# Status and development trend of the welding consumables industry in China

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***Abstract*** *We analyzed the status and development of the welding consumables industry in China during the* 12th *Five-Year Plan* (2011 – 2015) *period, and identified the major problems in the industry. We predicted the development trends that are expected for the* 13*th Five-Year Plan* (2016 – 2020) *period. We suggest some specific countermeasures and practices, which the Chinese welding industry should accelerate the transformation-upgrading and coordinated development of the industry and its firms, should work on improving their overall quality to improve the brand's influence, enlarge their input into research and technology upgrading, and develop a low-carbon green production mode that could be put in place to promote the development of the Chinese welding consumables industry.*

**Key words** welding consumables, development, trend

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## 0 Introduction

Steel is the main construction material used in the development of the Chinese manufacturing industry, and this industry underpins the country's economic and social development. In 2015, the global crude steel output was 1.62 billion tonne, of which China accounted for 0.8 billion tonne. The apparent global consumption was 1.5 billion tonne, and 1.02 billion tonne of this was consumed in China. China has become a great steel production and consumption nation with its crude output and apparent consumption representing about 50% and 63% of the world's total, respectively. The ratio of the demand for welding consumables to steel output has remained at 0.3% for several years in developed countries. The Chinese welding consumables output and apparent consumption have occupied more than 50% of the world's total, which makes it a great country for welding consumables production and consumption. The Chinese welding consumables industry has played an increasingly important role as the national economy has developed.

## 1 The status of the Chinese welding consumables industry development from 2011 to 2015

### 1.1 Stable and slightly decreased output of welding consumables

In the most recent 10 years, there has been a gradual increase in the welding consumables output; and it reached its peak at the initial stage of the 12th Five-Year Plan. Thereafter, it was stable and then slightly decreased. The output was 4.75 million tonne in 2011 and 4.15 million tonne in 2015. The annual output decreased by 12.6% during the 12th Five-Year Plan period. As shown in Fig. 1, the welding electrode output decreased by 22.6% and the flux-cored wire output decreased by 30%. The output of gas-shielded welding wire and submerged-arc welding consumables was generally stable. The output of manual electrodes, which has the disadvantages of high energy consumption, low efficiency, and environmental pollution, decreased, whereas the output of welding consumables, such as solid welding wire and submerged-arc welding consumables, continued to rise.

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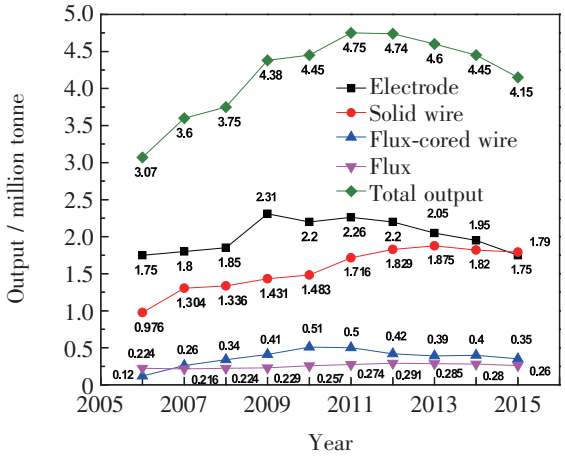


**Fig. 1 Output of welding consumables in China from 2006 to 2015**

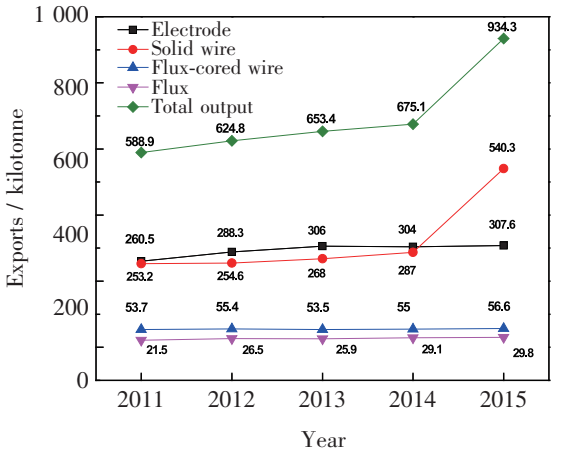


**Fig. 2 Exports of welding consumables from 2011 to 2015**

## 1.2 An obvious decline in the apparent consumption of welding consumables

In general, the key indexes measuring the development of the welding consumables industry of a certain country or region include, in addition to total outputs, imports, and exports, fixed investments and apparent consumption, which is an important index. The apparent consumption can not only mirror other indexes, such as the welding consumables capacity, but it can also forecast the development potential of the welding consumables industry in a certain region. This is defined as Formula 1.

$$Q_{ac} = Q_o + Q_i - Q_e \quad (1)$$

where $Q_{ac}$ is the apparent consumption, $Q_o$ are the outputs, $Q_i$ are the imports, and $Q_e$ are the exports.

China has become a welding consumables production nation. Due to improvements in the welding consumables production capacity and quality, as shown in Fig. 2, the exports have kept increasing in recent years. Fig. 3 shows that some premium welding consumables, which are required for some major projects and equipment, still rely on imports from developed countries and regions. Fig. 4 shows the apparent consumption.

The apparent consumption of Chinese welding consumables decreased from approximately 4.2 million tonne in 2011 to 3.3 million tonne in 2015. The apparent consump-

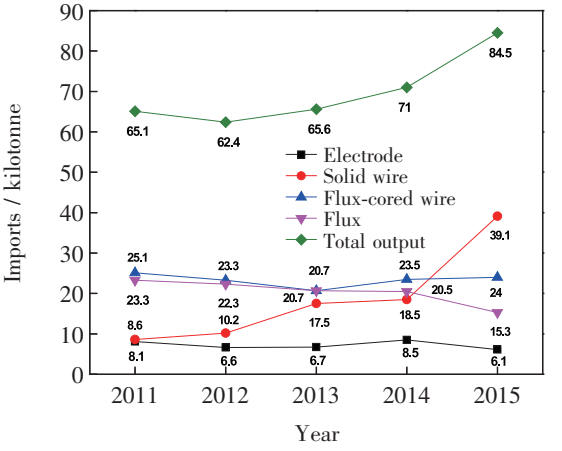


**Fig. 3 Imports of welding consumables from 2011 to 2015**

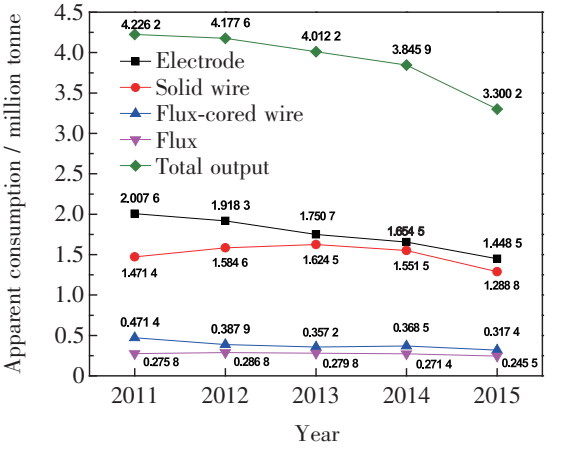


**Fig. 4 Apparent consumption of welding consumables from 2011 to 2015**

tion declined by 22% but the output declined by only 12.6%, which means that the exports of Chinese welding consumables have increased greatly.

### 1.3 A more rational welding consumables product mix

The variations in the proportions of the different welding consumables during the 12th Five-Year Plan period are displayed in Fig. 5, which shows the initial results of the product structure adjustments.

Fig. 6 shows the proportions of the apparent consumption of the different welding consumables. Electrode consumption still accounted for about 43% of the total consumption, while the proportion of the welding consumables that is used in automatic or semi-automatic manufacturing

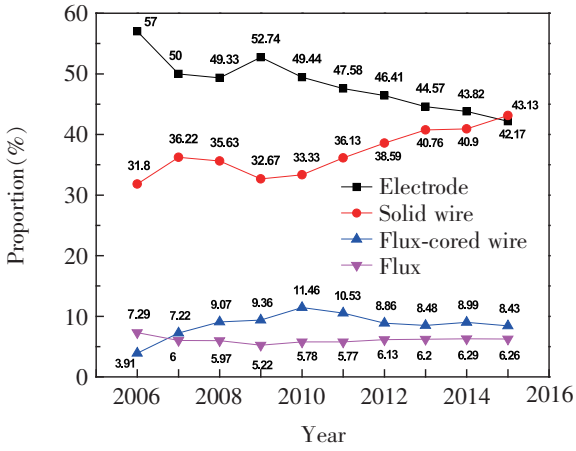


**Fig. 5 The proportion of the output of different welding consumables from 2006 to 2015**

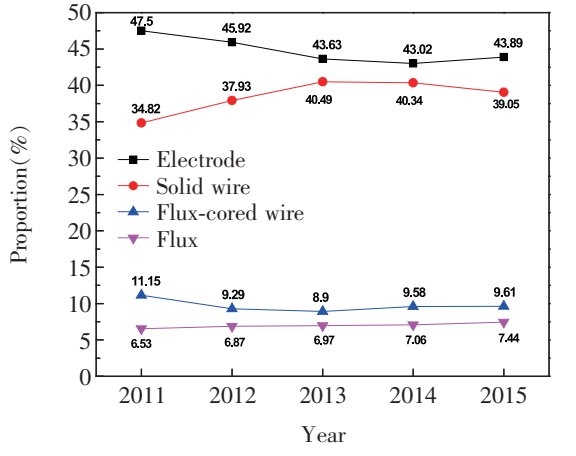


**Fig. 6 The proportion of the apparent consumption of different welding consumables from 2011 to 2015**

increased from 50% in 2006 to 56.7% in 2010 and remained steady increased to 62.5% in 2015. Although this proportion is still much lower than that in developed countries, which is above 80%, the product structure and consumption structure of China are adjusting and developing in a reasonable direction.

### 1.4 Obvious improvement in the production level of welding consumables

The welding consumables enterprises and institutes enhanced their investment in research and development (R&D) and premium welding consumables during the 12th Five-Year Plan period. The premium welding consumables industry developed rapidly, and the types of premium welding consumables, which include high-strength wire, self-shielded flux-cored wire, seamless flux-cored wire, and non-coppering wire, continuously increased. These welding consumables are used in nuclear power projects, ultra-supercritical units, large hydrogenation reactors, high-strength heavy machinery, pipelines, and high-speed rail, so the imports and accounts did not change obviously as a result of the increasing demand for premium welding consumables in China.

At the same time, the welding consumables enterprises in China steadily improved their manufacturing technology. They paid more attention to automation, environmental protection, and energy conservation during the manufacturing process to improve the automation of their processes and their productivity, reduce their production costs, and promote sustainable development. The technologies using high-speed wired core cutting, automatic powder compounding, large-scale single powder mixes, and automatic powder plugging were popularized in the process of electrode manufacturing. Some measures were adopted to test the quality of the product dynamically in the process of wire manufacturing. The wrapping quality and stability of barreled flux-cored wire improved obviously. There were breakthroughs in the technologies used for manufacturing high-strength wire, seamless flux-cored wire, and non-coppering wire. The method used for the examination of welding consumables changed from the mode of manual analysis to that of advanced equipment analysis, which improved the control of product quality and efficiency and

provided rapid and reliable data support.

## 2 The problems in the development of the welding consumables industry

### 2.1 The progressive appearance of excess capacity in the welding consumables industry

Due to the fast expansion of the Chinese economy since the early years of this century, short-term spending had been stimulated by the demands of the junior market. There were three tidal waves of low-cost expansion of the welding consumables industry during the 10th Five-Year Plan and the 11th Five-Year Plan. The production capacity of welding consumables is now approximately 7.5 million tonne, which represents about 60% to 70% of the designed capacity. The ratio of the domestic demand for welding consumables to steel output declined from 0.5% in 2011 to 0.41% in 2015, and it is expected to keep declining to the level of 0.3%, which is the average ratio for the developed countries. The experts predict that the steel output and domestic demand for welding consumables has reached a stable period and expect a slight decline henceforth. The steel output of China is predicted to decline to around 650 – 700 million tonne in 2020. Even if the ratio of welding consumables consumption to steel output is still 0.4%, the total domestic demand for welding consumables will be just 2.8 million tonne. Although the increasing level of exports can soak up some capacity, the excess capacity of the welding consumables industry appears likely to progressively increase in consideration of the present 7.5 million tonne output.

### 2.2 Lack of variety and poor quality of premium special welding consumables

There is a problem in China with the incomplete availability of all varieties of welding materials, such as electrodes, wire, and flux-cored wire. Premium nuclear welding consumables, including nuclear stainless steel, nickel-base alloys and high-strength steel, which are used in the manufacturing of nuclear island facilities, mainly rely on imports. In terms of other welding consumables, the electrodes used in supercritical boilers and ultra-supercritical boilers, cellulose electrodes, the stainless electrodes used in urea, the 3.5Ni and 9Ni steel electrodes, and the heat- resistant steel electrodes that need step cooling all need to be imported. In addition, special electrodes with atmosphere corrosion resistance, seawater corrosion resistance, and superalloys are purchased abroad. Some types of electrodes have various products with different uses in a series in some foreign companies.

Ultra-high strength engineering machinery steel, with a yield strength of 960 MPa, was invented in China in 2008, but the welding consumables for that grade of steel are still imported. X70, X80, and X90 line pipes, which are largely used in the pipe industry, require a matching high strength and high toughness flux-cored wire, metal powder cored wire, low-hydrogen electrodes and all-position gas-shielded solid wire, but the number of products with acceptable quality assurance standards and influential brands is low. The non-coppering gas-shielded solid wire manufactured abroad has achieved almost zero emissions, and the ratio of non-coppering solid wire to solid wire is above 30% in foreign countries but is much lower in China. The non-coppering wire produced in China has the disadvantages of unstable quality, poor electric conductive performance, unstable feeding, severe tip wearing, and tip blocking because of surficial attachment. All of these disadvantages constrain the development and supply of domestic non-coppering wire. The technology involved with the manufacturing of seamless flux-cored wire has been blocked by the foreign welding consumables enterprises, and the imported seamless flux-cored wire is very expensive. R&D for Chinese seamless flux-cored wire is still in the initial stages and is far from achieving large-scale production and utilization. The premium seamless flux-cored wire used in China is mostly imported; the manufacturing technology and production of seamless flux-cored wire has not been popularized in China.

The standards of welding consumables production in China are nominally the same as the international standards, such as the American and Japanese standards, but in practice, the foreign enterprises have stronger self-discipline. Their enterprises' standards are much stricter than the industrial standards, and the industrial standards are much stricter than the national standards. The quality of their welding consumables is much better than the international average quality. In China, because of the fierce

competition, many of the welding consumables enterprises focus on chasing profits and survival. This adverse situation has seriously hampered the development of the domestic welding consumables industry and the welding quality of the equipment manufacturing industry.

### 2.3 Relatively weak research ability and low level R&D

There has been a decrease in the number of Chinese universities and scientific research institutions studying the new welding consumables. Most of the studies mainly rely on some large enterprises. Because these enterprises closely guard their intellectual property, there is little sharing of resources and technology. The welding consumables industry as a whole lacks an organizational plan and uniform coordination, so its research strength is relatively weak, and because of the severe economic situation, the enterprises in this industry have reduced their input into new welding consumables research. In terms of the systematic nature of their research and the means deployed, there is a gap between the Chinese and foreign enterprises. The foreign enterprises have changed their examinations from a qualitative index to a quantitative approach, such as their work on the electrode extrusion press capacity and feeding stability. The welding consumables enterprises should test their products strictly in different conditions to improve their applicability and reliability. These different conditions should include different power, feeding systems, welding environments, technology, and operator skills. The welding consumables enterprises abroad often invest resources to find, develop, or select new materials or supporting materials to improve the performance levels or lower the cost; their Chinese counterparts should do this also.

## 3 The development trend of the welding consumables industry from 2016 to 2020

### 3.1 The opportunity for the development of the welding consumables industry

#### 3.1.1 The opportunity for the development of advanced welding consumables created by the "Made in China 2025" plan

In the ten main fields of the Made in China 2025 plan, there are eight fields that are closely related to the development of welding technology: aerospace equipment, marine engineering, high-tech vessels, advanced rail transport, new energy vehicles, electronic equipment, agricultural equipment, and new materials. According to the technology roadmap of the Made in China 2025 plan, the rapid development of these industries and the new technologies that come with them will require new welding consumables, which provides a chance for the development of welding technology. Especially in terms of new materials, China will break through with new technology for the materials, design, manufacturing, and application evolution of the steel used in the advanced equipment. The development and application of the high-performance maritime steel, new high-strength and tougher automobile steel, high speed and heavy load rail transport steel, compound function construction steel, oversized oil and gas pipe steel, composite rolling boards, super-strength stainless steel, and high performance light alloys used in special equipment will promote the research of new welding consumables[1]. The sales value of the premium equipment manufacturing industry will reach to above 30% of the total manufacturing industry's sales value in 10 years. Premium welding consumables will be a new hot spot in this market. Although the premium welding consumables sales proportion is now 10%, the proportion of the solid wire, flux-cored wire, and submerged wire products will increase to about 20% to 30% with the development of the premium manufacturing industry.

#### 3.1.2 The broad international market for welding consumables provided by the "Belt and Road Initiatives" strategy

The countries along the Silk Road Economic Belt are mainly developing countries and emerging economies. With the exception of Singapore, the industrialization degrees of the Central Asia and ASEAN countries are mostly not high. Their infrastructure construction still lags behind others. In the future, they will demand more infrastructure such as railways, pipelines, airports, ports, and nuclear power. The value of their market demand will be about 1.12 trillion dollars in the future, which will comprise 29% of the global market. This provides a huge market

opportunity for the Chinese manufacturing industry. Except for their investment in infrastructure construction, the countries along the Silk Road Economic Belt have been enhancing their industrial investment and level of cooperation, especially in equipment manufacturing. They need to push the process of industrialization and focus deeply on the best ways to integrate this process with their economies and societies. This is a key aspect of the Belt and Road Initiatives strategy. For a long period into the future the Chinese equipment manufacturing industry will follow this trend for industry transformation and the upgrading of these countries, and this will encourage and support the Chinese manufacturing enterprises to step out and invest in these countries. The development of manufacturing industries and the support of welding technologies are inseparable, and so is the supply of premium welding consumables. Meanwhile, the welding technology levels in these countries are low. They lack welding consumables enterprises, and their enterprises do not have enough market influence and competitive capacity. All of this provides a great chance for the Chinese welding consumables industry to step out and capture a substantial share of this much larger market.

### 3.2 The trend of the development of the welding consumables industry

#### 3.2.1 The demand for more premium welding consumables products

With the rapid development of modernization and industrialization and the persistent boost of the Made in China 2025 plan, the quantity of premium welding consumables required for equipment manufacturing is increasing yearly. The enterprises and industries that use welding consumables are in the process of transformation and upgrading, which will require higher technical expertise than the national standards. The R&D in respect of premium welding consumables will be the key factor for enterprises to fight for their share of the market and show their competitiveness. For example, the manufacturing of marine equipment, such as drilling platforms, oil production platforms, and ships, will require the use of premium welding consumables with the characteristics of high strength, toughness (particularly for low temperature operations), and seawater corrosion resistance. The R&D in respect of domestic welding consumables will need to focus on achieving excellent processing properties, ultra-low hydrogen, and high toughness. It is particularly important to obtain a high Crack Tip Opening Displacement (CTOD) value to meet the requirements of the domestic marine engineering industry and this is a key research direction. The 80 – 100 kg high-strength wire that is required for high-strength steel applications in engineering machinery mainly relies on imports at present, so the R&D on these welding consumables is extremely urgent. Although China is a big nuclear equipment manufacturer, the key research on nuclear welding consumables research started late, and a lot of the related materials are imported. This constrains the development of the domestic nuclear equipment manufacturing. A lot of the welding consumables required for the second generation heat-resistant steel that is used in the fossil power industry are consumed by enterprises in pressure container manufacturing. These consumables need to operate in an environment of 600 ℃ steam, and the popular products, such as P91, P92, SUPER304H, and HR3C are still monopolized by some well-known foreign enterprises. The third generation heat resistant boiler steel used under the condition of 650 ℃ steam is under development in China, and this steel requires welding consumables that have high temperature resistance and good creeping properties; R&D on these consumables is urgently required.

#### 3.2.2 Green welding consumables products and production

It is generally accepted that it is imperative to save resources and be environmentally friendly; this is consistent with the current trend of development, which is green production. Improving the workers' conditions and reducing emissions are important tasks faced by the welding consumables researchers; for example, reducing emissions and spatter should be the main research orientation for flux-cored wire, which is now increasingly applied. The welding consumables industry is one of the high-polluting industries. The pollution problems of emissions, industrial effluents, and noise have not been solved. Traditional solid wire is mostly coppered to prevent rust,

which pollutes severely. Domestic and foreign enterprises have launched non-coppering solid wire products in recent years. Engineering applications should be the next area of emphasis. With the development of non-coppering solid wire and seamless flux-cored wire, it is inevitable that non-coppering seamless flux-cored wire should be developed. Chinese welding consumables enterprises should concentrate on low-carbon green products and the production mode, and they should promote the development of green welding technologies that can be adapted to the requirements of the modern green factories in which the welding consumables requirements will evolve and change over time.

### 3.2.3 The scientific development of welding consumables enterprises

During the 12th Five-Year Plan period, the Chinese welding consumables enterprises made some progress with independent innovation, improving the product range, optimizing the quality, raising the automation level, and reducing costs. During the 13th Five-Year Plan period, it is their duty to establish China's own brand of welding consumables. They should form their own product features by finding their advantages and market positions, and as a consequence of this, the industry structure of some leading enterprises and a number of distinctive middle- and small-sized enterprises will be formed. This structure is needed for the development of the Chinese industry. The enterprises should also adapt and participate in the transformation and upgrading of the manufacturing mode from production to services, thereby leading to the upgrading of the industrial chain. They should enhance their ability to provide services to key industries and users and build a relevant internet-based service network by enhancing the integration of manufacturing and informatization and actively participating in the cloud platform construction to support an advanced manufacturing industry. The coordinated development of welding technologies will promote the development of integrated solutions for these technologies. The welding consumables enterprises should gather all of the necessary welding technologies, equipment, and materials to provide the technical support required by the premium manufacturing industry.

## 4 Some suggestions for the development of the welding consumables industry

### 4.1 Speeding up the transformation and upgrading of the welding consumables industry

The development of the Chinese economy has entered a new stage. The traditional "rough growth" mode, which was mainly based on increasing the quantity of production, is now unsustainable. The supply project and the information set out in the Made in China 2025 plan have provided challenges but have also outlined a direction for the development of the welding consumables industry. This should speed up the transformation of enterprises to meet the demands imposed by the development of the market and should especially enhance the rural supply transformation. The overall upgrading of the traditional welding consumables industry needs the technology of production to be improved, a progression to high- and mid-grade quality products, improvement of the supply quality, and meeting the increasing demands of the consumers. The welding consumables industry should enhance the development of high quality products and cooperate with consumption enterprises to find breakthroughs in domestic premium welding consumables. It should put emphasis on the welding consumables that are closely related to the fields proposed by the Made in China 2025 plan, which have a large development space. These breakthroughs will strongly promote the development of the Chinese welding consumables industry and bring considerable economic and social benefits to these enterprises. The breakthroughs will raise the market service consciousness and help to integrate the production and technology services.

### 4.2 Improving the brand's influence by improving overall quality

The quality of the products supplied determines the vitality of the brand in the market. The market expansion mode of low price, low quality, and a focus on quantity has come to an end. The welding consumables industry should put the improvement of quality as its top priority. In view of the industry's current condition of low popularity, poor application achievement, and deficient data, the Chinese welding consumables industry should create an integrated database that has different welding parameters as

well as the heat input and heat treatment required in practice during the research on premium welding consumables. It should carry out some adaptable industrial research to tighten the research focus and application. If the industry is able to ensure its products' adaptability, it will help the development and spread of new products and help to build the brand.

### 4.3 Increasing the input to the research and technology reform

The welding consumables industry should increase its input to research, emphasize the fundamental research of welding consumables, speed up platform construction, cultivate talent, and construct an improved capacity for R&D. It should also adjust to the evolving changes in the steel industry production, steel quality, and the increases in the variety of steels. The welding consumables enterprises should pay close attention to the development of steel uses in all industries. They should increase their input into research, develop welding consumables that match changes in steel varieties, strengthen their innovative abilities, develop their own premium and specialty welding consumables, and not rely on imports. In terms of the development of premium welding consumables, they should change the traditional conception of matching strength and composition to the new conception of an optimal design centering on the bead structure and performance. This new conception should include the planned purpose of the product, the control of the welding structure, and the systematic design of the bead structure. They should also adjust the research direction to give more attention to weld alloys. This will improve the performance of joints and thereby promote the development and production of welding consumables. These enterprises should follow the international trend by actively popularizing the advanced technologies and diligently improving the internal quality of welding consumables, thereby bridging the gap to reach the advanced international level. The production of welding consumables should be developed in the direction of automation and digitization. These enterprises should also enhance their quality control during production, including the control of raw and auxiliary materials, the dynamic monitoring of materials, semi-finished products and finished products, and enhance the upgrading of production equipment to create an environmentally friendly and highly automated production condition, thereby improving the enterprises' survivability. In addition, they should strengthen their innovation with regard to the integration of materials, equipment, and technologies as well as the automation of production by equipment upgrading to improve the productivity, technology level, quality stability, and product competitiveness.

### 4.4 Developing a low-carbon green production mode and welding consumables

Low-carbon green macro policies have been proposed by the government. With the emphasis on automation and green production by the manufacturing industry and the application of new structure materials, matched welding consumable materials are also required that have the characteristics of being green, diversified, highly efficient, and adaptable to automation. The welding industry is also a high-pollution industry, and the welding workers are now expected to improve their working conditions and reduce their emissions. The welding consumables enterprises should enhance their research on new low-carbon green technologies and the production of low ash and other pollutants. The welding materials industry has not yet solved the problem of emissions and noise. They should maintain a strong emphasis on researching and improving their technologies to enable them to develop efficient green practices, and they should strive to develop low-carbon green products, packaging, and production modes to promote the development of green welding technology.

### 4.5 Promoting the overall development of the welding consumables industry by coordination and cooperation

During the 13th Five-Year Plan period, the Chinese government will continue to decentralize their determinations down to the level of the industry associations. The welding consumables industry association should lead the development of the innovation strategies, promote the enterprises as the leading players, perfect the cooperation and innovation mechanisms required to make cooperation work, determine how the necessary studies and research

should be applied to production, moderate various resources, develop technology that is adaptable to the market, and accelerate the industrialization of the achievements in all of these areas. The industry association should promote innovation in corporations to enhance the initiatives and foresight of enterprises with regard to adjusting their product mix and transforming from product-oriented manufacturing to service-oriented manufacturing. It should establish the institution of modern enterprise management and quality control to speed up the industry standardization, enhance the implementation of industry standards, improve the standards of products, and gear up the domestic standards to international standards. The welding consumables enterprises should enhance their cooperation, draw on the wisdom of the masses, and learn from others' strong points to offset their weaknesses and thereby improve the technology and quality of the whole industry.

## 5 Conclusions

(1) During the 12th Five-Year Plan period, the Chinese welding consumables industry developed steadily. China has become a welding consumables production and consumption nation, but is not yet a premium welding consumables production nation. The Chinese welding consumables output has remained largely steady with just a slight decline, but the apparent consumption has clearly declined. The product mix is trending to be more rational. The manufacturing technology has clearly improved, but the excess capacity of welding consumables has become progressively larger. There is a lack of variety and quality in premium welding consumables and the research effort has been relatively weak. The above shortcomings all constrain the development of welding consumables.

(2) The Made in China 2025 plan creates a chance for the development of advanced welding consumables during the 13th Five-Year Plan period. The Belt and Road Initiatives strategy provides a broad international market for welding consumables. The welding consumables industry needs to develop towards the direction of high quality products, green production, and scientific development.

(3) The Chinese welding industry should accelerate the transformation and upgrading of the industry and its firms. They should work on improving their overall quality to improve the brand's influence, enlarge their input into research and technology upgrading, and develop a low-carbon green production mode. Their coordinated development will accelerate the general improvement of the welding consumables industry to make China a great welding consumables manufacturing nation.

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