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# History of steel production in Japan and estimation of scrap generation in the future

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The steel production in Japan during the past 45 years was investigated in terms of steel making methods and steel products. Then, the characters of steel scrap were analyzed quantitatively. Finally, the generation of steel scrap in 2010 is predicted, where Cu enrichment is discussed. Here, the database constructed by Hayashi in a forum of Iron and Steel Institute of Japan was used. To be noted is that Japan has recently changed from an scrap-importing country to exporting one and that the obsolete scrap occupies approximately 80% of the total domestic steel scrap at the present. As a result of this estimation, the industrial scrap was 6.73 million ton, and the obsolete scrap was 28.7 million tons in 2000. According to this estimation, the amount of industrial scraps generation will be 6.24 million tons, and the amount of obsolete scrap generation will be 31.4 million tons in 2010.

Key words: steel scrap, industrial scrap, obsolete scrap, steel reservoir

## 1. Introduction

An overview is explained regarding the supply of steel scrap in Japan. Domestic supply source of steel scrap is divided into two categories: one is in-house generation in steel makers, so-called "returned scrap" most of which is returned to steel making furnaces and the other is "market scrap" yielded from steel products after their use. The market scrap is further divided into two kinds: "industrial scrap" and "obsolete scrap". The industrial scrap is generated from manufacturing processes of steel users while the obsolete scrap is due to expiry of service life of buildings, machineries, etc. The currently available statistic system can tell us only the amount of in-house scrap. No information is available for the market scrap.

Figure 1 shows the material flow of the market scrap from generation to consumption, where scrap is collected, processed to be suitable for reuse like sizing, pressing etc, and then sold to steel makers. In Japan, there is an industry society peculiar to each of these stages. Very small companies, mostly transportation companies, are mainly responsible for the collection. The scrap processing sector is mostly composed of small companies using guillotine shears and or shredders. Such companies are distributed all over the country. Recently, it is becoming conspicuous that the collected scrap is supplied directly to steel makers or exported, skipping the processing stage. This is because the disposal of dust generated during the scrap processing became costly. Therefore, it is becoming usual to charge this disposal cost back to the companies at the preceding stage in the form of so-called "reverse charging".

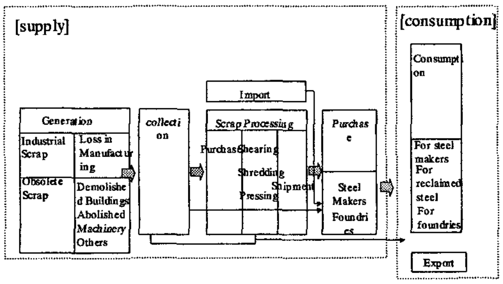



Fig.1 Flow chart of market scrap

As mentioned above, the three stages exist from generation to consumption in the market scrap. In spite of being anxious about the concentrations of tramp-elements, no official statistic date has been provided to grasp the amount of the market scrap as shown in Tablel 1. Because of the lack of statistical data directly to indicate the market scrap generation, the amount of scrap purchased by steel makers and foundries from domestic source, i.e., purchased tonnage of domestic market scrap, is used as a substitute of the generation tonnage of market scrap.

It is significant to analyze such a current condition more deeply and to understand the history of scrap to estimate of the scrap generation in the future. The steel reservoir should be regarded as potential raw material for steel making. Hence, it is important to know what steel reservoir is to discard because it suggests a macroscopic trend of the scrap generation in the future. In this report, at the first step of the estimation of scrap history, we estimated the history of steel production and the amount of steel reservoir and then predicted the amount of the future scrap generation, taking the kinds of steel products and furnaces used for their production into consideration.

Table 1 Statistic on scrap supply in Japan

| | Generation | Collection | Amount processed | Amount shipped | Purchased |
|---|---|---|---|---|---|
| Home scrap generation | ◎ | ◎ | (◎) | ◎ | × |
| BOF to EAF | × | × | × | × | ○ |
| Domestic Market Scrap | × | × | × | × | ◎ |
| Industrial Scrap | × | × | × | × | ○ |
| Obsolete Scrap | × | × | × | × | ○ |
| Import | | ◎ | | | ◎ |

Legend: ◎=Official ○=Industry ×=not available

2. Estimation Procedures

(1) Estimating steel production history

The estimation method used involves two stages. First, in order to consider the civil engineering division that shows the longest life, the steel production data in the past 45 years (1955-2000) were determined through two methods; one was based on steel making furnaces, and the other was the kinds of steel products. Here, the production data by individual furnaces in blast furnace makers were estimated, since no records were available. Second, comparing the steel production data with "the order-received statistics classified by use" published by the Japan Steel and Iron Federation, we estimated the amounts of production for individual use. Then, it is divided into domestic demand and export. The domestic demand was decomposed into 15 sections. Here, the data from 1955 to 1957 were estimated because no published data was available.

(2) Estimating industrial scrap

Estimation was made being based on "the Investigation of Industrial Scrap Generation" published in every 5 years by the Japan Ferrous Raw Materials Association covering roughly 1,500 plants of various manufacturing industries in Japan. The scrap shipment ratio of each industrial sector, i.e., the ratio of scrap shipped to the market was multiplied by the annual steel consumption obtained by the above (1).

(3) Macroscopic estimation of obsolete scrap

The collected, i.e., purchased amount of obsolete scrap was calculated by subtracting the shipment tonnage of industrial scrap obtained in (2) from the purchase tonnage of domestic market scrap which was given as an official statistic item. It should be noted, however, that the purchased amount of the domestic market scrap includes the returned scrap from blast furnace makers to electric arc-furnace companies in their corresponding company group. Because the amount of such a transfer was unknown, it was estimated and then the total amount was adjusted.

(4) Estimating steel reservoir

The steel reservoir was estimated by the following method. First, we calculated the annual steel accumulation, i.e., newly added steel reservoir, in each year by adjusting annual steel production taking direct and indirect import/export balance into account and subtracting the purchased tonnage of domestic market scrap. This method has advantages such that the calculation is simple and that it is convenient for macroscopically grasping the annual accumulation. The cumulative steel reservoir is a sum of the annual steel accumulations calculated as mentioned above from a starting year. The value of 13 million tons was estimated for 1920 by the Japan Iron and steel Federation which was used as the starting value in this study.

(5) Estimation of the future scrap generation

Assuming that the amount of crude steel production is 90 million tons, the amount of steel consumption of each section was estimated. The estimated amount of industrial scrap was multiplied by the shipping rate obtained in (2). The future obsolete scrap was estimated by considering the amount of steel reservoir as steel recycling source and assuming the annual rate of the accumulated reservoir increase. Next, the obsolete scrap-recycling rate was defined by the amount of the obsolete scrap gathered in a certain year divided by the amount of accumulation steel reservoir at the end of one year ago. Then, the amount of the obsolete scrap was macroscopically estimated.

3. Results

(1) History of steel production

Steel had been produced by three methods including Basic Oxygen Converter Furnace (OBC), Open Hearth Furnace (OHF) and Electric Furnace (EF) until 1972. Since 1973, BF and EF have been remained. Many kinds of steel products, such as sheets, coils, long products, pipes and tubes were produced by OBC. As shown in Fig. 2, the amounts of coils and heavy plates show little change with year but others show decreasing tendency.

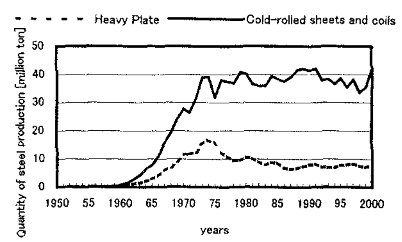



Fig.2 Steel production by OBC

On the other hand, long products such as shapes, bars, and wires, were main products by OHF as depicted in Fig. 3. The EF had produced sheets and coils till 1960 and after that shifted to long products such as bars and shapes. In the 1990s, the main products were bars and shapes although the trend of multi products including hoops, piles, etc. has appeared. As is shown in Fig. 4, the amount of production and the market share expanded from the 1970s to the 1980s.

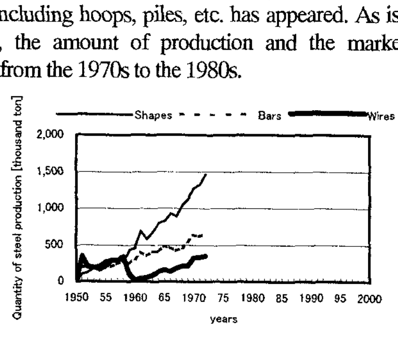



Fig.3 Steel production by OHF

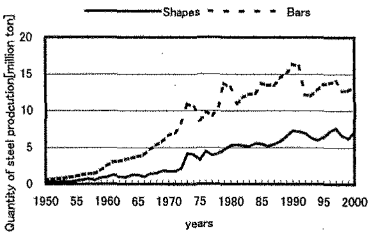



Fig.4 Steel production by EF

The steel production separated for the individual usage sections was overviewed in the past 45 years. Here, let us focus the analysis on the data in 1970, which are closely connected with the current scrap recycling. Table 2 shows the amount of steel production classified by furnaces or usage. The market shares of the individual furnace in the whole domestic demand are 76% for OBC, 5% OHF and 19% EF. Thus, the total share of OHF and EF is 24%, where these furnaces dominantly used steel scrap as the raw resources. The OBC occupies 95% in the consumption by manufacturing industries, such as machines and automobiles, and 48% in the civil engineering. The OHF supplied steel to civil, ship, and second process sections. Its market share in the civil engineering section is 8%. (see Table 2).

Table 2 Quantities of production classified by furnace and by usage

| | Quantity[thousand ton] | | | | Percentage | | | |
|---|---|---|---|---|---|---|---|---|
| | OBC | OHF | EF | Total | OBC | OHF | EF | Total |
| Construction | 4,904 | 810 | 4,450 | 10,164 | 48.2% | 8.0% | 43.8% | 100.0% |
| Industrial Machines | 1,808 | 71 | 212 | 2,091 | 86.5% | 3.4% | 10.1% | 100.0% |
| Electric Machines | 1,696 | 7 | 61 | 1,764 | 96.1% | 0.4% | 3.5% | 100.0% |
| Home and Office machines | 1,357 | 0 | 26 | 1,383 | 98.1% | 0.0% | 1.9% | 100.0% |
| Vessel | 4,276 | 254 | 700 | 5,230 | 81.8% | 4.9% | 13.4% | 100.0% |
| Automobile | 8,969 | 28 | 296 | 9,293 | 96.5% | 0.3% | 3.2% | 100.0% |
| Railways | 253 | 6 | 17 | 276 | 91.7% | 2.2% | 6.2% | 100.0% |
| Container | 428 | 1 | 22 | 451 | 94.9% | 0.2% | 4.9% | 100.0% |
| The Second Process | 3,326 | 293 | 926 | 4,545 | 73.2% | 6.4% | 20.4% | 100.0% |
| Selling Contractor | 10,932 | 903 | 2,944 | 14,779 | 74.0% | 6.1% | 19.9% | 100.0% |
| Others | 678 | 4 | 44 | 726 | 93.4% | 0.6% | 6.1% | 100.0% |
| Total Domestic Demands | 38,627 | 2,377 | 9,698 | 50,702 | 76.2% | 4.7% | 19.1% | 100.0% |
| Export | 16,251 | 329 | 1,268 | 17,848 | 91.1% | 1.8% | 7.1% | 100.0% |
| Total Production | 54,878 | 2707 | 10966 | 68551 | 80.1% | 3.9% | 16.0% | 100.0% |

The EF steel occupied 44% of the market share in the civil engineering section. Other sections for EF are ship, industrial machine, second process, and selling contractors. The market share of each section is from 10% to 20%. From the viewpoint of steel products, the share of EF in the bar section is 76%, while 16% is OBC and 7% is OHF as shown in Fig. 5. Fig.6 shows the case of cold-rolled coil where 98% is the share of OBC and 2% EF.

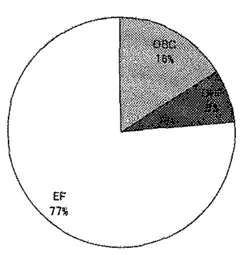



Fig.5 Total domestic demands of bars in 1970

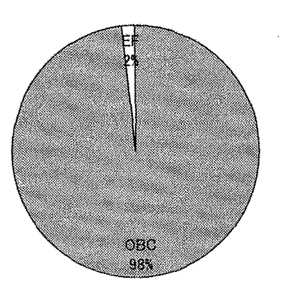



Fig.6 Total domestic demands of cold-rolled sheets and coils in 1970

(2) Industrial scrap

Figure 7 shows the change in the amount of generating industrial scrap with year. The amount shows a gradually decreasing trend. Figure 8 shows the amounts of scrap generation from the industrial sections in 2000. The scrap of 3.05 million tons were generated from the automobile section, 2.05 million tons from the industrial machine and electric machines and 0.72 million tons from the civil engineering section. Thus, the total amount is 6.73 million tons in which generation from the automobile section occupies 45%.

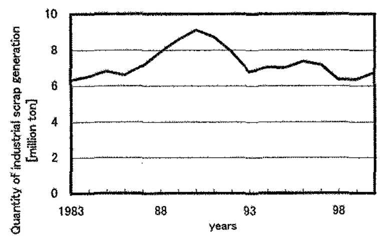
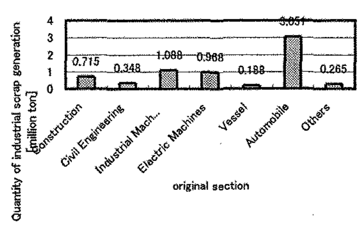



Fig.7 Quantity of industrial scrap generation

(a)




(b)

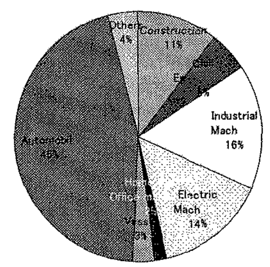



Fig.8 Scrap generation in original section in 2000 (a) Amounts of industrial scrap and (b) industrial scrap (percentage)

(3) Obsolete scrap

Figure 9 shows the historical change in the obsolete scrap. As seen, it indicates an increasing trend being different from the industrial scrap. The generation amount in 2000 is estimated to be 28.7 million tons in total including the domestic purchase and export. The recycling rate with respect to the amount of steel reservoir is 2.35%.

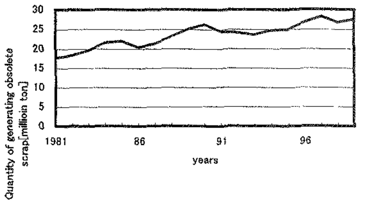



Fig.9 Quantity of obsolete scrap generation

(4) Steel reservoir

The result of reservoir estimation is shown in Fig. 10. The amount of steel newly stocked to the reservoir in 2000 is estimated to be 23.97 million tons, which is larger than 17.10 million tons in 1999 by 6.81 million tons. Consequently, the cumulative steel reservoir at the end of fiscal year 1998 is estimated to be 1,223 million tons. In Fig. 10, a low increasing rate in 1998 is noticed. The following two reasons are pointed out for this result: one is the extremely low domestic demand, the lowest record in the recent 26 years and the other is a relatively high amounts of export, the highest record in the recent 11 years. The increase in the reservoir is 12.25 million tons, the lowest value since 1960 as a result of combination of these two features.

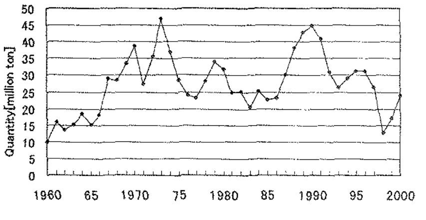



Fig.10 Accumulation increment

(5) Estimation of the future scrap generation

As listed in Table 3, the amount of industrial scrap generation in 2010 was predicted to be 6.24 million tons. This value brings a result that the amount of scrap decreases by 0.49 million tons in the industrial scrap compared with that in 2000. If we assume that the increasing rate of steel reservoir continuously keeps the value in 2000 and that the recycling rate is 2.15%, we would obtain 31.42 million tons as the amount of the obsolete scrap generation in 2010. In contrast with the industrial scrap, the amount of the obsolete scrap generation is predicted to increase by 2.73 million tons.

Table.3 Prediction of scrap generation in 2010 [unit: 1000 ton]

| | Industrial | Obsolete |
|---|---|---|
| 2000 | 6,728 | 28,690 |
| 2010 | 6,242 | 31,420 |

4. Discussion

The recycling rate may fluctuate depending on the domestic steel reservoir and general economic conditions. The rate was as high as 3.0% in the early 1970s when Japan was in a high economic growth period. It was 2.7 to 2.8% during the bubble economy period while 2.2 to 2.4% during the slump period encountered after that.

If it were possible to figure out the obsolete scrap recycling rate in all the countries of the world based on the identical definition described above, we would be able to reach a conclusion that the rate in developed countries keeps a constant value. However it has increased in developing countries. Hence, the recycling rate may be used as an indicator of economic development stage of a country. Here, the conditions peculiar to each country have to be taken into consideration: in some countries like Japan where land area available to use for human activities is limited, new capital investments require demolition of old constructions, whereas in countries like U.S.A. having large land areas, recycling of the obsolete scrap is mainly influenced by the scrap demand including export to other countries.

5. Conclusions and future work

A macroscopic estimation of steel scrap as a function of year was investigated. The steel production in Japan during the past 45 years is made clear from the two different points of view, i.e., steel making methods and steel products. The characters of steel scrap are estimated quantitatively. Then, the prediction of scrap generation in 2010 can be realized. As a future work, to predict the enrichment in concentrations of impurity elements, the estimation of the amounts of scraps classified by steel products generated from individual industrial sections are required. The estimation method should be improved by taking an economic index into consideration.

In the 1990s, Japan has changed to the exporting country of steel scrap. In the future, material flow of steel must be discussed from the Asian point of view. The export of steel scrap from advanced countries to developing countries is becoming obvious. Two trends can be pointed for the backgrounds; one is that the amount of the market scrap generation is exceeding the domestic demand in advanced countries; another point is the increase in the number of electric furnace in developing countries.

The amount of obsolete scrap generation in Japan is increasing and hence the export of scrap is predicted to increase. Nowadays, the steel scraps are regarded as international commercial goods, a common evaluation system throughout the world should be established.

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