Chemical engineering & nuclear power construction in China: an overview

Mr. Ma: "Large-scale over capacity in the chemical engineering industry has resulted in significant under-utilization of production capacity for many companies."

As the most populous country in the world, many of China's industrial production capacities rank first globally. While national consumption per capacity for these products also take the lead, the explosive growth in production capacity means the market is hard-pressed to keep up and absorb the increased rates of production. Serious over-capacity is the result.

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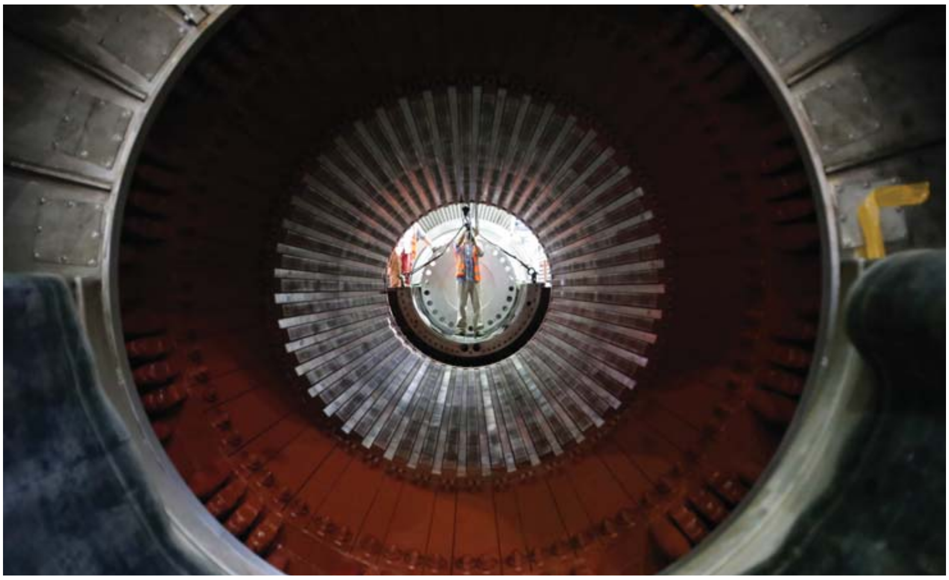
Following more than 20 years of rapid development, there is now a serious excess of production capacity in China's chemical engineering industry (with the exception of certain specific products such as LNG). Severe under-utilization of installed capacity has led to reduced economic efficiency for many enterprises.

Chemical engineering industry, incl. petrochemicals & coal

Since the beginning of the 1990s and especially after 2000, China's government has made large-scale investments in various industries. Production capacity thus saw high rates of growth in parallel with major improvements in product quality. In addition, in order to deal with the American financial crisis and European debt crisis, China's government increased the scale of its investments. See Table 1 for the production volume and industry operation rates for several typical chemical engineering products in 2014.

Table 1. An overview of China's fertilizer, methanol, PVC, polysilicon, and ethylic acid industries in 2014

Industry name	Output (10,000 tons)	Operation rate %
Chemical fertilizer	6934	70
Methanol	3676	62
PVC	1630	62
Polysilicon	13	85
Ethylic Acid	430	43



There are 28 nuclear power reactors under construction in China, each requiring 3,000 tons of austenitic stainless steel, zirconium and zirconium alloys, and nickel based alloys. Photo ©Westinghouse 2014.

Methane production is a good example to illustrate this problem. From 1995 to 2005, China's methane production capacity recorded an average annual growth of approximately 15%. In 2006, production capacity surpassed 10 million tons, in 2008 it reached 23 million tons, and in 2010 it topped 30 million tons, rapidly making China the world's largest producer and consumer of methane. From 2006 to 2007, average annual growth rates were 50%. From 2010 to the present, while the rate of production capacity increase has slowed, nonetheless, in 2010 production capacity growth was still as high as 38%. In 2013, China's methane production capacity was 55.90 million tons, and in 2014 it had risen to 69.35 million tons. The influence of methane installation construction on the usage of stainless steel is significant. For example, one methane plant with annual production of 1.8 million tons requires approximately 10,000 tons of various types (including plating, piping, and other cast and forged parts) of austenitic stainless steel, duplex stainless steel, and nickel base alloy materials. China is essentially able to provide these materials from its internal market, with the exception of nickel based alloys which are imported. The result of this rapid development has been the creation of economic problems as well as very serious environmental pollution. Land, water, and air have all been polluted to varying degrees, causing a series of serious ecological problems. Taking air pollution as an example, severe smog issues now occur in most areas across the country. In 2014, Beijing recorded that as many as 60% of days were marked by polluted air quality. Just like in other countries, there are sure to be stage-based adjustments following this rapid development. In the beginning of 2014 the Chinese government implemented strict controls on industries experiencing serious production over-capacity. Investment has dropped significantly in chemical engineering, with many construction projects halted or delayed. The demand by these industries for stainless steel, nickel, nickel based alloys, zirconium, zirconium alloys, titanium, and titanium alloys has likewise dropped precipitously.

Nuclear power industry overview

The Japanese Fukushima nuclear power station incident resulted in China's nuclear power industry going into hibernation for several years. However, due to the severe smog problems, there has been enormous pressure on the energy structure to improve environmental conditions. In addition, the demands of combatting climate change by reducing carbon emissions have also pushed the transition towards clean energy. Therefore, nuclear power is set to become an important pillar of industry for China's clean energy.

As of April 2015, China was operating 23 nuclear power units with total installed capacity of 21.40 million kilowatts. There are another 28 nuclear power units under construction or in planning with a total installed capacity of 28 million kilowatts. This means that, prior to 2020, China will add approximately 5 nuclear power units per year.

The highly radioactive material within a nuclear power station's reactor places special requirements on the construction materials. In addition to the basic mechanical properties, corrosion resistance, and process properties, the material must also have the following additional properties:

- it must be able to control the material's absorption of neutrons;
- the stainless steel must have good radiation hardness. This is because after the material in the reactor is neutron irradiated, the structural properties change, and its strength, hardness, plasticity, and ductility all decline. Research has shown that the following measures can improve the radiation hardness of materials:
    - limit the amount of sulphur and phosphate, reduce carbon content, and control manganese and nickel contents;
    - refine the grain and improve material ductility;
    - optimize refining processes to carefully select source materials to reduce the amount of impurities such as copper, arsenic, and aluminium, utilizing refining processes to reduce the contents of nitrogen, sulphur, phosphate, hydrogen, and oxygen;
    - utilize appropriate heat treatment processes to further improve product performance.

Austenitic stainless steel, zirconium and zirconium alloys, and nickel based alloys each satisfactorily meet the above noted requirements for material within nuclear power plant reactors. Therefore, they are

China's stainless steel market

In 2014, global stainless steel production volume was 41.7 million tons, of which China's stainless steel production volume was 21.69 million tons, accounting for 52%. China exported 3.85 million tons, and imported 820,000 tons. Even though China's stainless steel production volumes and export volumes are significant, its product quality exhibits a gap compared to industry peers in developed nations, especially in the realm of stainless materials with special requirements. Exported stainless steel products are primarily general residential use materials, and export targets are primarily nations in south-east Asia.

Rapid industrial development has created serious environmental pollution throughout most of China. Now pressure to reduce pollution, including cleaning up air quality, is driving ahead growth in the nuclear power generation in the country.

commonly used in nuclear power plants, primarily stainless steel 304, 316, 321, 347, and 310. These materials are mainly used in reactor pressure containers, components within the reactor, and primary circuit cooling systems. A nuclear power unit of 1 million kilowatts uses approximately 3,000 tons of austenitic stainless steel, zirconium and zirconium alloys, and nickel based alloys. Currently, for various reasons, the majority of these materials must be imported by China, although Chinese factories are of course developing their capabilities.

Challenges for Chinese stainless steel producers:

1. Chemical element matching

Many Chinese manufacturers believe that a product is compliant so long as it meets product compliance standards. Little do they know that requirements provided by ASTM standards are generally the minimum requirements, which do not guarantee usable properties for conditions in some special work conditions.

Industrial applications are complex, and due to differences in various work conditions, it is not the case that materials simply need to meet the standard requirements for each individual element. There are also matching issues relating to the ratios of chromium/nickel, sulphur/manganese, and carbon/titanium etc. The ratio between chromium and titanium also influences the high-temperature strength, oxidation resistance, and residual ferrite of austenitic stainless steel. The ratio between sulphur and manganese also influences the material's ductility and weldability. The ratio between carbon and titanium also influences the material's high temperature strength, degree of purity, and deformation processing properties.

2. Material purity

The purity of a material refers to the amount of existing impurities such as residual elements, miscellaneous elements, and non-metals. As everyone is aware, higher residual copper contents can markedly reduce the hot and cold deformation processing properties of austenitic stainless steel. Excess impurities such as sulphur or phosphate can reduce the material's deformation processing properties and resistance to corrosion, and can easily result in welding defects. Not only can relatively large quantities of non-metal impurities reduce metal ductility, they can also easily result in cracks during deformation processing, and so on. In general stainless steel product standards, the degree of purity of relevant materials is sometimes not given, and sometimes when it is given it is difficult to satisfy the requirements for special work conditions. Because many Chinese manufacturers lack experience, some material purities are not sufficiently high.

3. Residual ferrite content

316L MODs utilized in urea installations place strict requirements on ferrite contents, and some Chinese 316L MODs are hard-pressed to meet the requirements.

4. Intercrystalline corrosion

We conducted a market survey regarding the intercrystalline corrosion compliance rates for 300-series stainless steel piping. The survey found that the first-time compliance rate (based on ASTM A262 E method) was 60%-80% for Chinese 300-series stainless steel piping intercrystalline corrosion, whereas several mainstream international suppliers were essentially at 100% for first-time compliance rates. The compliance rate issues for stainless steel intercrystalline corrosion is in fact a multifaceted problem. It includes matching issues for several primary elements, and control of residual elements and impurities, heat treatment control problems, and deformation control issues during the process of deformation processing. At the same time, this shows that sometimes simply satisfying standard requirements is insufficient.

5. Type testing

Incomplete type testing is a common problem for many Chinese metal processing enterprises and among smaller scale companies these issues are especially pronounced. Incomplete type testing will directly influence product usage performance or cause product quality instability.

Stainless steel imports

In 2005 China imported 3.14 million tons of stainless steel, while in 2014 it imported only 820,000 tons. In 9 short years, imports dropped by more than 70%. Currently, the 300-series stainless steel that the chemical engineering industry still needs to import includes:

- HTHP and hydrogen work condition furnace piping and heat exchange piping;
- HTHP and hydrogen work condition large-diameter process piping;
- urea-grade stainless steel piping and steel plates;
- heat exchanger plates that require large deformation volume processing;
- high temperature or low temperature work condition wide and thick plates.

The majority of 300-series stainless steel for the nuclear power plant industry must be imported.

In addition, China will need to continue importing ferrous metal materials including nickel and nickel base alloys, zirconium and zirconium alloys for a relatively long time.