Considerations on Steel Manufacturing Process

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(Based on Honorary Member Lecture at Sophia University on March 28, 2002. Manuscript received on February 25, 2002; accepted in final form on June 14, 2002)

The comprehensive influence on the overall integration of steel manufacturing process is discussed in this paper, which influences not only the target group of technique and economy, but also the process emission and environment.

The evolution of steel manufacturing process for a long period is reviewed, which can be summarized as from simplicity to complication and then from complication to simplification. It is pointed out that the essence of steel manufacturing process is a production system which is combined mass state transformation, mass property control and mass flow control. It is a multi-dimensional mass-flow control system.

In fact, the optimization of steel manufacturing process is the analysis-optimization of the collection of procedure’s function, the harmony optimization of the collection of procedure’s relations and restructuring optimization of collection of procedures in the process. Based on above theory, the linkage optimization of function–structure–efficiency for steel plants will be realized and the mode of steel plants will be improved.

It is proposed that the social/economic role of steel plants should be positioned actively. The function of manufacturing process at the steel plants should be evolved from metallurgical function mainly to a multi-functional, which has both energy conversion and environmental treatment of social wastage. The steel plants may be an important part of the ecological industry zone in the future.

KEY WORDS: steel manufacturing process; analysis and integration; functions and positioning.

1. Development and Challenge

Steel will be as an important fundamental material in the new century. From a global viewpoint, the demand for steel in 21st century will increase slowly with fluctuations. The world steel output will be over 900 million tons in 2010. For developing countries, the consumption of steel products will be continuously increasing.

The steel industry has supported the development of Chinese economy. Especially during the period of 1990–2000, Chinese steel industry has developed rapidly due to the promotion of technological progress and the vast market demand.

Steel Tonnage Doubled in One Decade

The crude steel output in China was increased from 65.35 million tons in 1990 to 127.6 million tons in 2000 (Fig. 1).

- Improvement of Yield of Steel Product
  The average yield of steel product in china was improved from 83.2% in 1990 to 92.8% in 2000 and it was around 92.9% in 2001.

- Decrease of Energy Consumption per Ton Steel
  In 1990, the average energy consumption for Chinese

![Fig. 1. Transition of Chinese crude steel output and its share in the world steel output.](image-url)

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steel plants is 29.19 GJ/t, which was reduced to 22.42 GJ/t in 2000. And it was around 21.87 GJ/t in 2001.

- Enhancement of the Concentration of Steel Plants

In 2000, the number of steel plants with capacity over 1 million ton per year was 36. The steel output of these plants was 82.46% of total steel output in China. Among them, 7 steel plants are 3–5 million tons and 4 steel plants over 6 million tons annually in capacity. That means the concentration of steel industry and the scale of steel plants has been enhanced. In 2001, the number of steel plants with capacity over 1 million-ton has grown to 42.

- Great change in Geographic Distribution of Steel Plants

Through the construction and development in the past half century, especially in 1990’s, the geographic distribution of Chinese steel production has been greatly improved (Table 1). According to steel output in 2000, number 1 is the East region, then come to North, middle South, Northeast, Southeast and Northwest. Except Tibet, there are steel plants in every province. The steel plants are mainly located in the regions of East Coast and the middle and downstream of Yangtze River. The steel plants are located more close to the market, more close to the economic developed area, more close to the area where is more convenient for importing iron ore.

In China, the crude steel output was 148.93 million tons in 2001 and the apparent consumption of steel products was around 169.9 million tons. It is predicted that the apparent consumption of steel products will be more than 200 million tons per year in 2010.

Entering into the 21st century, the world steel industry is facing great challenges, especially in price/cost, environment/emission, consumer/quality, investment/profit etc. The general strategy is to optimize the steel manufacturing technological process.

The steel manufacturing process has a comprehensive influence (Fig. 2) and more attention should be paid to, not only on the steel production itself, but also on the emission in the process.

### Table 1

| Regions       | 1950 | 1970 | 1980 | 1990 | 1998 | 2000 |
|---------------|------|------|------|------|------|------|
| North (1)     | 12.72| 19.96| 21.51| 22.69| 26.10| 25.82|
| Northeast (2) | 82.83| 37.32| 26.44| 20.89| 14.30| 14.16|
| East (3)      | 1.95 | 23.7 | 24.74| 27.57| 31.60| 31.91|
| Middle South (4)| 0.90 | 13.57| 15.05| 16.64| 15.88| 15.95|
| Southwest (5) | 1.61 | 4.51 | 10.34| 9.38 | 8.80 | 8.93 |
| Northwest (6) | 0.0  | 0.94 | 1.91 | 2.82 | 3.40 | 3.43 |

2. The Trends of Steel Manufacturing Technological Process

The technological routes of steel production have been developed from simplicity to complication and then from complication to simplification (Fig. 3).

From Fig. 3, it is clear that the continuous casting (solidification) procedure is developed into the direction of near-net shape and high speed casting and promoted the steel production process to evolve into “continuation–compactness–coordinated”. Before continuous casting, the process is divided and optimized. It seems that the number of procedures is increased, but actually the functions of procedures are simplified. Hot metal treatment (de-Si, de-S, de-P) and secondary refining make the functions of all procedures more simplified. Then these procedures are possible to proceed faster with high efficiency and high frequency. After continuous casting, the processing procedures become more and more simplified, integrated, compact and continuous. In the procedures, not only many new technologies and equipment are appeared, but also some important “engineering effect” are observed:

- “bottle neck” effect and its elimination;
- effect of “criticalness-optimization” or “criticalness-compactness-continuation/quasi-continuation”;
- effect of “division-integration” (Table 2) or “flexible buffer engineering”;
- recycling effect of “artery–vein”.

In general, the steel production process is a manufacturing system combined with mass state transformation, mass...
property control and mass flow control. It is also a multi-dimensional mass flow control system. Its optimization must obey following principles:

- The principles of metallurgical physicochemistry, physical metallurgy and metal forming for optimization of procedure functions.
- The principles of optimization of relations between procedures for smooth and efficient mass flow within process.
- The principle of optimization of procedure functions, relations among procedures and the whole process, so as to optimize function—structure—efficiency systematically.

A common topic of the world steel industry is market competitiveness and sustainable development. Some characteristics of the steel manufacturing process are shown as follows:

- Steel manufacturing process will be a process of compactness/quasi-continuation/specialization in products, a clean production process and also a rational and optimized process (including the clean steel production).
- Effective control of emission process and minimizing the burden of pollutant treatment, and recycling and re-energization of emitted matter.
- The manufacturing process in steel plant should be evolved from metallurgical function to multi-functions, including energy conversion and pollutant treatment of social wastage.

### 3. Optimization of Steel Plants Operation

The features of steel plant route are complexity and integration. The operation of steel plants is developing into the direction of ordering, coordination, high efficiency and continuation.

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**Table 2.** Function analysis of BOF steelmaking process.

| Metallurgical Function | Hot metal Treatment | BOF | Secondary refining |
|------------------------|---------------------|-----|--------------------|
| Deslaborization        |                     |     |                    |
| Desulphurization       |                     |     |                    |
| Diphosphorisation      |                     |     |                    |
| Decarburization        |                     |     |                    |
| Heating-up             |                     |     |                    |
| Degassing              |                     |     |                    |
| Morphology control of inclusions |     |     |                    |
| Deoxidation            |                     |     |                    |
| Alloying               |                     |     |                    |
| Cleaning               |                     |     |                    |

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Ordering of Production Route: The ordering of procedures is realized by analytic study of process reaction thermodynamics and analysis-optimization of procedure function collection. The correspondence and simplification of equipment are realized by enlargement of equipment in each procedure. And the correspondence and simplifications should be the basis of ordering.

Coordination of Production Route: The stability of production process is promoted by reliability of equipment, use of expert systems and IT, improvement in the quality and stability of raw materials, and based on this stability the whole process can be operated with good coordination.

High Efficiency of Production Route: The efficiency of production route is increased by the technologies of near-net shape casting and endless rolling, hot metal pretreatment and high efficiency converter, by compact lay-out and property and long campaign life of equipment (20 years for BF (Blast Furnace), 40 years for coking batteries, 1 years for BOF (Basic Oxygen Furnace)) etc.

Continuation of Production Route: Based on ordering, coordination and high efficiency the whole process route can be quasi-continuous/continuous. The continuation is reflected in quasi-continuous mass flow, quasi-continuous process temperature, and continuation of process space utilization (in particular, minimization of slab storage, compactness of the plant layout between the caster and rolling mill). And finally it attributes to the continuation of operating time and operating period with high frequency.

The detail technical targets of operation optimization for steel plants are:
- Process running temperature:
  - >950°C even >1 000°C for coils
  - >900°C for long products
- Process running time:
  - <1 000 min for BF-BOF-HRM (Hot Rolling Mill) route^5
  - <180 min for EAF (Electrical Arc Furnace)-HRM route
- Green house gas emission per ton steel:
  - ≤1.510 kg/t^6 for BF-BOF-HRM route
  - ≤300 kg/t^7 for EAF-HRM route
- Logistics in production process: Except the materials and energy sources purchased and shipped product, and hot metal transfer between BF and BOF, the railways will be gradually abolished. The materials will be mainly transported by roller tables, belt conveyers, pipe line and crane, and the layout of steel plants will be more compact.

4. Social and Economic Role of Steel Plants

From the viewpoint of future strategy, the social/economic role of steel plants should be positioned actively. The role of steel plants should focus on the following points:

(1) The steel plants should optimize structure further based on the process engineering, for cost reduction, quality stabilization, variety salability, emission reduction and controllable, high efficiency and profitable.

(2) The steel plants should not only be steel producers, but also play the role of effective energy conversion system. A lot of energy in steel plants is possible to be converted into electricity, steam, hot water etc. In addition, urban steel plants will be able to supply steam, hot water to community in order to reduce the burden of cities. The steel plants are also capable of treating waste water and rubbish in community.

(3) The steel plants will be more friendly to environment and play an important role in promoting recycling, especially treating scrap, waste plastics and tires in society.

(4) The steel plant will be an important ring in ecological chain. There is a possibility to make hydrogen in steel plant. It will be located in some harbor area and region with resources, where integrated steel enterprise, cement plant, power station, steel structure plants or shipbuilding plant, automotive works, even chemical plants and petroleum manufacturing enterprise will be concentrated. A comprehensive ecological industry chain may appear in this region.

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