturing cooperation between QMD and Schuler Shanghai. Because of the role model effect of QMD in welding processing, other small scale welding factories in Huangdao district (the national economic and technology development zone in Qingdao city, Shandong province) also have the commission processing capacity in welding processing, based on the Europe standards.

6. The Status of the Southwest and Inland Areas' Welding Factories

In this section, four factories located at western and inland areas of China will be introduced according to the visiting sequences. This expedition was made by Xiaochen Yang from 6.4.2011 to 11.4.2011 in China. Those factories are built in Kunming city, Yunnan province, and Chengdu city, Sichuan province respectively.

The first expedition was made on 6.4.2011, and the target company is Yunnan Yunmeng steel structure manufacture factory (for short title: Yunmeng). This is a middle scale workshop established in west suburb area of Kunming city, Yunnan province. The main products and work for this factory is the welding, machining, and assembly of steel structure using in road and building construction works. This factory also does welding and machining works for machine parts. The foremost processing is welding in this workshop.

The second expedition was made on 7.4.2011, and the target company is Mechanical repair factory of Yunnan Copper Corporation. This is one of the independent operating branch factories of Yunnan Copper Corporation, which is located in west area of Kunming city, Yunnan province. The principle business of this factory is the repair work, which is including machining, welding, and assembly, for Yunnan Copper Corporation's machines and equipments. This factory also has their own business which is including some steel structure work and machining work for private enterprises. This factory does not have many contracts with the companies outside Yunnan province. This factory has the qualification for mechanical repair but do not have the qualification for mechanical manufacture. This factory do not allowed taking photos.

The third expedition was made on the morning of 11.4.2011, and the target company is

Chengdu Zhongling radio communication cable Co., Ltd. Zhongling is a leader firm of the cable equipment manufacturer in Sichuan province. The welding method which are using in this company is TIG argon welding. The main products of this factory are RF coaxial cable for wireless communication usage. There are many types of products manufactured every year, more and more innovative products ensured the competitiveness in the competitive market all over China and even the whole world. There are about 20 factories all over China for communication cable manufacturing (by using argon arc welding), which are distributed in Jiangsu province, Zhejiang province, Sichuan province, and Shanghai municipalities.

The last expedition was made on the afternoon of 11.4.2011, and the target company is Sichuan Tungtay new material technology Co., Ltd. This is a steel-plastic pipe manufacturing factory. The main welding process is TIG argon arc welding. This is an ISO 14000 and ISO 9001:2000 certified company and total area of this factory is about 50000 m². Average wage in this factory for workers is about 1000 RMB per month because the automatic production line does not require much human labor or working skills.

6.1. The Productivity Status of Southwest and Inland Areas

Because of the geographic environment, the southwest and inland areas of China have the lower productivity comparing with other areas. New technologies and new working skills need more time to bring in than north China or eastern China. Despite the disparities between all the Chinese areas nowadays becomes more and more insignificant, the number of cooperation with foreign companies in southwest and inland areas is still lower than that of other areas. The trend of transnational cooperation in southwest and inland areas is increase at recent years, but this situation will still not change very severe in the near future.

6.1.1. The Productivity Data from Yunnan Yunmeng Steel Structure Manufacture Factory

Numbers of workers:

This factory has $2 \times 1000 \text{ m}^2$ welding workshops, and 8-12 welding workers. Eight of the welding workers are regular workers; four of them are especially working for stainless steel. Every welder has 5 years working experiences in this factory.

Customers nowadays:

The customers of Yunmeng are some road and building construction corporations, or some private mechanical manufacturing factories.

Worker skills:

Every welding worker has the technician certificate. 1 or 2 welding workers are senior technician, 80% of the welders are intermediate technician. Every welder should have very perfect engineering drawing reading skills.

Plants' situations:

Yunmeng has an indoor workshop, but the poor condition of this workshop can not ensure the high productivity well (see in figure 61). Meanwhile, the irregular working or cleaning skills or activities of workers also can not assure their health.



Fig61. The situation of the workshop

Like the figure 62 shown, orderless working environments is easily leading to fire or electric shock.



Fig62. The orderless working environment

Manufacturing tools & machines:

The list below was shown the manufacturing tools which are using in this factory:

- Straight cutting machine (3 meters) × 1 (Wuxi Kaipu NC welding and cutting technology co., ltd);
- Board correction machine × 1 (Wuxi Chuangxin HYJ 40 H);
- Submerged arc welding machine × 1 (Chengdu Huayuan ZD5 - 1250) (see in figure 63);



Fig63. Submerged arc welding machine (welding machine parts)

The SAW machine using in Yunmeng is not manufactured under the national standards, the hidden dangerous of this machine is serious (see in figure 64).



Fig64. The submerged arc welding machine (control parts)

- Plasma cutting machine × 1 (Changzhou Boka APC - 100);

In the high humidity environment, the working of plasma cutting machine have serious hidden dangerous, like leads to electric shock (see in figure 65).

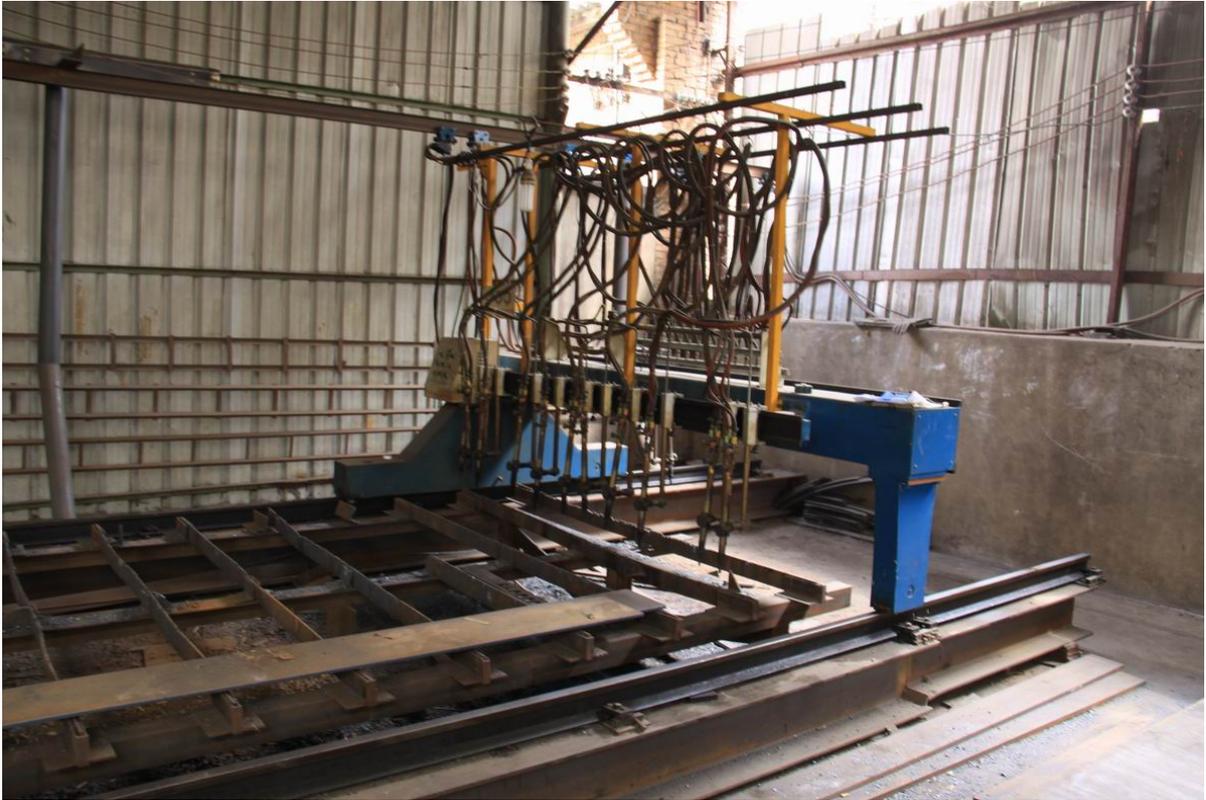


Fig65. Plasma cutting machine

- CO₂ or mixed gas welding machine (MAG) × 4 (Chengdu Huayuan NB – 500 KD and NB – 500 IGBT) (see in figure 66);



Fig66. The MAG welding machine

- AC spot welding machine (MMA) × 1 (BX1 - 500) (see in figure 67);



Fig67. The poor working condition of MMA welding machine

- Contour cutting machine × 1;
- Semi-automatic cutting machine × 3.

Materials:

- Steel board, steel type: Q235, Q345; Stainless steel board;
- Welding wire: Xinqiao brand welding wire;
- Welding flux: 431 type.

The consumption of SAW wire is 5 to 5.5 tons per year. The consumption of MAG welding wire is 4 tons per year.

Environments and climates:

The temperature require when doing the welding work is over $+5^{\circ}\text{C}$. The annual air temperature of Kunming city is about $+8^{\circ}\text{C}$. In the rainy and windy days, the welding works inside the workshop is allowed, but the outside welding works must be stopped. The humidity requirement is strict in this factory.

6.1.2. The Productivity Data from Mechanical Repair Factory of Yunnan Copper Corporation

Numbers of workers:

There are 7 – 8 welders in this factory; the total number of workers is 18.

Customers nowadays:

Steel structure welding work for middle and small scale private enterprises is the nowadays customers of this factory.

Worker skills:

70% of the workers are senior technician. 20% to 30% of the workers are technician. All the workers have their own technician certificate.

Plants' situations:

There are 3 workshops in this factory, 1 of them is outdoor workshop. The total area for welding is about 1000 m³

Manufacturing tools & machines:

The list below shows the manufacturing tools which are using in this factory:

- MIG (Argon as shielded inert gas) welding machines×5 (Panasonic-TIG WP 300×3, Weldingking NBC-500A×2);
- MAG (CO₂ as shielded active gas) welding machine×3 (Panasonic 505 FL4);
- AC MMA welding machine×3 (Hugong BX1-500F-3 and Hunan electronic welding machine factory BX1-500F);
- DC MMA welding machine×2 (Hugong MZ1-630K);
- DC seam automation welding machine × 1 (Chengdu welding machine factory FZD-3×100)

Brand of welding wire: Pacific CHS132 welding wire.

Materials:

Almost all the metal materials can be manufactured in this factory, the material selection and chosen will decided by the customers. The biggest amount processing material is steel. Copper is the product of the parent factory, but the processing materials which customer required of this repair factory is not copper.

Environments and climates:

In the raining environment, all the welding works will be stopped. The electric welding works will be finished in outdoor workshop. The argon arc welding and plasma cutting process will be done in indoor workshops.

6.1.3. The Productivity Data from Chengdu Zhongling Radio Communication Cable Co., Ltd

Number of workers:

There are 6 production lines and 3 workers for each line. Total worker number is 18 because of the perfect automation manufacture technology in this factory.

Customers nowadays:

The customers are including China mobile, China Unicom, and China telecom.

Plant situation:

In order to manufacturing the inner core of the communication cable, the copper belt will be firstly formed as a circle structure, and secondly welding the seam to form the inner cable core (see in figure 68).

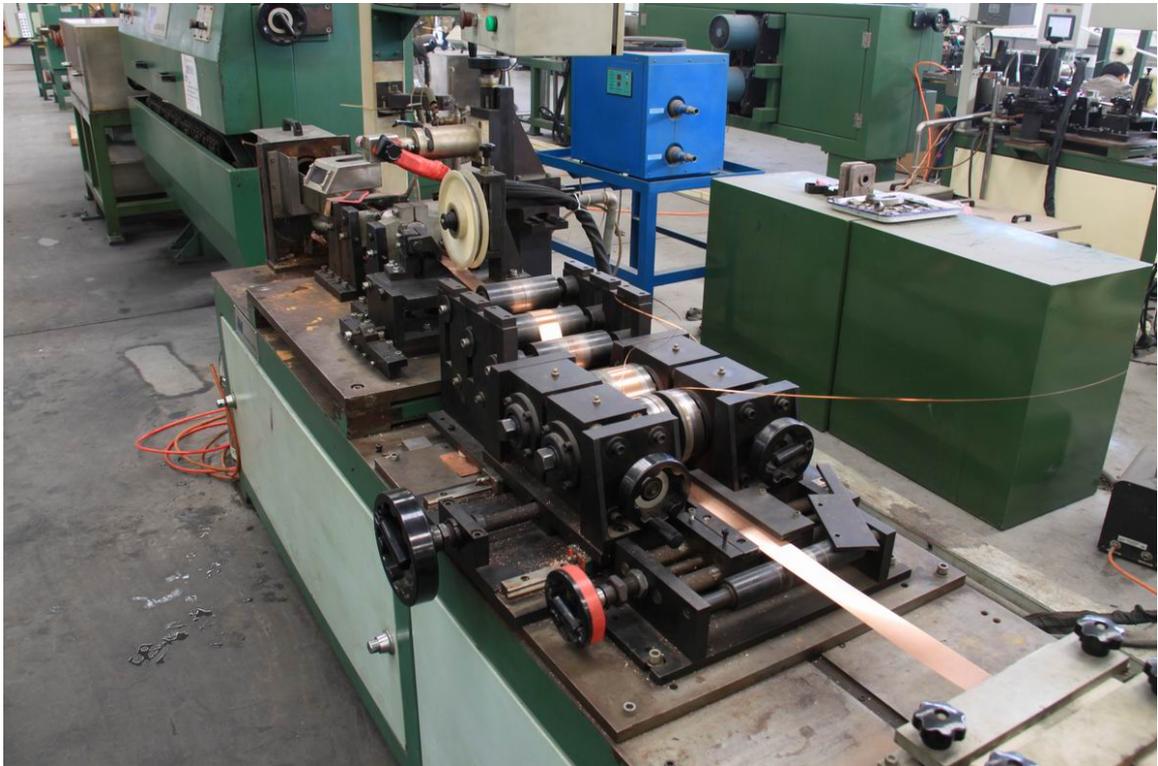


Fig68. The copper belt welding line

In this copper belt welding line, copper belt was sent into the machine, and forming to a ring

structure. By using TIG seam welding method, the copper ring belt will finally formed as the inner core of the communication cable.

The environment of this factory is neat and clean, because of the automation production lines (see in figure 69 and 70).



Fig69. The main situation of the plant



Fig70. The environment of the plant

The six manufacturing lines ensure the productivity of the manufacture (see in figure 71).



Fig71. Six manufacturing lines

Worker skills:

Because the manufacturing line of TIG welding process is totally automatic executed, the worker do not need welder certification when they enter the factory, but the enter plant training should be conducted when the workers become the regular staff of the factory.

Equipment and machines:

There are 6 high frequency TIG (argon as shield gas) automatic continuous welding production lines in the production area. The welding machines which are using in the production lines are: Miller Maxstar350×3 (see in figure 72), Miller Syncrowave 350 LX×1, and EWM Tetrix 500 DCTGD×3, as the figure 73 shown.



Fig72. The Miller Maxstar 350 welding machine



Fig73. The EWM welding machine

Manufacturing materials:

This factory is using copper belt, or aluminum belt to complete the manufacturing of communication cables.

Environment matters:

Normal temperature and humidity can be assured in this factory. All the welding works will be done in a relatively constant environment.

6.1.4. The Productivity Data from Sichuan Tungtay New Material Technology Co., Ltd

In Tungtay, there are three ways to manufacture the inner core of the tubes related with welding technology (see in figure 74).

The first working process is: perforated-strip feeding → perforated-strip bending and welding seam forming → TIG (argon as shield gas) welding of seams (see in figure 75, 76, and 77) → inner core ready → next steps (form the surface of the tube). Like the next figure demonstrated, each step for this manufacturing method is totally automated; every production line only needs few workers to finish the works.



Fig74. Production line for steel-plastic pipe

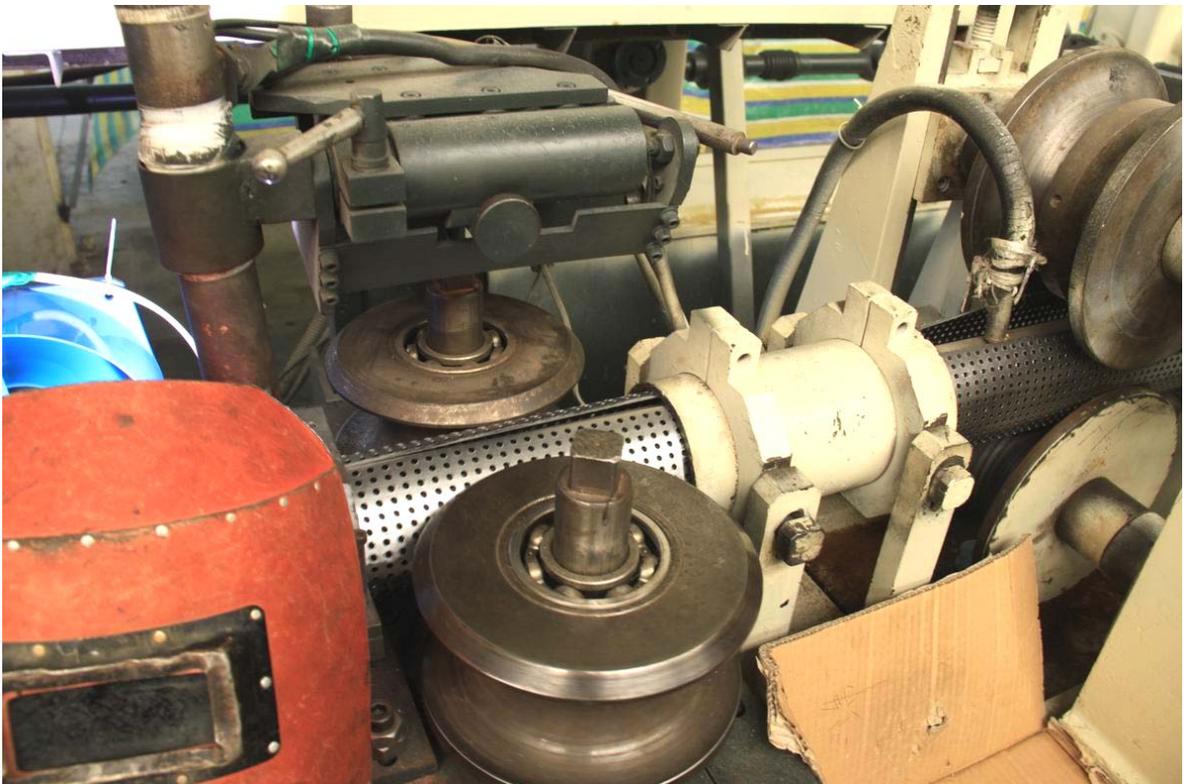


Fig75. Perforated-strip bending and welding seam forming



Fig76. TIG argon arc welding

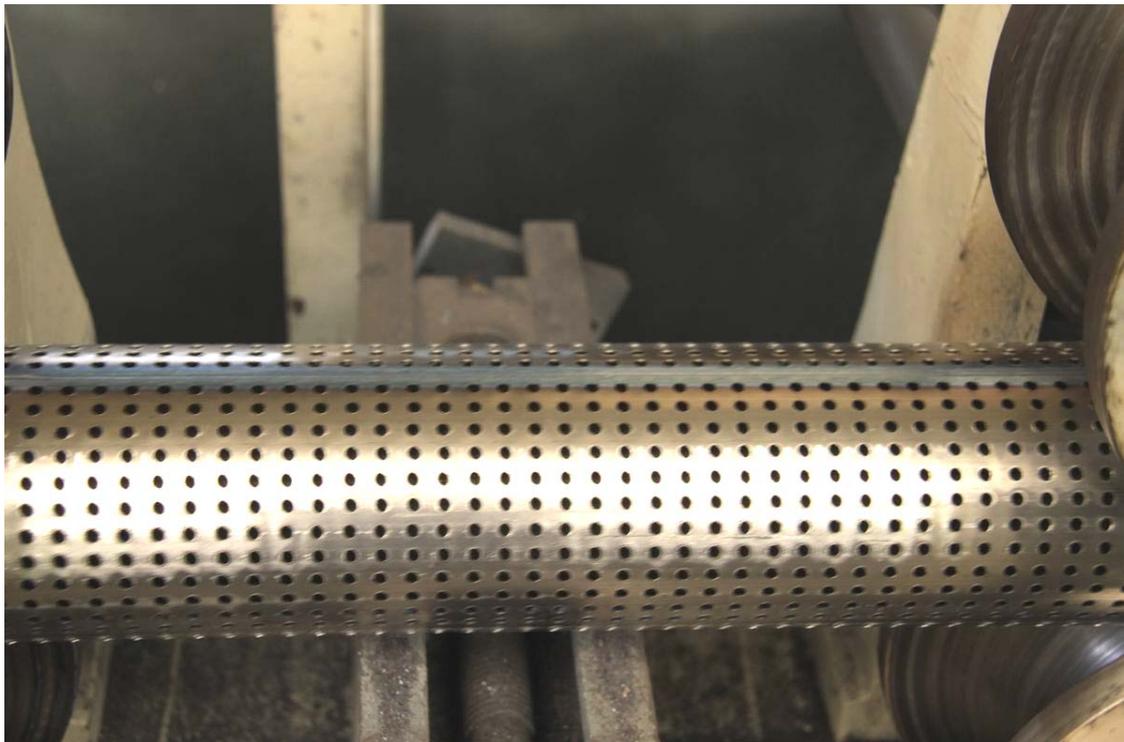


Fig77. The welding seams

The second working process is: perforated-strip spiral forming of the metal belt → TIG (argon as the shield gas) welding for the welding seams → inner core ready → next steps (forming the soft plastic surface of the tube), like the figure 78, 79 and 80 shown.

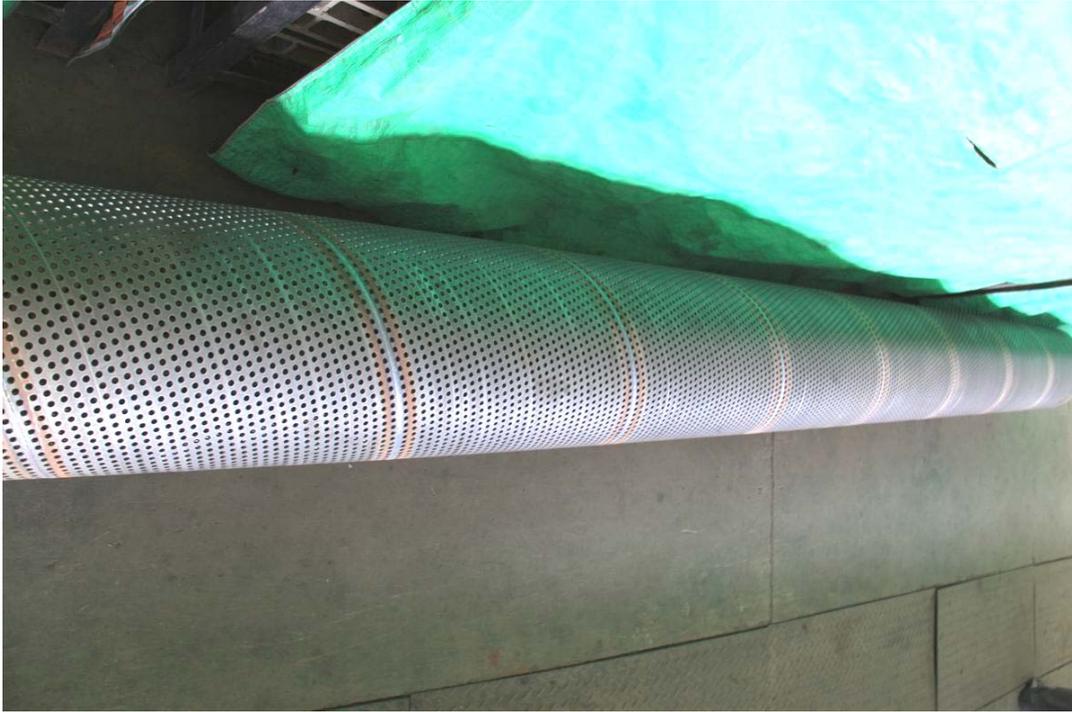


Fig78. The inner structure of perforated-strip spiral pipe



Fig79. TIG welding production line (the welding torch)



Fig80. TIG welding machine using in the second method

The last working process is: warp direction and weft direction steel wire feeding → spot welding for steel wire net → inner metal net ready → next steps (forming the plastic surface of the tube), like the figure 81 shown.

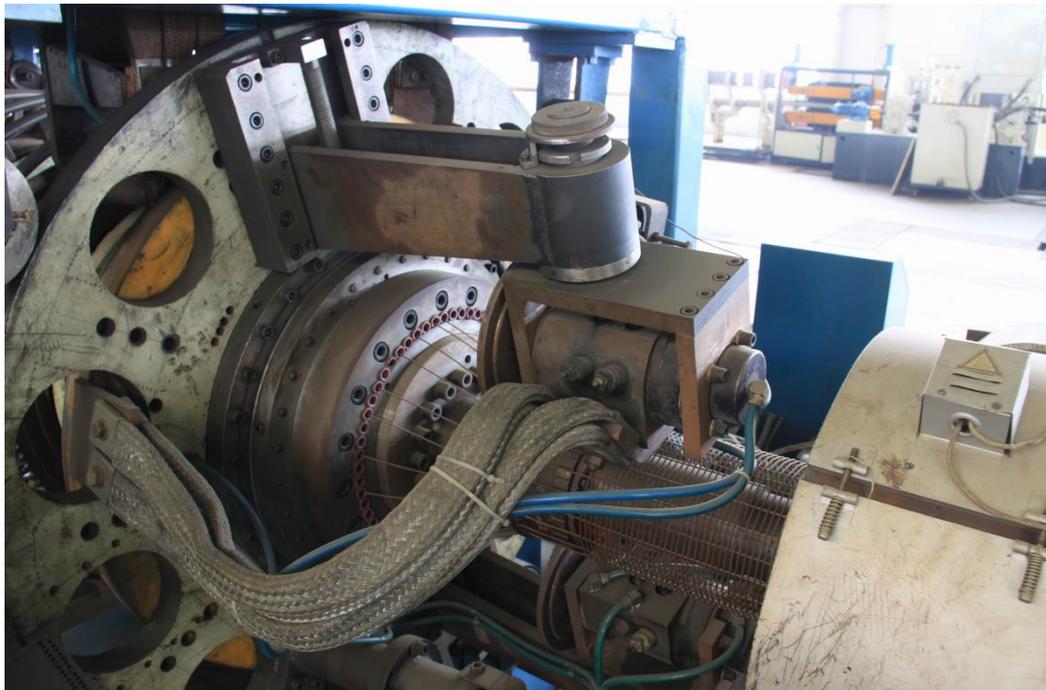


Fig81. Spot welding for steel wire net (inner structure for steel-plastic pipe)

6.2. The Cost and Economy Status of Southwest and Inland Areas

The significant features to the cost and economy status of southwest and inland areas in China is the lower labor cost than other regions. Because of the relatively low living cost in this area, the wages for welders also stay at a lower level than other areas. Meanwhile, this area located in a deep inland place, the transportation cost may relatively higher than other place. For the cost of raw material and welding auxiliary materials, this area does not have more superiority than other places in China.

6.2.1. The Cost and Economy Data from Yunnan Yunmeng Steel Structure Manufacture Factory

Workers salary:

Average wage for welders is 3000 RMB per month. 20% of the workers have higher wage level which is 4000 RMB per month, 20% of the workers have lower wage level which is 1500 RMB per month. The management and accident control methods implemented in this factory ensure the low accident or defective rate, so this factory does not have any major accident over 20 years. The low accident or defective rate leads to no rules about the wage deductions in this factory. The salary level will decide after the welder's first working week.

Materials cost:

The cost of steel board, profile steel, and steel occupied 75-80% of the total cost. The steel price changes fluctuant at recent year. The entire prices for main materials are the market price on the date of the contract, and can not be changed in future. The steel price is 4600 RMB per ton at December 2010, but now is 5200 to 5300 RMB per ton (April 2011, all over China steel market).

Logistics cost:

Highway transport for materials and products is the main transportation way, including the transportation of steel. The logistic fee should be paid when the inbound for steel, but the

logistic fee for products will be paid by customers. All the logistic cost will be included in the price for all the gas and welding wire.

Processing cost:

Auxiliary materials using in the processing: welding rod, welding wire, welding flux, oxygen, propane, argon, industrial gas, carbon dioxide, brush, paint, and roller. The Auxiliary materials cost is 12% of the total cost. Water and plant rent: 8% of the total cost. The table 3 is the summary of the gas, electricity and water price comparison between 2010 and 2011 (see in table 3):

Table 3: The industrial gas, electricity and water price comparison (case: 2010 & 2011)

Material name:	Price in 2010	Price in 2011
CO ₂ gas welding wire	6500 RMB per ton	8800 RMB per ton
CO ₂	40 RMB per 40kg	60 RMB per 40kg
O ₂	8-12 RMB per 6 m ³	16-20 RMB per 6 m ³
Water	2 times than civilian use	3 times than civilian use
Electricity	1.3 RMB per kWh	1.3 RMB per kWh
Total processing cost	800-900 RMB per ton	1200-1400 RMB per ton

Turnover:

The turnover is 3 million to 4 million RMB for the whole factory last year.

6.2.2. The Cost and Economy Data from Mechanical Repair Factory of Yunnan Copper Corporation

Workers salary:

The average wage for welders in this factory is 3000 RMB per month, which is including the five insurances and one fund. The employment technician's wage is 5000 RMB per month, which is not including the five insurances and one fund.

Materials cost:

The price of the steel board is according to the market price, which is including most of the type of steel board and steel bar.

Logistics cost:

The logistic and transportation cost will be response for the purchasing department in the Yunnan copper corporation. This repair factory itself does not need to consider the logistic and transportation cost. The private customers must pay the logistic cost by themselves.

Processing cost:

All the processing cost will do a pre-estimation before manufacturing. Processing costs are including the water, argon, oxygen, acetylene, electricity and every type of welding rods.

Other cost:

Depreciation cost for manufacturing machines and cost of equipment loss.

Turnover:

100000 RMB per year for the private enterprises contracts because this factory do not have any market development activities. The turnover for Yunnan Copper Corporation is 300 million RMB per year.

6.2.3. The Cost and Economy Data from Chengdu Zhongling Radio Communication Cable Co., Ltd

Workers salary:

The main task for workers in this factory is solder pin grinding works, solder pin installation, welding current adjusting, gas flow adjusting, and solder pin position adjusting. The average wages for workers is 1500 RMB per month.

Manufacturing cost:

Argon: 20 litter/min, 20 hour/day, 26 days/month. The total cost for one month is the price/litter \times 62400 litters.

Helium: Only using when welding the aluminum materials. This factory does not have this work commonly.

Solder pin: one solder pin could weld copper belt for 10 kilometers, usually every month 500 – 1000 kilometers' copper belt will be welded. The average number is 800 km/month.

Water and electricity: 0.5 RMB per 1 meter copper belt.

Turnover:

The turnover for Zhongling is 1.3 billion RMB last year.

6.3. The Welding Quality Status of Southwest and Inland Areas

All the production of those factories in southwest areas of China must compliance with the national standard and corporate standards. For the quality control methods, the Yunmeng and mechanical repair factory of Yunnan Copper Corporation do not use NDT test if the customers do not request. The two factories in Chengdu, because there are only automatic manufacturing lines related with welding technology, meanwhile those two factories did not facing any quality problem to their products until now, they do not have a systematic quality control criterion in using in their manufacturing processes.

6.3.1. The Quality Control Information from Yunnan Yunmeng Steel Structure Manufacture Factory**Working steps of the welding and machining workshops:**

In this factory, the manufacture processes are: raw material cutting \rightarrow assembly \rightarrow

riveting and welding (spot welding and seam filling welding) → steel board correction (completed on the board correction machine) → painting (see in figure 82).



Fig82. Products after painting

No special pWPS, WPQR or WPS are using in this factory. The experiences or requirement on the drawing for welding parameters is the only standard in the production.

Culture and human factors:

Most of the workers come from Kunming city, Yunnan province (southwest China area).

Worker skills and personal training methods:

There are two standards for the welder training and testing. The first standard is the welder should have the welding certificate for boiler and pressure vessel. The second standard is the safety training which is including the use of water, gas, and electricity, ground protection for electricity, and decompression for gas.

Inspect methods:

The following steps are the inspection working in this factory: geometry size test (workers self test) → weld dimensions test (factory test) → NDT (ultrasonic test, X-ray test, and magnetic particle test, if request) → products ready.

The entire welding seam ND test will be conducted after 24 hours when welding work is finished. Inspection will be done by the professional personals from the quality assurance office (see in figure 83). All the personals have the inspection certificate for boiler and pressure vessel. All the inspection works should meet the requirement of design.



Fig83. The welding seam appearance after inspect

Machine and equipment maintenance:

Everyday there will be a basic cleaning and maintenance of the equipment after work by welders. All the broken machines will repair by the manufacturer.

Material storage and treatment:

Steel board and welding wire were storage in the special warehouse, preventing moisture. The humidity of electrode must below than 40% and sealed.

Environment and climate:

Working mask, light barrier, and welding groves for welders are using in the production, but because the warm temperature and outside working condition, the welders always lack of protection (see in figure 84).



Fig84. The welders at working

The processing waste will collected by specialized company on time.

6.3.2. The Quality Control Information from Mechanical Repair Factory of Yunnan Copper Corporation

Working steps of the welding and machining workshops:

This is the processing steps in this factory: engineering drawing reading and review →

materials preparation → processing steps → manufacturing (machining and welding) → inspection → products ready.

Culture and human factors:

All the welders are coming from Kunming city, Yunnan province (southwest areas of China).

Worker skills and personal training methods:

The assessment method is based on the national standards, which are including security assessment and skill assessment. The security assessment is more important in this factory. The factory will held some training courses every month, and also have special training course before the welder certificate examination. All the freshmen will select an older worker as a teacher, after a short period of training, the freshmen then can acquire the welder certificate and become a regular staff.

Inspect methods:

Inspection will be done by the professional personals from the quality assurance office. The size and dimension will be inspected at first, then the gas pocket and trachoma will be inspected by destructive testing.

Machine and equipment maintenance:

Everyday there will be a basic cleaning and maintenance of the equipment after work. The welding machine, welding wire and cable should be put in a storage position after daily works.

Every week the professional personals from the equipment office will do the maintenance for every machine and repair the broken ones. The non-maintenance machines will be sent back to the manufacturer and do the repair by them.

Material storage and treatment:

Steel boards were storage at outdoor environment. Welding wire and welding rods were

storage in the special warehouse. All the auxiliary materials will be managed by the special team from storehouse.

Environment and climate:

All the protection equipment will hand out to the welders, which is including overalls, special masks, and welder groves. All the protection equipment will purchase from 3M Company.

6.3.3. The Quality Control Information from Chengdu Zhongling Radio Communication Cable Co., Ltd

Working steps of the welding and machining workshops:

The manufacturing processes for welding in this factory are: former steps → copper belt bending → seam welding by using TIG argon welding method → water cooling → next steps (see in figure 85, 86 and 87).

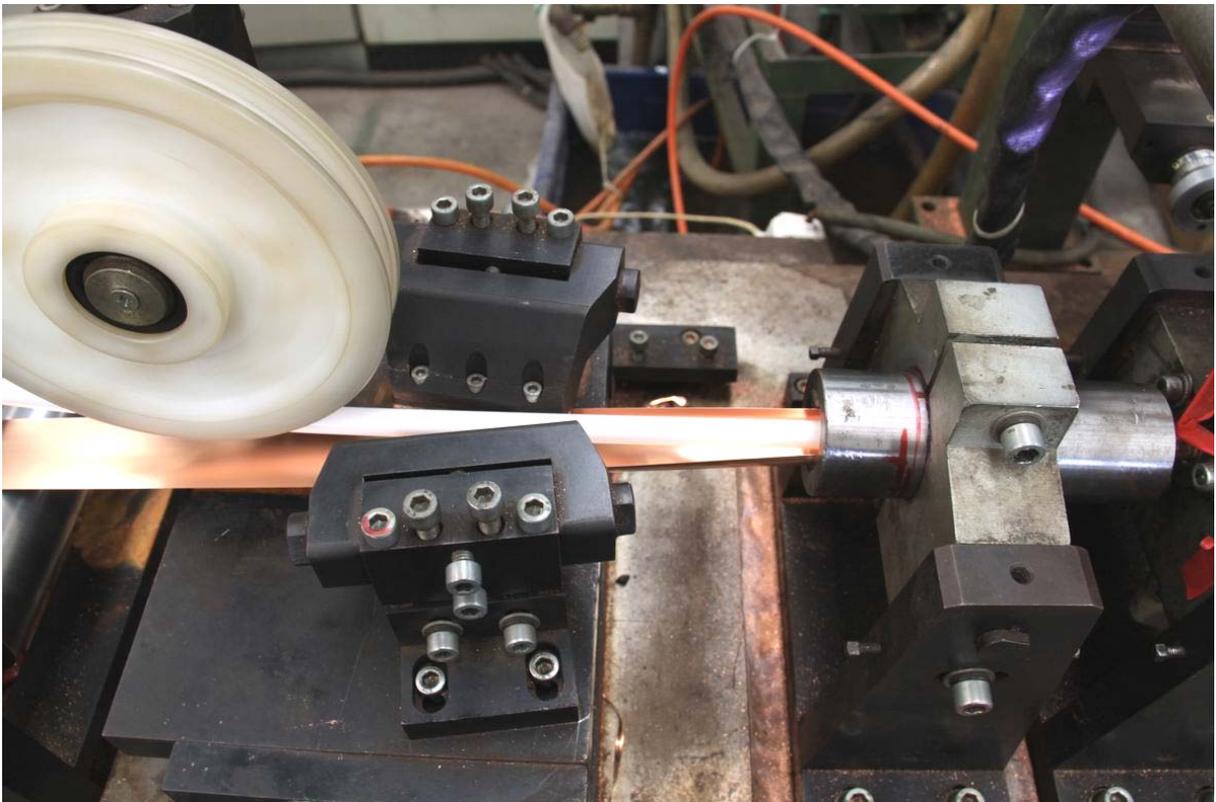


Fig85. Copper belt bending and feeding into the welding machine



Fig86. Copper belt welding (TIG argon arc welding)



Fig87. Fine welded copper belt

Culture and human factors:

50% of the welders in this factory are coming from the rural area of Chengdu city; the other 50% are coming from other places in Sichuan province.

Quality control methods:

There has no welding accident until now (the establish time of this factory is 1999). The main quality control method is using the weld leakage detector nowadays.

Environment conditions:

Humidity and temperature conditions are well controlled when the manufacture is conducted. The storage of manufacture materials is very strictly in this factory.

6.4. Overview of the Welding Industry in Southwest and Inland Areas

The professor He Pang of Kunming University of science and technology gives out the information about welding industry situation in southwest China areas. If considering the overview level of all the provinces' welding industry in southwest China areas, the Sichuan province occupy the first place, the second one is Yunnan province, and the last one is Guizhou province. If compared with other places inside the whole Chinese domain, welding industry in southwest areas is still in a low level. The eastern and costal area has the best welding industry.

Before 80's, the MMA welding is nearly the only processing method for welding works. From the beginning of year 1980, MAG (CO₂ as shielded active gas), MIG (Argon as shielded inert gas), and SAW are using in welding works gradually. Nowadays, the 70% to 80% of the welding works in southwest China will finish by MAG (CO₂ as shielded active gas), the second place welding method for processing is MMA. Large scale and state-owned factories have bigger application ratio for MAG (CO₂ as shielded active gas) than the middle and small scale factories. The famous commercial factories in Kunming city, like Sanhe steel structure

factory, Kunming shipbuilding factory, and Huabang steel structure factory, have more advanced welding technologies. The Yunnan railway machinery factory have large amount of welding application works, the equipments and machines inside this company is more advanced than other factories, automation welding lines, and welding robots are using in this factory. FAW-GM Hongta Yunnan automobile co. ltd has 14 welding robots nowadays, and they are purchasing manual spot welding lines recently. Some private factories also have welding robots, but the welding accuracy is low. The Meishan locomotive plant in Sichuan province has big amount of automation welding lines. In Guangxi province, laser welding and electron beam welding have a certain level of application. For the cutting processing, only large scale factories in southwest China have NC cutting machine. For the welding material, low carbon steel welding occupy the first place. Number 422 welding wire is the most widely used filler material.

Considering about the welder training, the assessment criteria is backward and unilateral. There are appointment permit and grading permit for joiner welders, intermediate welders, and seiner welders. The content of assessment is mainly MMA welding for thick steel boards. The testing for welding sheet boards is ignored usually. The welding skills for special materials and structures are low. Big amount of the welders do not have the knowledge about NDT. The concept of WPS is also not built inside the welding teams, this leads to the most of the welding works were finished by experiences. The welders also do not have agility to treat different processing measures and materials. Even sometimes the welding certification could be purchased. The key companies like Yunnan boiler factory, or Yunnan chemical industry light machine plant, have the professional inspection teams, or the national qualified professional inspection and experiment laboratories and NDT test for welding works. Other factories always only have the visual inspection for welding seams, and do not pay attention to NDT test. The middle and small scale factories always guarantee the quality orally, but ignore the quality problem and inspection in production. Considering about the NDT test, ultrasonic test and X-ray inspection are two testing methods using in the production, the penetration inspection and magnetic particle testing are not usually using in production because of the narrow range of applications. The small scale factories also do not pay

sufficient attention on the temperature change and humidity avoids, that also may lead quality problems in Yunnan province. Considering about the welding machine maintenance, a big amount of factories can not complete the maintenance according to the manuals instruction. The daily maintenance of welding machine directly relate with the diathesis of the welders. The maintenance work in large scale factories were better than other factories, but also can not assure the short-term maintenance.

The Chinese made welding machines are usually using in southwest areas' welding factories because of the low price. The domestic made welding machine only cost 1/3 of the price of foreign welding machine. Some foreign brands like Panasonic, or OTC, because the welding machines were manufactured in China, the price do not high. The Lincoln welding machine have high price, so the market for this brand is not big in southwest China. The inverter welding machines, which are made in Shanghai, Shenzhen, and Chengdu, are in the promotion period now. The margin of welding processing in southwest China is high, especially in the private small scale factories. The processing cost is low, the equipment is cheap, and meanwhile, the labor cost and welding material cost is very low. Usually, the monthly salary for welder is 1000 to 2000 RMB, the daily salary for welders with pressure vessel certification is 200 RMB, the daily salary for welders only with welding certification is 70 RMB, and without welding certification is 50 RMB. For some special personnel, the monthly salary is only 500 RMB. The welding certification sometimes becomes the signs touting, the certification holder always do not participate the welding works.

The southwest China areas do not have much foreign cooperation. The well equipped factories will have contract from other countries. Compared with other areas in China, the amount of southwest China areas' cooperation work with foreign companies is very low. The commonly export route from Yunnan province is: Yunnan → Shanghai (by railway) → foreign countries (by ship). In southwest China areas, the welder skill level, the equipments of the plant, and the welders' diathesis are the significant factors which may influence that if foreign companies will chose a factory to be their subcontractor or not. Like other areas in China, private factories usually willing to accept the contract with foreign companies.

Considering about the domestic welding cooperation, the southwest and inland area also have the situation that large scale factories give their welding works to professional small scale welding factories or even the family workshops. The advantages in this area is the lower labor cost, the lowest salary for welders in this area is 300 RMB per month.

7. The Future Prospect of the Finland Companies' Investment in China and Suggestions to the Chinese Subcontractors

In this chapter, the summary of Chinese welding factories will be included, and the suggestions to the Finnish companies who have the willing to find a Chinese welding factory as their subcontractor or have the willing to build a welding workshop in China also will be included. The information of status quo and future prospect are all based on the real information gathering from China.

7.1. The Advantages and Disadvantages in Three Areas and Different Scale Factories in China

Form the research and information of the previous contents, the advantages and disadvantages of different Chinese areas and different company scale are summarized as fellows.

The advantages of north China areas are: 1) two fine harbor, Tianjin and Dalian, for export easily, 2) because of the heavy industrial background of north China and northeast China, the worker skill in this area is easy to ensure, 3) the factories near Beijing have higher level of business management than the national average level, 4) the workers' wage and material cost are at the middle level, 5) form the cultural factors, the workers in north China area have a good loyalty, 6) considering about the climate factor, the north China area do not have humidity season which will influence the welding processing works. *The disadvantages of north China areas are:* 1) the total welding management is not complete implemented, 2) ND test is inadequate in the production process, 3) the pWPS, WPQR, and WPS is usually overlooked, 4) considering about the climate factor, the north China area have cold winter which will influence the welding processing works.

The advantages of eastern and coastal China areas are: 1) many fine harbor, like Qingdao, Shanghai, Lianyungang and Ningbo, for export easily, 2) the factories located in this area have higher level of business management system than the national average level, 3) because of the formal training process, the worker skill in this area is easy to ensure, 4) the eastern and coastal areas have a good cooperation history with foreign companies, 5) form the cultural factors, the workers in the eastern and coastal area have diligent character, 6) considering about the climate factor, the eastern and coastal China area do not have cold winter which will influence the welding processing works, 7) the quality control and inspection work level is higher than the national average level. *The disadvantages of eastern and coastal China areas are:* 1) the workers wage is the highest comparing with other Chinese areas, 2) considering about the climate factor, the eastern and coastal China area have heavy humidity season which will influence the outdoor welding processing works.

The advantages of southwest and inland China areas are: 1) the workers wage is the lowest comparing with other Chinese areas, 2) considering about the climate factor, the southwest and inland China area do not have cold winter which will influence the welding processing works. *The disadvantages of eastern and coastal China areas are:* 1) the southwest and inland areas do not have a good cooperation history with foreign companies, 2) the transportation cost is higher than other Chinese areas because the geographical conditions, 3) considering about the climate factor, the eastern and coastal China area have heavy humidity season which will influence the outdoor welding processing works, 4) the quality control and inspection works is not sufficient in this area, 5) the worker skill level is lower comparing with other Chinese areas.

The advantages of small scale welding factories are: 1) the professional working conditions only focusing on the welding works, 2) usually the welder skill is easy to ensure, 3) have strong will to find the cooperation with foreign companies, 4) the cost of small scale factories is lower than other factories, 5) usually have a higher working efficiency. *The disadvantages of small scale welding factories are:* 1) usually the quality control and inspection works are inadequate, 2) no sufficient management system using in the factories, 3) the probability of

false in processing is higher than other factories, 4) relatively lack of the protect equipment of the welders than the large scale factories.

The advantages of large scale welding factories and welding workshops in large scale factories are: 1) have a complete welding quality control and management system to ensure the production quality, 2) the worker skill is easy to ensure, 3) the enterprise management system is reliable, 4) have the higher credibility, 5) have better processing equipment and working environment. *The disadvantages of large scale welding factories and welding workshops in large scale factories are:* 1) the cost of large scale factories is higher than other factories, 2) state-owned factories usually do not have strong willing to find cooperation with foreign factories, even do not accept the foreign contracts.

The middle scale factories on one hand have relatively low cost, the willing to cooperate with foreign companies, and the adequate working skills, on the other hand have suitable enterprise management system, the adequate quality control and inspection team, and the well equipped welding machines.

All the summaries above are based on the average situation, the special cases are existence. For the special cases, the targeted survey for them is recommended before to decide them to be a subcontractor.

In future, Chinese welding factories will not change severe, because of the stable and profitable working pattern using in China nowadays. The equipment update will be the most significant change in future, and the promotion of more advanced enterprise management system will be not so notable. In the near future, Chinese welding factories, including small and middle scales, will keep the intensive enthusiasm of foreign co-operations. The cost of welding processing will not change severe in the near future. The quality control will be better gradually in future.

7.2. The Improvement Suggestions to the Chinese Welding Subcontractors and Factories

The quality control and production management are two significant problems towards almost all the Chinese small scale welding factories, portion of the middle scale welding factories, and even some of the large and state-owned factories. To solve the two problems, the advanced and standard production management theory, the proper enterprise management system, and more welding production standards should be employed in those factories. The total welding quality management, the PDCA theory, the 5S methodology, the Six Sigma business management strategy, and more formal welding standards can help a factory to avoid management or quality problems efficiently. Some of the management or quality control theories had already applied in some Chinese factories, like XCMG, most of the other welding factories in China do not have application of those theories.

The plain willing to cooperate with foreign companies are problems to the Chinese state-owned factories. The suggestion to those factories is that the cooperation with foreign companies can improve the enterprise management model, improve the enterprise reputation, enhance the enterprise credit, and increase the profitability. In the future, strengthen the cooperation between Chinese state-owned factories and foreign companies will be an important issue that the state-owned factories should be considered.

7.2.1. Total Welding Management

The total welding management means a welding working team, basing on the full personal participation, put the quality as their working focus, and the aim is to reach the long-term success by satisfying the customers and benefiting the society and all the staffs inside the welding team. The management theory of total welding management is: concepts of total welding management, quality management of total welding processes, and the quality management for the total staffs' participation. The orientations of total welding management are: customer service first, prevention first, real data first and PDCA first. [18] The

significance of total welding management is: improve welding quality, ameliorate the product design, accelerate the production process, inspire the staff morale, enhance the quality awareness, reduce the operating cost, and reduce the accidents. [19]

The total welding management requires each participate inside the welding work consider the next operations as their customer. The welders do not only response for their own work, but also have the responsibility to the next processing. It can make sure that the quality problems in the production chain do not influence next steps intensively. [20][21]

The total welding management requires the prevention-oriented welding work. Prevention is important than inspection. The prevention work can effectively avoid or reduce the defect rate. Furthermore, the prevention will also reduce the accident rate inside a factory. The reducing of defect and accident rate on one hand can increase the safety level to the staffs or customers, on the other hand can also decrease the processing cost. [20][21]

The total welding management requires every staff who participates the welding processing have the responsibility of inspection. Only the build up of inspection awareness of each staff can finally acquire the fine products. [20][21]

The figure 88 gives out the recycling relationship between each working steps, this interaction working model is the core idea of total welding management. Furthermore, the total welding management has four critical functions which are based on the four departments: design engineering, manufacturing engineering, manufacturing operations, and quality assurance. Design engineering department has the responsibility to design the products or structures to meet the customer requirements, processing conditions, and quality expectations. Manufacturing engineering department has the responsibility to make sure each welding or processing step is easy and efficient to achieve. Manufacturing operations personal has the responsibility to assure each welding operation that developed by design engineering and manufacturing engineering is properly executed. The quality assurance personal provides the audit systems to report each deviation from specifications throughout the manufacturing

process. [22]

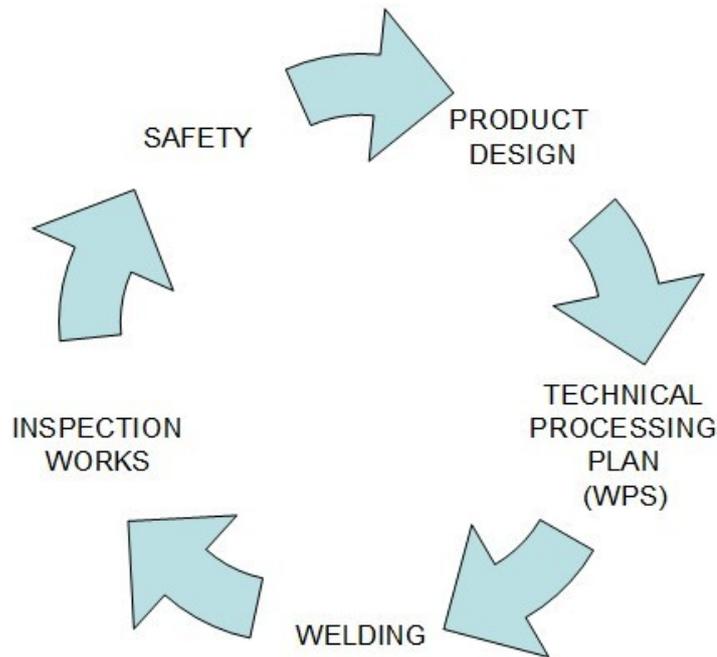


Fig88. The quality control process of total welding management

The using and understanding of total welding management in the Chinese welding workshops in future will improve the competitiveness of enterprise and enhance the basement of the cooperation with foreign companies.

7.2.2. The PDCA Theory

The PDCA cycle is a four-step problem solving working process used in the business or industrial working improvement. The aim of PDCA is to find out every place where defect may occur and prevent them; meanwhile, the PDCA method is a continuous improvement process to the whole working cycle for the guarantee of the reliability. [23] The process of PDCA cycle was shown in the figure 89, each step is connected with other steps, meanwhile, every working step may also contains several PDCA cycles.

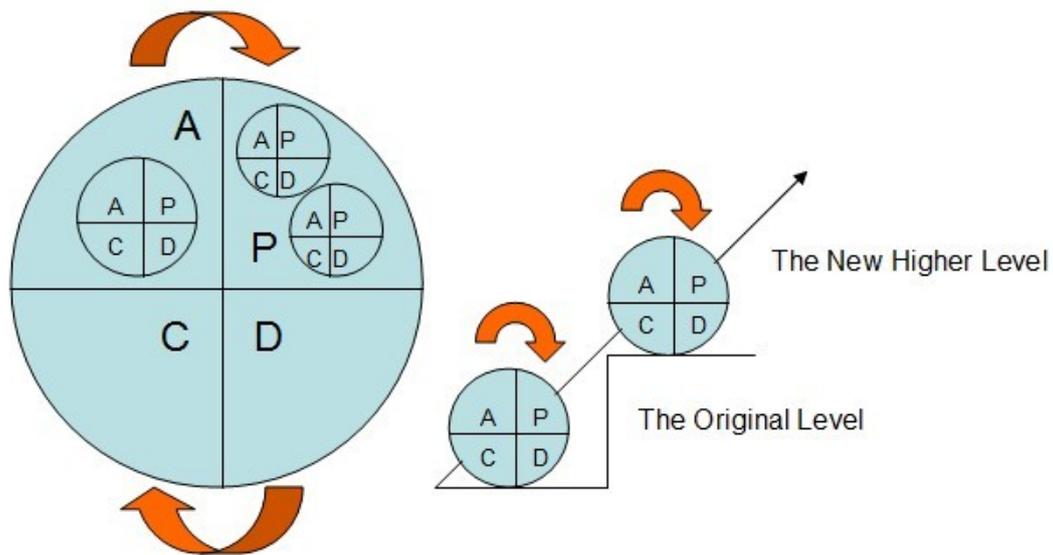


Fig89. The PDCA cycle [18]

P means Plan. This step requires the coordinator to establish the achievement of the working processes and each process which can obtain the expected results. The reliability of the whole work should be set up in the plan step; all the actions in this working process are focusing on the achievement of reliability. [23]

D means Do. This step requires the implementation of the new improvement processes. This step also has the function of the possible effects testing, often on a small scale. [23]

C means Check. This step is the result analysis step, which is to compare the existing achievement (acquire from the 'Do' step) and the expected achievement (set up in the 'Plan' step) in order to ascertain the possible or existing differences. The purpose of this step in a word is to measure the new processes. [23]

A means Act. This step analyzes the differences in order to determine the cause. Each will be part of either one or more of the PDCA cycles. Determine where to apply changes that will include improvement. When a pass through these four steps does not result in the need to improve, refine the scope (fine smaller working steps can apply a PDCA cycle) to which PDCA is applied until there is a plan that involves improvement. [23]

The utilization of PDCA working steps will refine and improve the existing working methods and working habits in China, to help the welding factories in China find out the spatial for their quality improvement. The planning and the sustainable growth of a company will be reflected by the using of PDCA theory.

7.2.3. The 5S Methodology

5S is the name of a workplace organization methodology that uses a list of five Japanese words which are Seiri, Seiton, Seiso, Seiketsu and Shitsuke. Translated into English, they mean Sort, Set, Shine, Standard, and Sustain. The list describes how to organize a work space for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items, and sustaining the new order (see in figure 90). [24]



Fig90. The 5S workplace organization methodology [24]

The aim of 5S methodology is to acquire another 5S result, which are Sales, Saving, Safety, Standardization, and Satisfaction. [25] The ordered and tidy workplace always increases the probability of contract with customers, which will help the sale. The reasonable arrangement of working tools and materials utilization will help the cost saving. The shining and

brightening working place and the proper regulations of stacking will help the decreasing of the accident rate. The standardization and sustain will help the stable quality and the satisfaction of customers and staffs themselves.

5S workplace organization methodology is very important to the Chinese welding factories in future. This methodology will help those factories to improve the working environment, to reduce the processing waste, to improve the safety level, and to enhance the market competitiveness.

7.2.4. The Six Sigma Business Management Strategy

Six Sigma is a business management strategy, it seeks to improve the quality of process outputs by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes. The maturity of a manufacturing process can be described by a sigma rating indicating its yield, or the percentage of defect-free products it creates. A six sigma process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects (3.4 defects per million). [26]

Six Sigma projects follow two project methodologies inspired by PDCA Cycle. These methodologies, composed of five phases each, bear the acronyms DMAIC and DMADV. The DMAIC is used for projects aimed at improving an existing business process; meanwhile, the DMADV is used for projects aimed at creating new product or process designs. The Chinese factories are aimed at improving an existing business process, so the DMAIC is more significant to them. [26]

The DMAIC project methodology has five phases:

- Define the problem or task, advise or requirements from the customer, and the project goals and aims.
- Measure key aspects of the current working process and collect relevant data.

- Analyze the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Find out core cause of the defect.
- Improve or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
- Control the future state process to ensure that any deviations from goal are corrected before they result in defects. Implement control systems such as statistical process control, production boards, and visual workplaces, and continuously monitor the process. [26]

The result of Six Sigma methodology is notable. The variables which are including the methodology analysis will be optimized. The improvement measures at various stages of the being analyze management system are Sigma impact, cost/benefit impact, customer satisfaction impact, time impact, top line impact, bottom line impact, and the improvement of productivity. Six Sigma methodology using in welding processes proves to be an effective strategy of finding solutions to eliminate the root causes of performance problems in welding processes that already exist in the concern and thereby eliminating the unwanted defects produced by the welding process. [27]

The analysis methods of Six Sigma will help those Chinese welding factories who do not attach importance to the product quality to improve the working habits; meanwhile a welding factory utilizing the Six Sigma strategy means that the guarantee of quality is ensured.

Combine with 5S, Six Sigma or TWM methodologies; there also have another management strategy called lean management. Lean management asks each team enrolled in the manufacturing processes uses 'lean thinking' to treat their works. The core of 'lean thinking' is by using the smallest amount of working materials, which are including human power, facilities, equipments, funds, materials, time, and spaces, to achieve values as much as possible, meanwhile supply the customers new products and services timely. [28] The central idea of lean management has the same thoughts with other management methodologies,

meanwhile asks the smallest amount of production waste. Considering more about decreasing of processing waste conform the situation of the Chinese enterprises, because the future requests for the industries in China emphasize the reduction of waste and environmentally friendly.

7.2.5. The Implement of GB and EN-ISO Welding Standards

GB standard means the national standards of China. The implementation and enforcement of GB standard in Chinese welding factories is good, but only few welding factories in China, like some joint-venture companies or state-owned large scale factories, will consider about the EN or ISO standards.

The GB standard related with welding industry is listed in the appendix II. There are eight categories of the standard which are common welding criteria, welding material criteria, quality test of welding, welding quality, A-4 welding methods and process standards, standards of welding machines, safety and health, and standards of welder assessment.

The EN and ISO standards related with welding industry and can be illustrated in Chinese welding workshop is listed in the appendix III. The classification of those standards are pre-welding works, welding processing standards, and welding test (DT and NDT). The most significant welding quality requirements standard is EN ISO 3834- 'Quality Requirements for Fusion Welding of Metallic Materials'; the standard provides details of how to control the various welding and welding-related operations to achieve the desired quality consistently.

The Chinese welding factories should using the three standards, GB, EN, and ISO, based on the evaluation of their welding activities, to build up the unique welding working, processing, and testing standard manual which is fitting each individual welding factory, and firmly execution the standard manual. The implement of welding standard, instead of the experience working, will increase the product quality and decrease the accident rate eminently. [29][30] The welding coordinator, like IWE, nowadays only working in the large scale welding plants

like state-owned factories or joint-venture enterprises. In China, The EN, ISO, or GB standard requirements of the professional welding coordinator should be fulfill in all kinds of welding factories in future gradually.

7.3. The Optimal Choice Suggestion for the Finnish Companies

The analytical hierarchy process can be utilized to make the optimal choice of Chinese welding factories. [31] The future suggestion of Finnish companies and organizations will be divided into three aspects.

7.3.1. The Optimal Choice of Chinese Welding Subcontractors

According to the analytical hierarchy process, there are main criterias and sub-criterias to evaluate the subcontractors and the suppliers. The main criterias for the subcontractors will be quality, performance, service, cost and supplier profile. Each main criteria also have some sub criterias.

The sub criterias of quality are quality defects, defects analysis, and documentations. The sub criterias of performance are customer request date, original promised date, average late days, and lead-time. The sub criterias of service are ease of communication, process flexibility, response to changes, information sharing, and customer support. The sub criterias of cost are price development, price competitiveness, and product cost. The sub criterias of supplier profile are location, financial status, facility and equipment, and capacity. [32]

By using the analytical hierarchy process and the knowledge of Chinese welding factories situation, each Finnish company will easily find out their exclusive rules for the subcontractor selection. For the most general case and empirical analysis, the middle scale welding factories located in the eastern and coastal areas, or north China areas is the most suitable choice today for the Finnish companies.

7.3.2. The Future Suggestion of China Business to the Finnish Companies

a). the market expending in China:

The counselor of science and technology of TEKES Beijing Mr. Kari Hiltunen gave out the suggestion to the Finnish companies business in China. He suggests that Finnish companies should develop the Chinese market positively. The subcontractor selection in China should not only base on the business in Europe, but also should relying on this to open up the Chinese market broader, in a variety of industries. The counselor of science and technology of TEKES Shanghai Mr. Jarmo Heinonen talked about the successful experiments of Metso and ABB in China. The Chinese market nowadays is one of the most significant places in the global market. More and more Finnish companies in every industry should pay their attention to the Chinese market, in order to obtain a better profit in future.

b). the enterprise management system promotion in China:

The Finnish companies who has the ability to formulate, verify, and operate a blameless and practical management system especially for a welding workshop or factory can sale and promotion this system in China, in order to on the one hand strengthen the efficiency and quality level of the Chinese welding factories, on the other hand increase the earnings of those Finnish companies.

This enterprise management system should contains the provision of working and management personals, the basic requirements of plants and equipments, the way of daily operation, the marketing model, the requirements of working environment and rectification, and the basic welding standards using to make the individual working process manual. The selling policy to this management system should be puerile, because the sales amounts in China are easy to ensure rather than the selling price.

c). the establishment of welding factory certification system in China:

The last suggestion to the Finnish companies, the Finnish universities and welding research institute, and the Finnish government is that to establish a welding factory certification or qualification system in China. This is a win-win model because on the one hand the Chinese factories who obtains the qualification is easy to award the contract with Finnish companies, on the other hand the Finnish companies will be happy and disburden to accept the contract with a qualified Chinese welding factory, moreover, the Finland qualification agency also can obtain substantial revenue by authenticating their Chinese customers.

This Finland qualification agency will constitute by the Finnish companies who are working in the welding industry or have the mature work experiences on welding, the Finnish universities who have strong research strength on welding, and the Finnish government departments who are in charge of the welding technologies. The qualification or certification system will include the qualification of the welding plant, the qualification of the welding personal, the qualification of the welding technologies, equipment and processing materials, the qualification of the working environment and welder safety, and the qualification of the enterprise management system.

The implementation of this qualification system of Chinese welding factories will reduce the trouble of Finnish companies who have the aspiration to find a Chinese subcontractor; moreover, the Chinese welding factories who have the willing to the foreign co-operations also will feel relaxed to sign the contract with their Finnish contractors.

8. Conclusion

The production scale and conditions decide the availability of a factory whether can receive a contract or not. The fact shows that those welding factories located in the north China areas and eastern and coastal areas have more competitive than other Chinese areas. Those large scale or state-owned factories nowadays have enough domestic or foreign contracts cause that the lack aspiration to the private co-operation between foreign companies. Choosing small and middle scale Chinese factories to cooperate is the suitable choice for the Finnish companies today. Based on the comparing, there are three factories are suitable for the selection, they are Shijiazhuang Yulong machining and manufacturing company, Shougang industrial equipment plant, and Qingdao Qiyao Wärtsilä MHI Linshan marine diesel co., ltd.

Yulong has the ability to accept the continuous low-level amount production, like the Junttan's work, because of the small scale of this factory. SIEP has the ability to accept any scale production, because it is one of the largest professional welding plants located in the north China area. QMD has the ability to conduct the small amount but large product manufacturing, because on the one hand QMD has its own work, on the other had QMD has a professional welding workshop focusing on the large equipment manufacture.

China is a large country, the more factory information was collected, the more exactly welding industry situation was described. The study in this thesis is only the beginning of the research of the development of Chinese welding industry. The future work suggestions are:

- More information collection from different Chinese areas and factory scales;
- More detailed classification of the research directions;
- Systematic and regularized information collection in order to acquire the real-time changes of Chinese welding industry situation, because of the rapidly developing of China;
- Government or business assistance research on this topic should be strengthened in future;

- More demands collection from Finnish companies in future.

The three suggestions: a) the market expending in China, b) the enterprise management system promotion in China, and c) the establishment of welding certification system in China also should be paid attention, in order to achieve a more stable, reliable, and harmony co-operate model in future between China and Finland.

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Appendix

Appendix I. The Trip Map of This Research



Appendix II. The Temperature and Humidity Statistics Data of Different Chinese Areas (Year 2009)

Table 4: The average temperature statistic data of different Chinese areas (units: °C)

AREAS	SPRING (3-5)	SUMMER (6-8)	AUTUMN (9-11)	WINTER (12-2)
North China (south part)	14.0	25.3	11.1	-2.6
North China (north part)	9.0	21.7	6.5	-12.2
Eastern and coastal areas (eastern part)	16.8	27.6	18.5	6.3
Eastern and coastal areas (south part)	22.7	28.6	24.2	17.1
Southwest and inland areas	15.7	22.8	16.0	7.5

Table 5: The average relative humidity statistic data of different Chinese areas (units: %)

AREAS	SPRING (3-5)	SUMMER (6-8)	AUTUMN (9-11)	WINTER (12-2)
North China (south part)	43.2	57.9	61.5	48.3
North China (north part)	49.9	73.3	65.8	65.9
Eastern and coastal areas (eastern part)	62.8	73.2	69.3	68.8
Eastern and coastal areas (south part)	79.1	77.9	71.9	73.2
Southwest and inland areas	61.5	68.8	65.9	63.3

Data collected from "China Statistical Yearbook 2010"

Appendix III. Chinese GB Standards of Welding Industry

Table 6: The Chinese GB standards of welding

Categories	Standard Number	Standard Name
Common Welding Criteria		
	GB/T3375--94	Welding Terms
	GB324--88	Weld Symbol Representation
	GB5185--85	Symbolic Representation for Metal Welding and Soldering Methods on Drawings
	GB12212--90	Technical Drawings: Weld Symbol Size, Proportions and Simplified Representation
	GB4656--84	Technical Drawings: Metal Structural Representation
	GB985--88	Groove's Basic Form and Size in Gas Welding, Manual Arc Welding, and GSW
	GB986--88	Groove's Basic Form and Size in Submerged Arc Welding
	GB/T12467.1—1998	Welding Quality Requirements: Fusion Welding for Metal Part 1: Selection and Use Guide
	GB/T12468.2--1998	Welding Quality Requirements: Fusion Welding for Metal Part 2: Integrated Quality Requirements
	GB/T12468.3--1998	Welding Quality Requirements: Fusion Welding for Metal Part 3: General Quality Requirements
	GB/T12468.4--1998	Welding Quality Requirements: Fusion Welding for Metal Part 4: Basic Quality Requirements
	GB/T12469--90	Welding Quality Requirements: Requirements and Defect Classification for Molten Steel Joints
	GB10854--90	Seam Dimensions for Steel Structure
	GB/T16672—1996	Definition of Weld Seam, Working Location, Dip Angle, and Rotation Angle

Welding material Criteria		
Welding rod	GB/T5117--1995	Carbon Electrode
	GB/T5118--1995	Low-Alloy Steel Electrode
	GB/T983—1995	Stainless Steel Electrode
	GB984--85	Surfacing Electrode
	GB/T3670--1995	Copper and Copper-Alloy Electrode
	GB3669--83	Aluminum and Alloy Electrode
	GB10044--88	Cast Iron Electrode and Welding Wire
	GB/T13814—92	Nickel and Alloy Electrode
	GB895--86	Technical Conditions for 395 Marine Electrode
	JB/T6964—93	Ultra-fine Carbon Steel Electrode
	JB/T8423—96	Evaluation Method for Welding Electrodes Performance
	GB3429--82	Wire Rod for Carbon Electrode Steel
	JB/DQ7388--88	Quality Grading of Surfacing Welding Electrode
	JB/DQ7389--88	Quality Grading of Cast Iron Electrode
	JB/DQ7390--88	Quality Grading of Carbon Steel, Low Alloy Steel, and Stainless Steel Electrode
	JB/T3223--96	Quality Management Procedures for Welding Materials
Welding Wire	GB/T14957—94	Steel Wire for Fusion Welding
	GB/T14958--94	Steel Wire for GSAW
	GB/T8110--95	Carbon and Low Alloy Steels Welding Wire for GSAW
	GB10045--88	Carbon Steel Flux Cored
	GB9460--83	Copper and Copper Alloy Welding Wire
	GB10858--89	Aluminum and Aluminum Alloy Welding Wire
	GB4242--84	Stainless Steel Wire for Welding
	GB/T15620--1995	Nickel and Nickel Alloy Welding Wire
	JB/DQ7387--88	Product Quality Grading of Copper and Copper Alloy Welding Wire
Welding Flux	GB5293--85	Flux for Carbon Steel Submerged Arc Welding

	GB12470--90	Flux for Low Alloy Steel Submerged Arc Welding
Solder	GB/T6208--1995	Representation of Solder types
	GB10859---89	Nickel Solder
	GB10046--88	Silver Solder
	GB/T6418--93	Copper Solder
	GB/T13815--92	Aluminum Solder
	GB/T13679--92	Manganese Solder
	JB/T6045--92	Brazing Solder
	GB4906--85	Gold, Silver and Alloy Solder for Electronic Devices
	GB3131--88	Tin-Lead Solder
	GB8012--87	Cast Tin-Lead Solder
Gas for Welding	GB6052--85	Liquid Carbon Dioxide for Industrial
	GB4842--84	Argon
	GB4844--84	Nitrogen
	GB7445--87	Hydrogen
	GB3863--83	Oxygen Gas for Industrial
	GB3864--83	Nitrogen Gas for Industrial
	GB6819--86	Acetylene
	GB11174--89	LPG
	GB10624--89	Purity Argon
	GB10665--89	Calcium Carbide
Others	GB12174--90	Carbon Rod
Quality test of Welding		
Steel Test	GB1954--80	The Ferrite Content Determination for Ni-Cr Austenitic Stainless Steel
	GB6803--86	Non-Plastic Transition Temperature Drop-Hammer Testing Method For Ferrite Steel
	G132971--82	Fracture Testing Method for Carbon Steel and Low Alloy Steel
Weldability Test	GB4675.1--84	Weldability Test: Welding Crack Test for Oblique Y-Groove
	GB4675.2—84	Weldability Test: CTS Welding Crack Test
	GB4675.3--84	Weldability Test: Welding Crack Test for T-Joint
	GB4675.4--84	Weldability Test: FISCO Welding Crack Test
	GB4675.5—84	Testing Method for Maximum Hardness of HAZ

	GB9447--88	Testing Method of Fatigue Crack Growth Rate for Welding Joint
	GB/T13817--92	Rigid Restraint Welding Crack Testing Method of for Butt Joint
	GB2358--80	Crack Opening Displacement (COD) Testing Method
	GB7032--86	Bending Test for T-Type Angle Welding Joint
	GB9446--88	Cold Cracking Test for Welding Bolt
	GB4909.12—85	Bare Wire Testing Method--Coating Weldability Test: Weld Ball Method
	GB2424.17--82	Basic Environment Testing Procedures for Electric and Electronic Products: Soldering Guide
	GB4074.26—83	Enameled Wire Testing Method: Cyclic Test
	JB/ZQ3690	Weldability Testing Method of Steel Board
	SJ1798--81	Weldability Testing Method of PCB
Mechanical Test	GB2649--89	Sampling Method of Mechanical Performance Testing for Welding Joints
	GB2650--89	Impact Testing for Welding Joints
	GB2651—89	Tensile Testing for Welding Joints
	GB2652—89	Tensile Testing for Welding Seam and Deposited Metal
	GB2653--89	Bending and Compression Testing for Welding Joints
	GB2654--89	Metal Hardness Testing Method for Welding Joints and Surfacing Weld
	GB2655--89	Susceptibility Testing for Welding Joints in Strain
	GB2656--81	Fatigue Testing for Welding Joints and Welding Seam
Test of Welding Materials	GB3731--83	Determination of Coating Electrode Efficiency, Metal Recovery, and Deposition Coefficient
	GB/T3965--1995	Diffusible Hydrogen Determination for Deposited Metal
Welding Inspection	GB/T12604.1--90	NDT Terms: Ultrasonic Test
	GB/T12604.2--90	NDT Terms: X-Ray Test
	GB/T12604.3--90	NDT Terms: Penetration Test
	GB/T12604.4--90	NDT Terms: Acoustic Emission Test

	GB/T12604.5--90	NDT Terms: Magnetic Particle Test
	GB/T12604.6--90	NDT Terms: Eddy Current Test
	GB5618--85	Liner Image Quality Indicator
	GB3323--87	Steel Fusion Welding Butt Joints Radiographic Process and Classification
	GB/T12605--90	Steel Pipe Fusion Welding Butt Joints Radiographic Process and Classification
	GB/T14693--93	NDT Symbols for Welding Seam
	GB11343--89	Contact Ultrasonic Oblique Beam Inspection
	GB11345--89	Manual Ultrasonic Testing for Steel Welding Seam and Testing Result Classification
	GB11344--89	Contact Ultrasonic Pulse-Echo Method for Thickness Test
	GB2970--82	Ultrasonic Testing for Medium-Thick Steel Board
	JB1152--81	Ultrasonic Testing for Butt Weld Seam of Boiler and Steel Pressure Vessel
	GB/T15830—1995	Ultrasonic Testing for Steel Pipe Butt Joints and Testing Result Classification
	GB827--80	Ultrasonic Testing for Hull Welding Seam
	GB10866--89	Metallographic and Fracture Test for Welding Joints of Boiler Pressure Parts
	GB11809---89	Weld Seam Metallographic Examination of Nuclear Rod
	JB/T9215--1999	Quality Control Method for Radiographic Images
	JB/T9216--1999	Quality Control Method for Penetrate Testing Material
	JB/T9217--1999	Radiography Testing Method
	JB/T9218--1999	Penetration Testing Method
	JB3965--85	Magnetic Particle Testing for Steel Pressure Vessel
	EJ187--80	Magnetic Particle Testing Standards
	JB/T6061--92	Classification of Weld Seam Magnetic Particle Inspection and Defects

	JB/T6062--92	Classification of Weld Seam Penetration Inspection and Defects
	EJ186---80	Color Detection Method Standards
	JB/ZQ3692	Drilling Test for Welding Penetration Capacity
	JB/ZQ3693	Destruction Testing Method for Internal Defects of Steel Welding Seam
	GB11373--89	NDT Method for Thermal Spray Coating Thickness
	EJ188--80	Operating Rules for Welding Seam Vacuum Box Leak Detection
	JB1612--82	Technical Conditions for Boiler Water-Pressure Test
	GB9251--88	Water Pressure Testing Method for Gas Vessel
	GB9252--88	Fatigue Testing Method for Gas Vessel
	GB12135---89	Technical Conditions for Periodic Check Station of Gas Vessel
	GB12137--89	Tightness Testing Method for Gas Vessel
	GB11639--89	Determination of Porous Packing Specification for Dissolved Acetylene Vessel
	GB7446--87	Hydrogen Testing Methods
	GB4843--84	Argon Testing Methods
	GB4845--84	Nitrogen Testing Methods
	JB4730—94	NDT of Pressure Vessels
	DL/T820-2002	Technical Specification of Ultrasonic Testing for Pipe Welding Joint
	DL/T821-2002	Technical Specification of Radiographic Inspection for Steel Pressure Pipe
	DL/T541-94	Radiographic Method and Quality Classification of Fusion Steel Welding Angle and Seam
	JB4744—2000	Mechanical Performance Test for Welding Test Plate of Steel Pressure Vessel
Welding Quality		
	GB6416--86	Technical Factors of Steel Fusion Welded Joints Quality

	GB6417--86	Classification and Description of Imperfections in Metallic Fusion Welds
	TJ2. 1--81	Requirements in Construction Machinery Welding Quality
	JB/T6043--92	Defect Classification of Metal Resistance Welding Joints
	JB/ZQ3679	Quality of Welding Parts
	JB/ZQ3680	Quality of Seam Appearance
	JB/TQ330--83	Welding Quality Inspection of Fun
	GB999--82	Welding Seam Quality Verification in Hull Surface
A-4 Welding methods and Process Standards		
	GB12219--90	Bar Pressure Steel Welding
	GB11373--89	Metallic Surface Preparation in General Thermal Spraying
	JB/Z261--86	Process Method of Tungsten Inert Gas Welding (TIG)
	JB/Z286--87	Specification in Carbon Dioxide Welding Process
	JB/ZQ3687	Manual Arc Welding Specifications
	SDZ019--85	Technical Criteria of General Welding
	J134251—86	General Technical Criteria of Friction Welding
	ZBJ59002.1--88	Thermal Cutting Methods and Classification
	ZBJ59002.2--88	Thermal Cutting Terms and Definitions
	ZBJ59002.3--88	Quality and Size Deviation in Thermal Gas Cutting
	ZBJ59002.4—88	Quality and Size Deviation in Thermal Cutting and Plasma Arc Cutting
	ZBJ59002.5--88	Surface Quality Model of Thermal Gas Cutting
	JB/ZQ3688	Automatic Cutting of Steel Board
	ZBK540339--90	Technical Criteria of Cast Steel Parts Repair Welding in Turbine
	NJ431—86	Technical Criteria of Cast Iron Parts Repair Welding

	GB11630--89	Technical Criteria of Third Class Cast Steel Repair Welding of Anchor
	GB/Z66--87	Copper-Metal Arc Welding
	JB/TQ368—84	Repair Welding of Pump Cast Steel
	JB/TQ369---84	Repair Welding of Pump Cast Iron
	HB/Z5134--79	Welding Technology of Structural Steel and Stainless Steel
	JB/T6963—93	Evaluation of Steel Parts Fusion Welding
	JB4708--2000	Welding Process Evaluation of Steel Pressure Vessel
	JB4709—2000	Welding Procedures of Steel Pressure Vessel
	DL/T752-2001	Dissimilar Steel Welding Procedures in Thermal Power Plant
	DL/T819-2002	Welding Heat Treatment Procedures in Thermal Power Plant
	DL/T868-2004	Evaluation Procedures of Welding Process
	DL/T869—2004	Welding Procedures of Thermal Power Plant
Standards of Welding Machines		
	GB2900-22--85	Electro technical Term: Welding Machine
	GB8118--87	General Technical Conditions of Arc Welding Machine
	GB8366--87	General Technical Conditions of Resistance Welding Machine
	GB10249--88	Methodology of Welding Machine Types
	GB10977--89	Friction Welding Machine
	GB/T13164--91	Submerged Arc Welding Machine
	ZBJ64001--87	Technical Conditions of TIG Welding Torch
	ZBJ64003--87	Rectifier of Arc Welding
	ZBJ64004188	MIG / MAG Arc Welding Machine
	ZBJ64005--88	General Technical Conditions of Resistance Welding Machine Controllers
	ZBJ64006--88	Arc Welding Transformer
	ZBJ64008--88	General Technical Conditions of Resistance Welding Machine Transformer

	ZBJ64009--88	Technical Conditions of TIG Welding Machine
	ZBJ64016--89	Technical Conditions of MIG / MAG Welding Torch
	ZBJ64021—89	Technical Conditions of Wire filler Machine
	ZBJ64022--89	Technical Conditions of Arc Generator
	ZBJ64023--89	Fixed Convex Point Welding Machine
	JB5249--91	Portable Spot Welding Machine
	JB5250--91	Seam Welder
	ZBJ33002--90	Welding Positioner
	ZBJ33003--90	Welding Roller Frame
	JB5251--91	Fixed Butt Welding Machine
	JB685--92	DC Arc Welding Generator
	JB/DQ5593.1—90	Quality Grading: General Rules
	JB/DQ5593.2--90	Quality Grading: Arc Welding Machine Transformer
	JB/DQ5593.3--90	Quality Grading: Portable Arc Welding Machine Transformer
	JB/DQ5593.4--90	Quality Grading: Arc Welding Rectifier
	JB/DQ5593.5--90	Quality Grading: MIG/MAG Arc Welding Machine
	JB/DQ5593.6--90	Quality Grading: TIG Welding Machine
	JB/DQ5593.7--90	Quality Grading: Arc Welding Generator
	JB/DQ5593.8--90	Quality Grading: TIG Welding Torch
	JB/DQ5593.9--90	Quality Grading: Cooling Fun for Welding Machine
	JB/DQ5593.10-90	Quality Grading: MIG/MAG Welding Torch
	JB/DQ5593.11-90	Quality Grading: Resistance Welding Machine Controller
	JB/DQ5593.12-90	Quality Grading: Friction Welding Machine
	JB/Z152--81	Series Model of Welding Machine
	JB2751--80	Plasma Arc Cutting Machine
	JB33001—87	Trolley Torch cutting machine
	JB10860--89	Fast Cutting Nozzle
	GB5110--85	Injective Cutting Torch

	JB/T5102--91	Coordinate Type Gas Cutting Machine
	JB5101--91	Cutting Torch for Gas Cutting Machine
	JB6104--92	Rocker-Copying Gas Cutting Machine
	GB5107--85	Hose Connector for Welding and Gas Cutting
Safety and Health		
	GB9448—88	Security of Welding and cutting
	GB10235--88	Electric Shock Guard for Arc Welding Transformer
	GB8197--87	Requirements of Safety Shield
	GB12011--89	Insulated shoes
Standards of Welder Assessment		
	GB6419--86	Rules of Diving Welder Examination
	JJ12.2--87	Procedures of Welder Technical Examination
	EJ/Z3--78	Procedures of Welder Training and Examination
	DL/T679--1999	Procedures of Welding Technology Assessment
	JB/TQ338--84	Examination Standard for Fun Welder
	GB/T15169--94	Examination Method for the Steel Fusion Welder Qualification
	SDZ009--84	Examination Standards for Manual Arc Welding and Submerged Arc Welding
	JB1152--88	Grade Standards for Welding Skills, Ministry of Machine Industry

Appendix IV. The EN and ISO standards related with welding industry (Suitable in China)

Table 7: The EN and ISO standards related with pWPS, WPQR, and WPS

Standards Number:	Standards Name:
SFS-EN ISO 15613: 2004	Specification and qualification of welding procedures for metallic materials --- Approval by a pre-production test (Revision of EN 288-8)
SFS-EN ISO 15614-1+A1: 2004	Specification and qualification of welding procedures for metallic materials. Welding procedure tests. Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (Revision of EN 288-3) (WPQR)
SFS-EN ISO 15609-1: 2000	Specification and qualification of welding procedures for metallic materials - Welding procedure specification. Part 1: Arc welding (Revision of EN 288-2) (WPS)

Table 8: The EN and ISO standards related with welding processing

Standards Number:	Standards Name:
EN 287-1:2004	Qualification test of welders — Fusion welding — Part 1: Steels
EN 1090	Execution of steel structures and aluminum structures

EN 1090-1: 2009	Execution of steel structures and aluminum structures - Part 1: Requirements for conformity assessment of structural components
EN 1090-2: 2008	Execution of steel structures and aluminum structures - Part 2: Technical requirements for steel structures
EN 1090-3: 2008	Execution of steel structures and aluminum structures - Part 3: Technical requirements for aluminum structures
EN 1011: 1998-2004	Welding. Recommendations for welding of metallic materials
EN 1993-1-8: 1993	Eurocode 3: Design of steel structures – Part 1-8: General – Design of joints
EN 13133: 2000	Brazing - Brazer approval
EN 22553: 1995	Welded, brazed and soldered joints – Symbolic representation on drawings
ISO 4063:1998	Welding and allied processes, Nomenclature of processes and reference numbers
SFS-EN ISO 6520-1: 1998	Welding and allied processes, classification of geometric imperfections in metallic materials – Part 1: Fusion welding
SFS-EN ISO 6947: 1997	Welds, working positions, definitions of angles of sloop and rotation
SFS-EN ISO 13916: 1996	Welding, guidance on the measurement

	of preheating temperature, interpass temperature and preheat maintenance temperature
ISO 2553: 1992	Welded, brazed and soldered joints symbolic representation on drawings
SFS-EN ISO 3834: 2006	Quality requirements for fusion welding of metallic materials: Part 1: Criteria for the selection of the appropriate level of quality requirements Part 2: Comprehensive quality requirements Part 3: Standard quality requirements Part 4: Elementary quality requirements Part 5: Documents with which is necessary to conform to claim conformity to the quality requirements of ISO 3834-2, ISO 3834-2, or ISO 3834-4

Table 9: The EN and ISO standards related with testing

Standards Number:	Standards Name:
SFS-EN ISO 5817: 2007	Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfections
EN 12062: 1997	Non-destructive examination of welds - General rules for metallic materials
EN 970: 1997	Non-destructive examination of fusion welds / Visual examination
EN 1290: 1998 A1: 2002	Non-destructive examination of fusion

	welds / Magnetic particle examinations
EN 1714: 1997	Non-destructive examination of fusion welds / Ultrasonic examination
EN 571-1: 1997	Non-destructive testing, penetrate inspection
EN 895: 1995	Destructive testing of welds, transverse tensile test
EN 910: 1996	Destructive testing of welds, Bend testing
EN 875: 1995	Destructive testing of welds, Impact tests: Test specimen location, notch orientation and examination
EN 1043-1: 1995	Destructive tests on welds in metallic materials - Hardness testing - Part 1: Hardness test on arc welded joints
EN 1321: 1996	Destructive testing of welds, Macroscopic and Microscopic examination
EN 10204: 1991	Inspection documents for metallic products

Table 10: The EN standards related with welding and inspection personals

Standards Number:	Standards Name:
SFS-EN ISO 287-1: 2004	Qualification test of welders — Fusion welding — Part 1: Steels
EN 1418: 1997	Welding personnel - Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials

EN 473: 2000	Non destructive testing - Qualification and certification of NDT personnel - General principles
SFS-EN ISO 14731: 2006	Welding coordination. Tasks and responsibilities