Coil coatings gather pace in China

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The market for coil coaters and coatings has grown rapidly over the past nine years in China and excessive capacity expansion is a pressing issue to be solved. Coil coated metal has found important applications in cool roofing and the automotive industry. New raw materials including new resins for coil coatings are continuing to improve film performances and ensuring that they meet environmental regulations. An invention of FT-IR new accessories for curing studies is reported.

The practice of coil coating originated in the United States in the 1930s [1] and has now become an important sector of industry. Continuous roller coating application and highly automated processes contribute to the high efficiency of metal coil coaters. In order to meet the requirements for high performances of coating films for post-formed and shaped fabrication and long-term durability, it is vitally important to achieve high output and high qualities of liquid coatings from batch to batch.

A worldwide production level of coil coated metal of 14.959 million tonnes in 2001 was reported by the European Coil Coating Association (ECCA).

Coil-coated metal came to China in the 1980s

In the 1980s the Bao Steel Works of Shanghai imported foreign technologies and equipments from Wean United Co. of the US, while Wuhan Steel Works so imported similar expertise from the UK. The first coil-coater line in China was put in operation in the 1990s. Since then coil-coater lines have been built up rapidly and widely in China. The total consumption of steel coil in China from 1995 to 2003 is shown (Figure 1) [2,3].

The consumption has been steeply increasing at an average annual rate of 98 %. Within this, however, considerable portions have been imported directly for use. The consumption in 2003 consisted of 1.700 million tonnes from domestic production and 1.102 million tons from import (Figure 2).

Major coater lines

There were about 100 coater lines in China at the end of 2003. Shanghai Bao Steel was the largest with its 2 lines and 395,000 tonnes capacity. Other major industry players in 2003 included Wuhan Steel (1 line, 64,000 tonnes capacity), Anshan Steel (2 lines and 300,000 tonnes), Beijing Capital Steel (1 line and 170,000 tonnes) and Panzhihua (1 line and 100,000 tonnes). Other major lines are expected to come on stream in 2004. Southwest Aluminum, which is an importing coater line from Bronx of UK, is the major aluminium coil coater line in China. The chairman of the China Steel Association, Bingsheng Luo, stressed at the First Information Conference 2004 that the steel output in China was 222.34 million tonnes in 2003, which was a rise of 22 % compared to 2002. China is the only country in the world producing more than 200 million tonnes and continued to hold the top position worldwide in 2003 for the eighth consecutive year. The production capacity of coil coaters increased from 4.46 million tonnes up to 8.73 million tonnes rose 95.7 %, in last year. Of this 1.04 million tonnes (12 %) were produced by the Association Members. Since 2000 the production capacity of steel coils has been swiftly expanded as illustrated (Figure 3).

Economic factors

There are estimated to be 200 companies and 474 coater lines (20 % for aluminium coil) in 40 countries worldwide for coil production. The total capacity in the world is about 14 million tonnes per year and the utilization of capacity is 70 %. The coil coated metal industry in China has grown from nothing to a 2.786 million tonne consumption (a little more than half the output of North America) within the past 10 years.

This was a reasonable response to the blooming Chinese market. Based on the population of 1.3 billion one might think that the output should be higher and higher to meet the market demand. As a matter of fact, the capacity in 2003 expanded to 8.48 million tons, three-fold over the total consumption, including that of imported coil coaters. The production capacity, however, can not be raised too fast and risked too much. Recently many coil coaters in China have been operating below their maximum capacities. Bare metal coils are in short supply and run out from time to time. Therefore, macro-economic manipulation, although this is not the only approach, has to be done. China has been developing rapidly, however, facing many problems at the same time.

The suppliers of coil coatings in China

In China, traced back to the 1980s, the coil coaters and coatings were projected by the two Ministries of the Metallurgical Industry and Chemical Industry. The Reliance Universal Co. (now Akzo Nobel) transferred its technology to Chenhua Paint of Shanghai Coatings Co. Since then Shanghai Coatings has supplied coil coatings to Bao Steel and also made many improvements and modifications to its coil coating technology. Shanghai Coatings has implemented ISO 9001: 2000 standards for its quality system and can supply a wide range of varieties of coil coatings such as polyesters, epoxies, polyurethanes, silicon-modified polyesters, acrylics, alkyls, PVC plastisol and fluoropolymers to meet customer demands.

Shanghai Coatings is positioned as the largest producer of coil coatings in China now and the annual outputs are given (Figure 4).

The other major producers of coil coatings in China include Akzo Nobel, KCC (Korea), Valspar, Jiangsu Hongye Coatings, Nippon Paint, Beike (Becker), Jiangsu Haiba, Shenzhen Zhongqiang, Changzhou Baoxin, Beijing Red-Lion Dura Coat and Wuxi Litong (mainly for aluminium coil coating). Competition in China is getting hotter and hotter.

Coil coated metals help energy saving

Energy saving has received more attention than usual from the governments in many countries recently. "Energy Star" has been promoted and emphasized in the United States. Shanghai is one of the biggest cities in China and reached a record-high of 16 million kilowatt load on the electric power grid in summer 2004 and approximately half of that was consumed by air-conditioning. The municipal government has dedicated much more to safety measures. According to information on the Energy Star website, some Energy Star-qualified exterior roof products can lower roof surface temperatures by up to 100°F and can cut peak cooling demands by as much as 10 to 15 %. As an important application of coil coatings, cool roofing is an important topic for reducing the "hot roof" phenomenon, reducing the "heat island effect" and cutting down the electricity peak load in large cities. A 1-mil factory-applied coating exerts as much influence on the radiative properties of a metal (or any other) roof as a 20-mil field-applied roof coating, or a 100-mil roof membrane [4].

Automotive applications
Coil coated materials have also been adopted in the automotive industry. The SMART car is the only current application for coil-coated roof panels, although other programmes are under development. It has been reported that BASF (coating) and Arvin-Meritor (forming and assembly) will collaborate to produce a coil-coated module which includes an integrated fabric sunroof.

**Chromate-free primers offer environmental benefits**

Environmental problems have caused a trend towards using chromate-free pretreatment and primers in the coil coating industry. A. Barbucci et al. indicated nitro-cobalt chemical conversion, with fluoro-zirconate passivation coated by an epoxy-polyurethane primer that had ionic exchange active pigments. This gave the best solution for the system studied [5]. Anticorrosive titanium dioxide pigment and ion-exchanged silica has been suggested as a potential material to replace chromates. Much progress has been made on chromate-free primers for general purposes.

**Hardness versus film flexibility**

Passing the 0 T bending test and having a satisfactory film hardness is a difficult, but achievable target in coil coating. Raw new materials, such as 2-methyl-1,3-propanediol (MPDiol) and 2-butyl-2-ethyl-1,3-propanediol, are allowing greater use of inexpensive dicarboxylic acids such as phthalic anhydride and terephthalic acid for the manufacture of high-performance, yet low-cost, polyesters. These diols are reported to provide relatively high levels of internal flexibility that ultimately yield melamine-cured coil coatings with an excellent balance of hardness and flexibility. Usually hardness and impact resistance are contradicting properties for a coating film. Researchers, however, have been making great efforts to find balancing materials through various paths. Dazhong Wang and Frank N. Jones found that “mesogenic groups with liquid crystal” could enhance mechanical properties of polyester thermosts in 1987. Pencil hardness reached 3-4 H with reverse impact resistance 80 in-lb.

**Further research is needed**

Many things need to be discussed and explored further. Recently nano-particles made in situ or introduced as additives have drawn more and more attention in coatings. The basic principal mechanism appears to be from the same ideas. Powder coatings with their environmentally friendly performances and excellent toughness have drawn increasing interest in coil coatings. The line speed has apparently not been run as high as conventional solvent-borne coil coatings.

**Salt spray test is not useful**

The salt spray test, a typical of which is ASTM B-117, has been widely used for coating evaluation for decades. Frank Jones gave a seminar in Shanghai on this topic at the beginning of the 1990s. Zeno Wicks and his co-authors remarked: “It has been repeatedly shown that there is little, if any, correlation between results from salt spray tests and actual performance of coatings in use” [6].

S. B. Lyon et al. published a paper in 1999 comparing various accelerated cabinet tests that have been used for the evaluation of the cut-edge corrosion of coil-coated architectural cladding. Comparisons with outdoor exposure samples revealed that the B-117 test shows unrealistic corrosion morphology with the most realistic cut-edge corrosion given by the modified tests. It was concluded that, over a 1000 h test time, the standard Prohesion test appears to show the best combination of realism and acceleration [7].

**Improving electrochemical impedance tests**

Electrochemical impedance spectroscopy (EIS) has been used to assess the degradation of coil coatings. However, the technique finds limitations when the painting systems confer good protection since the impedance response is dominated by the capacitance of the paint. The period of time necessary to probe the paint resistance can be of several months. C.G. Oliveira and M.G.S. Ferreira suggested an improved EIS method and gave strong consistence among the data achieved in the tests carried out at various solution temperatures for ranking coil coating samples [8].

As the coil coating industry has grown, deeper and finer research has been done. The segregation phenomena of minor components, such as flow agents, have been investigated by high-resolution XPS (X-Ray Photoelectron Spectroscopy), not only in coil coating primers of urea formaldehyde-epoxy systems, but also in polyester top coats with hexamethoxymethyl melamine as the crosslinker.

**FT-IR is a powerful tool**

Cross-linking is a key factor for coil coating. It is related to all film performances: various mechanical properties, anticorrosion, weathering and durability. Within the industrial process of coil coating, film formation is limited to less than one minute and usually occurs in seconds. FT-IR (Fourier Transform Infrared Spectroscopy) has been widely used for investigation of coil coatings for many years. Marek Urban and his co-workers found the enrichment phenomenon of melamine in top surface layer of polyester coil coating [9, 10]. My group has invented a set of accessories including a special sample cell and recording system for FT-IR recently [11]. Real-time 3-dimensional spectra can be visually displayed (Figure 5,6).

Figures 5 and 6 clearly show 3 D real-time FT-IR spectra at 3357 cm-1 group in a sample of coil coatings, in which the peaks rapidly decrease within less than 1 minute, while Figure 7 shows the unchanged peaks of the -CH2 stretch at 2963 cm⁻¹. It is no doubt that this methodology is a powerful tool for the research and development of coil coatings and its potential applications can be extended to any thermal reactions at high heating rates, including monitoring the degree of curing, evaluation of process and formulation, assessments of curing parameters and catalysts, kinetics and studies of crosslinking.

Any further cooperation on this technique and device is sincerely welcome.

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**References**


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Figure 1: Total Consumption in China

Figure 2: Import and Domestic Production

Figure 3: Production Capacity of Steel Coil
Figure 4: Coil coating output of Shanghai Coatings Co., Ltd.

Figure 5: 3-D Real Time FT-IR Spectra of 3357 cm⁻¹ group in a sample of coil coating

Figure 6: 3357 cm⁻¹ Transmittance vs. Time
Figure 7: 3 D Real-Time FT-IR Spectra of -CH2 and 3357 cm$^{-1}$ group