Current Situation and Future of Chinese Industrial Robot Development

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***Abstract*—As top aggregation of modern electronics and software technology, robots have paid great attention. With the automation development trend of international manufacturing industry, the market demand of industrial robots is powerfully rising and has been honored with "the pearl on the top of the crown in the manufacturing industry". China, as the largest developing country in the world, has been speeding up to march from big manufacturing country into powerful manufacturing country. This paper mainly introduces the development background and current situation of industrial robots in China as well as prospect of China-made industrial robot.**

***Index Terms*—robot; industrial robot; China-made**

I. Introduction

At present, the market application of global robots is major in industrial robot. Thus, developing intelligent robot industry is an important part of industrial intellectualization with features of digitization, intellectualization and networking. This means that the development of robots not only replaces manual labor but also replaces mental labor. In 2015, World Robotics Conference was held in China National Convention Center and President Xi Jinping sent a letter to congratulate. He said, the prosperous development of intellectual industry, represented by robot technology, has been a significant symbol of modern science and technology innovation. China has listed robots and intelligent manufacturing as the priority development fields of national science and technology innovation.

It is not difficult to see from Manufacturing Revival Plan in America, Industry 4.0 Strategy in Germany and China Manufacturing 2025 Plan in China that industrial robot is an important content of the manufacturing industry. Industrial robot is the representative industry of digital revolution in the manufacturing industry, typical leading industry of the third industrial revolution and the strategic emerging industry with future development priorities to occupy the commanding height in the international division of labor. Therefore, fully understanding the international status and pattern of China's industrial robots is of great realistic significance to the development of China-made industrial robots. This paper introduces the generation, development, current situation and future of industrial robots in China.

II. Development Process of Chinese Industrial Robots

Studies on industrial robots in China started from 1970s. It was relatively late and because of the limits of the economic system at that time, the development of industrial robots was slow and its research and application were low. In 1985, with the numerous application and popularization of industrial robots in industrial developed country, China listed industrial robots in the development plan in Science and Technology Program of Seventh Five-Year Plan of China [1]. Ministry of Machine-Building Industry triggered the first research fever of industrial robots.

In 1990s, to realize the close joint of high technology development and national economy main battlefield, National 863 Plan set the development guideline with equal stress on specialized robots and industrial robots and application driving key technology and fundamental research. Through the hard work of many scientific and technical workers, 7 kinds of industrial robot series products and 102 kinds of specialized robots are developed and about 100 items of robot application projects are implemented.

At the end of 1990s, China established 9 robot industrialization bases and 7 scientific research bases, including SINSUN of Shenyang Automation Research Institute, BOSHI Automation Equipment Co., Ltd. of Harbin Institute of Technology, Robot Development Center of Beijing Research Institute of Automation for Machine-building Industry, and Haier Robot Co., Ltd [2]. At the same time, some enterprises have independently developed or cooperated with research institutes for robot industrialization development according to the market demand, for example, spot-welding robot industrialization development between Chery Automobile and Harbin Institute of Technology; machine tool feeding and blanking transfer robot industrialization development between Xi'an Kitamura Machine Works Co., Ltd. and Harbin Institute of Technology; arc-welding robot development between Kunlun Huaheng welding Co., Ltd. and Southeast University; welding robot by GSK CNC equipment Co., Ltd.; and arc-welding robot by Jiangsu Yancheng HTC.

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In 2012, Harbin successfully developed four new industrial robots, namely, Huayu I-type spot-welding robot, Huayu II-type arc-welding robot, Dongfang I spraying robot and Xingguang I-type rectangular coordinate spot-welding robot. Experts agree that these marked that China mastered the manufacturing techniques of the first generation industrial robot and new robot industry was born in China. These also are a milestone in China's industrial robot development during the past over 50 years.

III. Application of Industrial Robots in China

Under the influences of rapid technological development, increasingly scarce labor, and to-be-improved production efficiency, global industrial robots will have wider development space and faster development speed in the future. In the regional distribution, with the manufacturing industry development in Asia, each industry has increasing demands of industrial robots, so the market demand of industrial robots gradually moves from Europe and America to Asia. Under this background, the industry of industrial robots in China faces both opportunities and challenges.

In recent years, driven by the fast spreading demand and national independent innovation policies, a lot of enterprises in China have independently developed or cooperated with research institutes for industrial robot so that industrial robots in China have entered into initial industrialization stage. Some products have industrialized and produced for application. However, the precision and speed are not as good as the similar imported products, so the industrialized application degree of these products is low, lacking brand recognition and with small market share. At present, China has basically grasped the design and manufacturing technology, hardware and software design technology of the control system, kinematics and trajectory planning technology of robot manipulators, producing some key components and parts of robots and developing spraying robots, arc-welding robots, assembling robots and transfer robots. Though the technological level of some products has reached the international advanced level, there is a big gap with them on the whole, only equal to the foreign level in the middle of 1990s.

A. Market Sale of Industrial Robots in China

2011~2015 is the time of China Twelfth Five-year. During this period, the development of industrial robots is paid great attention to and strong supports by the government of China. National 863 Project, major projects of National Support Plan and major projects of international cooperation have relevant projects to robots. Each region, province and city also invests a lot in the construction of robot industry. The visual information of industrial robot sale and growth ratio during China Twelfth Five-year is shown as "Fig. 1", which is given by Robot Industry Research Institute. It can be known that the market sale of industrial robots is in sustainable growth. Only in 2012 the growth ratio decreases slightly due to the shrinkage of electronics manufacturing, metal and machinery industry. In 2013 the sale of industrial robots in China reaches 36,860, with year-on-year growth ratio of 36.9%. Since then, China surpasses Japan, becoming the biggest market in the world.

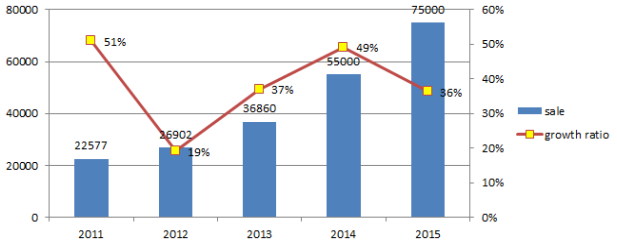

Figure 1. Market sale and growth ratio of industrial robots in China during 2011~2015

Data source: Statistics from China Robot Industry Alliance

TABLE I. Import Sources of Chinese Industrial Robots During 2011~2013

2011			2012			2013		
Source	Volume of import (10,000 dollars)	Share	Source	Volume of import	Share	Source	Volume of import	Share
Japan	70106	40.7%	Japan	64513	39.7%	Japan	56584	39.6%
Germany	43641	25.3%	Germany	44692	27.5%	Germany	30974	21.7%
Korea	11295	6.6%	Korea	12624	7.8%	Korea	9997	7.0%
US	8677	5.0%	US	6665	4.1%	US	8322	5.8%
Sweden	6934	4.0%	Switzerland	6236	3.8%	Switzerland	5718	4.0%
Austria	5081	2.9%	Sweden	5451	3.4%	Sweden	4824	3.4%
Italy	3869	2.2%	Australia	3699	2.3%	France	3999	2.8%
Switzerland	3854	2.2%	France	3596	2.2%	Italy	3589	2.5%
France	3497	2.0%	Italy	2170	1.3%	Austria	3351	2.3%
Singapore	2572	1.5%	Singapore	1691	1.0%	UK	1161	0.8%
total	159525	92.6%	total	151338	93.1%	total	128517	89.9%

Data source: statistics from United Nations commodity trade database

So far, the market of China industrial robots is basically mature and they have been applied in each industry and field. However, most domestic enterprises purchase and use imported robots, shown as Table I. The major import sources of China industrial robots during 2011~2013 are Japan and Germany, accounting for about

60~70% import share of China industrial robots, followed by South Korea and America. Top 10 import sources in total accounting for about 90% of the import market of China industrial robots, with high import concentration. Especially, the import dependence degree on Japan and Germany are very high.

B. Main Application Fields of Industrial Robots in China

China is the largest consumer market of industrial robots in the world at present. Ten widespread application fields include automobile industry, electrics industry, rubber plastics industry, casting industry, food industry, chemical industry, glass industry, household appliance industry, metallurgical industry and tobacco industry [3]. Similar to the global industrial robot market, three application industries of industrial robots in China are automobile and parts, electronics, chemical industry (plastics and rubber), with slight difference in ratio. At present, robots in automobile industry account for about 40%, with electronic manufacturing industry of 28% and rubber and plastics 10%, shown as "Fig. 2".

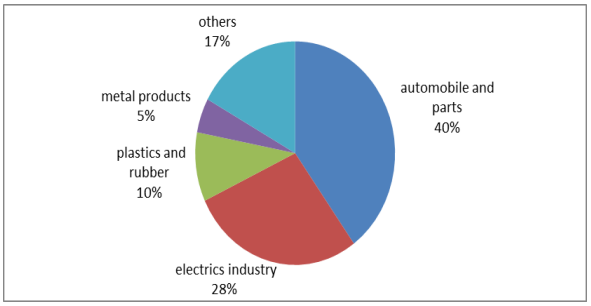

Figure 2. Structural analysis of robot application

1) Automobile industry

With the supports of government policies, the application of industrial robots has been universal in automobile industry. However, because of high requirements in robot consistency and precision of automobile, the share of domestic robots in the automobile market is less than 5%. China has been actively encouraging automobile enterprises to develop digital workshop demonstration project. In March 2015, Implementation of Program of 2015 Intelligent Manufacturing Pilot Demonstration Specific Project issued by Ministry of Industry and Information Technology points out that in digital workshop, the automobile field can organize and develop the construction of digital workshop pilot demonstration project and boost the equipment intellectual updating, process flow modification, basic data sharing and other pilot applications.

2) Electronics industry

The economic environment in China is stable and its market potential is large. At the same time, the government of China provides supports on consumer electronics industry and preferable industrial policies, which promote the vigorous development of electronics industry. Moreover, electronics industry is an industry with fast upgrading speed, so it needs the support of innovating force. Robots used in the electronics industry are specially made by according to the demands of electronic manufacturing industry by domestic manufacturers. Small-scale and simplified features realize the high-precision electronic packaging, satisfying the increasingly fining demands of electronic assembly processing equipment. Automatic processing greatly promotes production efficiency. With the development of electronics industry, the number of robots in this industry may exceed the automobile industry.

3) Plastics and rubber industry

Plastics industry is one dynamic industry that throughout all the industrial fields and almost all the application ways of plastic processing needs robot technology. Pingyang County in Wenzhou is called the city of plastics weaving and its weaving industry has over 30-year development history. In 2014, the accumulated industrial investment of Pingyang County is 5.882 billion yuan, with machine-human replacing technology improvement investment of 3.412 billion yuan. Over 10 enterprises with technology improvement input of over 2 million, accounting for 58.01% of industrial investment ratio. The largest-scale plastics weaving industry in Pingyang's three pillar industries accounts for a large ratio.

IV. Problems and Countermeasures on Chinese Industrial Robots

After years of development and application, the development of industrial robots in China tends to develop with robot technology as dominance and transfer the research and development direction to basic equipment and complete equipment. Industrial robots in China started late and the basic industry supporting field is weak. These make industrial robots in China lag behind similar abroad products. The major manifestations are, the quality and reliability of industrial robots are lower than those of foreign products, the development pattern is single, and there is certain difference between domestic production line system technology and abroad one. Also, the application of industrial robots is no match for the foreign companies. Compared with foreign industrial robot application, the development of industrial robots in China has not formed a systematic system. Small-batch design is made according to customers' requirements, which leads to various product specifications of industrial robots, low part universalization degree, high cost and long supply cycle. All these have serious influences on the development of industrial robots in China.

A. Reasons for Problems

- The manufacturing capacity of base parts and components of industrial robots in China needs improvement. At present, the key parts of domestic industrial robots (for example, high-precision servo motor, harmonic drive and real-time operating system) mainly rely on import. Though few domestic parts can be used for industrial robots, heavy-load industrial robots parts cannot be satisfied.

- The design concept of industrial robots in China is not mature. The domestic robot production mostly is based on the realization of function. There is certain difference in stability and robot performance is not high.
- The market order of industrial robots in China is chaotic. With the rapidly increasing demand for industrial robots, most enterprises are optimistic about the market of industrial robots. However, a large swarm of enterprises with different strengths are sure to cause cut-throat competition in the domestic market of industrial robots. In China, there are about one hundred colleges and institutes and enterprises for industrial robot researches, but the current system makes researches too independent and closed and studies on robots are disperse and fail to form a joint force. The same technology may be studied repeatedly, which wastes large quantities of research and development expenditure and time [4]. Most enterprises are keen on large and comprehensive and enterprises, therefore, some enterprises with good research and development basis of robot key parts shift to the complete machine production of robots. It is difficult to form orderly and fined industrial chain of industrial robot development, production, manufacturing, marketing, integration and service.

B. *Countermeasures and Effects*

From the world scale, Industry 4.0 concept leads the world development direction of the manufacturing industry. It focuses on the industrialization and intellectualization development road and it has been learnt by some regions with developed manufacturing industry. Referring to the experience of developed countries and considering the realistic condition of rising labor cost, changing population structure, lagging production behind demand [5], China must forge China-made 2025 to march from big manufacturing country to strong one. Therefore, China carries out many policies to support the robot industry.

1) *Supporting policies*

From the aspect of technological development, the major policies are as follows.

- Enhance the supports of research and development of high and new technology industry. National 863 Project, major projects of National Support Plan and major projects of international cooperation have relevant projects to robots.
- Promote the coalition-building of industry-university-research cooperation, forming a powerful team of study, development and application and strengthening the talent team construction of robot industry [6].

From the aspect of robot industrialization, national supporting policies are as follows.

- In October 2013, Ministry of Industry and Information Technology issued Special Action Plan of Deeply Integrated Informatization and Industrialization (2013~2018). It clearly puts forward speeding up the application of industrial robots in the production process. During 2013~2015, It is planned to promote and implement the intellectually updating of manufacturing equipment in automobile, engineering machinery, petroleum and petrochemical, metallurgy, bio-pharmaceutical and other key industries; encourage qualified enterprises to apply modulated, networked, intelligentized and bionic industrial robots; realize the mass scale application of advanced manufacturing technology in key industries and establish 5 benchmarking enterprises with advanced manufacturing technology application model. During 2016~2018, it aims to promote the overall application of intelligent manufacturing mode in each industry and scale application of industrial robots in key industries, establishing over 20 benchmarking enterprises with advanced manufacturing technology application model.
- In May 2015, China-made 2025 published by the State Council makes deployment on industrial robots, actively developing new products according to the demands of industrial robots in automobile, machinery, electronics, danger manufacturing industry, national defense military industry, chemical industry, light industry and other industries, promoting robot standardization and modularization development, expanding market application, and breaking through the technological difficulties in robot main body, reducer, servo motor, controller, sensor, actuator and other key components and system integrated design and manufacture.
- With the end of China Twelfth Five-year Plan, Ministry of Industry and Information Technology will specially organize and formulate China robot technology roadmap and Thirteenth Five-year Development Plan of robot industry, aiming at solving the weak technological basis in the development process of China robot industry, dependence of key core components on import and lagging-behind commercialization of research outputs.

2) *Achievements*

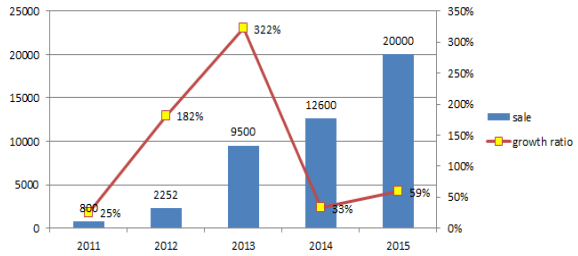

Figure 3. 2011~2015 sale and growth ratio of domestic industrial robots

Data source: statistics from United Nations Merchandise Trade Database

With the active supports of national policies, robot enterprises increase the research and development

strength on robots according to the market demands. Therefore, domestic robot sale is raised greatly, shown as "Fig. 3". In 2013, self-owned brand enterprises in China have dramatic rise in the sale of industrial robots in China, with total amount of over 9,500, accounting for a quarter of the national industrial robot sale.

V. Prospect of China-Made Industrial Robots

A. Prospect of Market Demand

At present, the market of the global industrial robot main body is dominated by China, Europe, America and Japan. The stock of Japan, the United States, Germany, South Korea and China accounts for 71.24% and sale reaches 69.92%. "Fig. 4" shows the robot use density per 10,000 workers in each country. In China, only 30 industrial robots are used per 10,000 workers, even less than half of the global average, 62. In intensity, there is great improving space. Thus, three application industries of future industrial robots, automobile and parts, electronics, plastics and rubber industry will further enhance the robot intensity and electronic manufacturing industry may exceed automobile industry, becoming an industry with the most widespread use of industrial robots. For Guangzhou in the Pearl River Delta Region, it is forecast that over 80% manufacturing enterprises will apply industrial robots and intelligent equipment by 2020. The sample survey of Dongguan, the World's Factory, shows that in recent five years 66% enterprises in this city have invested funds to develop robot-human replacing work and 92% enterprises intend to enlarge input or prepare to develop relevant work in the future two years. Thus, domestic robot market in the future still maintains high growth and by 2017, the total robots in China will increase from 162,000 to 428,000, exceeding the largest five economic entities in Europe and North America and becoming the largest country with industrial robots in the world.

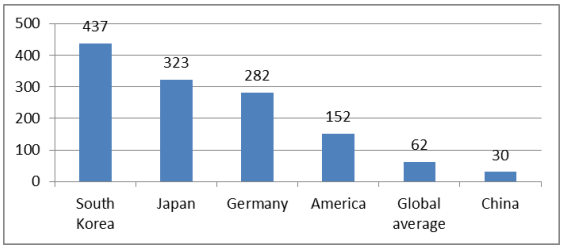

Figure 4. Industrial robot use density in the world

B. Prospect of Technological Development

With the rapid development of robot industry, the pressure also increases gradually. On one hand, industrial robots in China have a severe gap between basic original research achievements and development products, with low achievement transformation ratio and industrialization ratio, which seriously limits the development of autonomous robots and automation equipment industry. On the other hand, because of high input and long development cycle of robot industry, especially the high requirements of robots by precision industries, the situation where import is dominant still continue for certain time. However, with the substantial support and active guidance of national policies as well as the drive of market requirements, domestic enterprises must increase input in technology research and development, unite scientific research institutions to tackle key robot technology, master core technology, and improve the technology research and development strength. Moreover, robot manufacturers shall be oriented by domestic market demand, actively layout the robot industry, integrate resources, take robot industry chain as the focus of industry development, and establish domestic brand of robot industry, so as to seize the international market in the future market competition.

VI. Conclusion

This paper introduces the development, current situation and prospect of industrial robots in China in details. After 50 years' development, robot industry in China has achieved considerable development. Especially, in recent years, the demands of industrial robots have been in full swing, involving automobile, machinery, electronics, danger manufacturing industry, chemical industry, light industry and other industries. However, some key robot technology needs to be solved, so in short time robots still depend on import. With the increasing bonus of national policies, demands of industrial transformation and upgrading in China-made 2025, attention and input of capitals in robot market, and weakening population bonus, all these series of opportunities are doom to jointly accomplish the glorious development of robot industry in China.

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