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Cost of Corrosion in Japan

Toshio Shibata

Committee on Cost of Corrosion in Japan
Japan Society of Corrosion Engineering and Japan Association of Corrosion Control
Department of Mechanical Engineering, Faculty of Engineering
Fukui University of Technology
Gakuen 3-6-1, Fukui, 910-8505, Japan

The first report on the cost of corrosion in Japan had been published at 1977. The report estimated that the corrosion loss in Japan which did not include indirect loss was 1-2 percent of GNP at that time. Since then, almost two decades have been passed and the industrial structure has drastically changed. Corresponding to this situation, the committee on the cost of corrosion in Japan was organized at 1999 jointly by Japan Society of Corrosion Engineering (JSCE) and Japan Association of Corrosion Control (JACC). The project was funded by the National Research Institute for Metals(NRIM) in the program of the Ultra-Steels (STX-21) Project. Direct cost of corrosion at 1997 was estimated by the Uhlig method and the Hoar method. The estimated cost was compared with the past data which was estimated at 1974 by the same Uhlig and Hoar method. In addition to the above estimation, the preliminary analysis by the Input/Output method is performed for estimating the total cost of corrosion including the direct and indirect cost. The overall cost estimated by the Uhlig and Hoar method at 1997 was found to be 3,938 billion yen and 5,258 billion yen, respectively, which is equivalent to 0.77 % and 1.02 % to the gross national product(GNP) of Japan. The total cost including the direct and indirect cost, which is estimated preliminary by the Input/Output analysis, is likely to be 2-4 times larger than the direct cost estimated by the Uhlig method.

Keywords *: cost of corrosion, Uhlig method, Hoar method, ratio to GNP.*

1. Introduction

Through the last decade of the 19th century and beginning of 20th century, the steel production increases year by year because of the huge demand with industrialization and war. Such rapid increase in steel production raised an alarm for deficiency in natural resources including iron ore, coal and lime. It is said that corrosion study should be promoted for the sake of saving the natural resources. Hadfield[1] stated first that the wastage of iron due to corrosion is estimated to be about 40% of the steel production. In the late 1940's, Uhlig[2] reported the first detailed assessment of the cost of corrosion in the US. His approach was based on summation of the direct cost which was needed for prevention of metallic corrosion by using various preventive methods. Then this procedure for estimation is called the Uhlig method. In the late 1960's and the beginning of 1970's, several countries had started the committee for estimating the cost of corrosion and reported huge amount of money consumed for preventing metallic corrosion. The UK committee (Chairman: T. P. Hoar) published the report in 1971, which has been most frequently referred and called the Hoar report.[3] The committee comprised a large number of sub panels, which made inquiries and obtained confidential information from each industrial sector. Then the method to estimate the cost of corrosion by summarizing the cost in each industrial sector which comprises the national economy is called the Hoar method. In Japan, the committee started at 1975 and estimated the cost of corrosion in Japan[4] by using both of the Uhlig and Hoar method. The direct cost of corrosion in Japan in 1975 was estimated by the Uhlig method and found to be 2,500 billion yen which was equivalent to 9.2 billion US dollar on 1974 basis and about 1.8 % of the Gross National Product (GNP) at that time. On the other hand, the cost of corrosion estimated by the Hoar method was found to be 1,600 billion yen which was less than the cost estimated by the Uhlig method. Big difference in both estimations was attributed to a loss of counting in the estimation by the Hoar method. It was required to make more complete list of the industrial sectors which were affected seriously by corrosion.

1975, the National Bureau of Standards (NBS) and the Battelle Columbus Laboratories (BCL) conducted jointly

the study for estimating the cost of corrosion to the US.[5] The study used an Input/Output Model which was developed by BCL and manifested that the corrosion cost of the US was estimated to be $82 billion which was 4.9% of GNP of the same year. The Input/Output analysis could count the indirect cost in addition to the direct cost and provide a whole picture of the cost structure in the national economy. In 1995, the cost of corrosion in the US was updated[6] by using the same procedure as 1975 by a panel of Battelle scientists. They found that the total 1995 cost of metallic corrosion was $296 billion and occupied 4.2% of GNP which had been reduced from 4.9% of GNP at 1975. It is suggested that the reduction is caused by a broader application of corrosion-resistant materials, improvement in corrosion-preventive practice, and an investment in corrosion related research.

Since the first study on the cost of corrosion in Japan, almost two decades have been passed and industrial structures have been changed drastically. Industrial sectors which need corrosion technology have changed and have to be identified for the most effective way to save materials and energy, which also responds to the public concern about the environmental issues.

In this occasion, the National Research Institute for Metals (NRIM), Japan, has created a new project for the 21th Century which is called the Super Iron and Steel 21 (STX21). The STX21 aims to develop a new concept for creating super iron and steel materials which have two times higher strength and two times longer life. The two times longer life, that is, the two times higher corrosion resistance is the major target in the corrosion study. The STX21 responded to the proposal by the Japan Society of Corrosion Engineering (JSCE) for reevaluation of the cost of corrosion in Japan after two decades. The Committee on the Cost of Corrosion in Japan was organized in JSCE at April, 1999, and conducted the study with conjunction of the Japan Association of Corrosion Control (JACC). The program had continued two years from 1999 to 2000 and the final report was published at the end of March, 2001. Th main outcomes of the study are given in the following, but the details should be referred to the final report,[7]

2. Change in the industrial structure in Japan

In Figure 1, GNP and its growth rate since 1955 are shown with important events related to corrosion, that is, the first and second study on the cost of corrosion, the establishment of both Corrosion Societies (JSCE and JSCC), and publishing Journal of Corrosion Engineering.

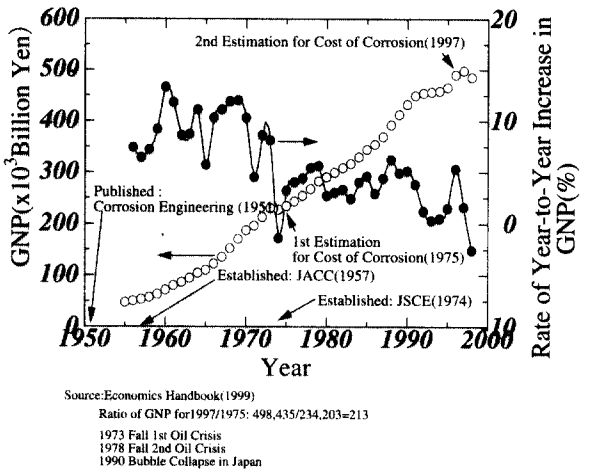

Fig. 1. GNP and its growth rate of Japan

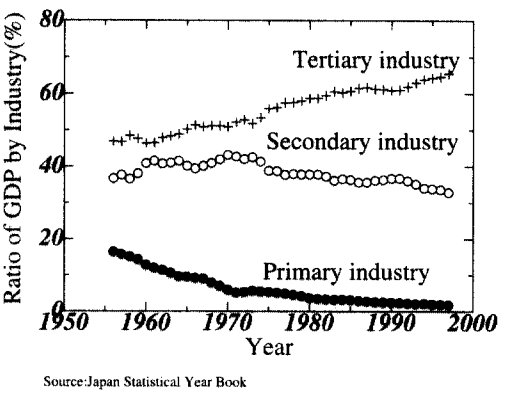

Fig. 2. Change in the industrial structure in Japan

The GNP value is shown at the constant current basis of 1990. Japanese economy made a rapid growth after the end of the Second World War and its growth process can be divided into three periods: the recovery period from ruins for 1945-1955, the rapid growth period during 1955 to 1972 and the relatively lower growth period from 1972 to the present time. Recent ten years in the 1990's, the Japanese economy struggles to restore the damages due to "bubbles" and shows a low growth rate as can be seen in Figure 1, but will be expected to rise with a new growth tide of IT related industries for the next decade. The first estimation of cost of corrosion was done just at the end of the rapid growth period and the second estimation after two decades is just at the end of the steady and a low growth rate economy period as indicated in Figure 1. Figure 2 shows that the relative proportion in the Gross Domestic Product (GDP) of the primary industry which is mainly agricultural and the secondary industry consisting of production industries, such as steel, chemical, machine, automobile and other important heavy industries,

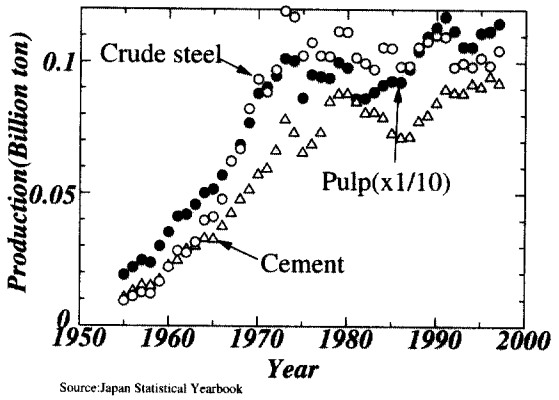

Fig. 3. Production of basic materials in Japan

decreases constantly with the increase in proportion of the tertiary industry. A similar trend can be observed for the other advanced industrial countries, but he change in Japan seems to be so fast. Another important change can be seen in the level of the basic materials production as seen in Figure 3. Production level of steel, pulp and cement which are basic materials for fabricating machines, constructing and building all other structures shows a rapid growth up to the mid 1970's, after which the production level showed almost saturation. Following this saturation, automobile and electronics industry made an important contribution to the growth of the national economy. In addition, the investment to the infrastructure continues the growth even after "bubbles" at 1991 and the maintenance industry for the infrastructure, the plants and machines which have been installed during the rapid growth periods, keeps growing. The maintenance and life extension of the infrastructures have became a big issue in Japanese society because publics are greatly concerned with saving materials and energy relating to environmental concerns, and corrosion and prevention technology are expected to expand in this area.

3. Cost of corrosion in japan

Three methods of 1) the Uhlig method, 2) the Hoar method, and 3) the Input/Output method
are used for estimation of the cost of corrosion in Japan. The results are briefly summarized in the following.

3.1 Cost of corrosion estimated by the uhlig method

In Table 1, the estimated cost of corrosion by the Uhlig method at 1997 is compared with the corresponding data reported for 1974. The total amount of the corrosion cost at 1997 was estimated to be 3,938 billion yen which is 1.54 times larger compared with 2,551 billion yen at 1974. The ratio to GNP at 1997 is 0.77% which decreases

Table 1. Cost of corrosion by the Uhlig method

Preventive measures for corrosion	Corrosion cost (1997) (Billion yen)	Percent in total Cost(%)	Corrosion cost (1974) (Billion yen)	Percent In total Cost(%)	Ratio Of 1997/ 1974
Painting	2299.46	58.4	1595.48	62.5	1.44
Surface finishing	1013.52	25.7	647.62	25.4	1.57
Corr.res.materials	443.24	11.3	238.82	9.4	1.86
Anti-corr.Oil	63.68	1.6	15.65	0.6	4.07
Inhibitor	44.90	1.1	16.10	0.6	2.79
Cathodic protection	21.68	0.6	15.75	0.6	1.38
R&D for corrosion	41.65	1.1	21.51	0.8	1.94
Corrosion inspection	9.56	0.2			
Total	3937.69	100	2550.93	100	1.54
%GNP	0.77		1.72		0.45

compared with 1.72% at 1974. The decrease in the GNP ratio after two decades can be attributed to the change in the industrial structure in Japan, that is, the decrease in the proportion of the secondary industry compared with the tertiary industry in the national economy as already discussed in the previous section. In addition, the development of the corrosion prevention technology in the all industry contributes surely to decrease in the corrosion cost in the national economy. Relatively larger increase in the cost of corrosion is observed for corrosion resistant materials, anti-corrosion oil and corrosion inhibitor as can be seen in Table 1, suggesting that these technologies are largely applied in the industry. Actually the amount of production of the corrosion resistant materials is found to increase largely during two decades with decreasing the cost per tonnage of the materials. The price down of the corrosion resistant materials seems to induce an expansion of the usage of the corrosion resistant materials to the wider fields, contributing to extend the corrosion failure life of various parts, machines and other structures. The reason for the large increase in the cost of anti-corrosion oil at 1997 is due to difference in the sampling method at 1974. It should be emphasized that almost a half of the corrosion cost is due to paint in both years of 1997 and 1974.

3.2 Cost of corrosion estimated by the hoar method

The cost of corrosion estimated by the Hoar method at 1997 and 1974 is shown in Table 2. The estimation was made by inquiries and visiting important factories by

Table 2. Cost of corrosion estimated by the Hoar method

Industrial sectors	Corrosion cost(1997) (Billion yen)	Corrosion cost(1947) (Billion yen)	Ratio of 1997/1947
Energy	456.8	59.8	7.64
Transportation	544.7	194.5	2.80
Chemical	1070.0	154.3	6.93
Mechanical	1561.5	427.8	3.65
Metallurgical	27.6	26.5	1.04
Construction	1597.6	175.2	9.12
Total	5258.2	1038.1	5.07
%GNP	1.02	0.70	1.46

the committee members. As can be seen in Table 2, the total cost by summing up the cost in each industrial sector is found to be 5258 billion yen at 1997 which increased very much compared with 1038 billion yen at 1974. It was pointed out that the estimation by the Hoar method at 1974 could not cover the concerned items extensively because of luck of data. In the contrary, the estimation at 1997 could be made extensively, so that the estimated cost at 1997 seems to increase compared with 1974. In addition, the cost estimated by the Hoar method includes the maintenance cost which was estimated in detail at 1997, contributing to the large increase in the 1997 survey. The increasing trend in the maintenance cost at 1997 was admitted typically for the chemical industry sector. Increase in the construction sector at 1997 is attributed again to the increase in the maintenance cost in addition to the detailed survey.

The cost of corrosion estimated by the Hoar method is found to be 5,258 billion yen(1.02%GNP), which is larger than 3,938 billion yen(0.77%GNP) estimated by the Uhlig method. In the estimation by the Uhlig method, the indirect cost is included in part, while much higher percentage of the indirect cost is included in the Hoar method. The higher cost by the Hoar methods again seems to reflect the increase in the indirect cost such as maintenance. It is required to make more precise estimation for the indirect cost. The total cost including the indirect and direct cost could be estimated if the following Input/Output method could be used.

3.3 Cost of corrosion estimated by the input/output method

The estimation of the corrosion cost by the Input/Output method using the Input-Output table has been done at first by NBS/BCL in 1978, and the total cost of corrosion including the direct and indirect cost in the US was estimated to be 3-4% of GNP. In our investigation at 1997,

Table 3. Cost of corrosion at 1997 estimated by the Input/Output method

	Corrosion cost Estimated by the In/Out method (Billion yen)	Direct corrosion cost estimated by the Uhlig method (Billion yen)	Corrosion cost estimated by the Uhlig method (Billion yen)
Total cost	9694.72	2418.50	3937.69
%GNP	1.88	0.47	0.77

the methodology of the Input/Output method was studied and a preliminary application of the Input/Output method was made for the estimation of the total cost of corrosion in Japan.

The Input/Output table consisting of 32 x 32 items was used for the estimation, in which the direct cost of corrosion obtained in the Uhlig method was put in the concerned items in the table and the change in the total output was calculated. The difference in the output when the direct cost is subtracted from the concerned items yields the cost of corrosion including the direct and indirect cost. The result of the preliminary estimation using the Input/Output method based on the data by the Uhlig method is shown in Table 3. The direct cost of corrosion in the 3rd column can be deduced from the cost of corrosion in the 4th column which was estimated by the Uhlig method. The total cost in the 2nd column was calculated by putting the effect of the direct cost into the concerned items in the Input-Output table. It can be seen that the direct cost of 2,419 billion yen affects to the output, resulting in a 4 times larger cost of 9,695 billion yen. In the detailed Input/Output analysis done by NBS/BCL, the capital investment ,or the stocks and their life cycle cost are included in the Input/Output analysis. The total cost, thus obtained, reaches to a huge amount of 3-4 % of GNP. In our case, also much higher cost than 9,695 billion yen(1.88% of GNP) which was estimated by this preliminary analysis will be expected if the detailed Input/Output analysis could be made.

3.4 Cost of corrosion in the national economy in Japan

The cost of corrosion estimated by three methods is compared with the gross national product (GNP) of Japan in Table 4. The second line in the table is GNP for 1997 and 1974 at the 1990 base constant price. During 22 years, the national economy of Japan expands 3.47 times as shown in the last column, while the cost of corrosion by the Uhlig method increases 1.54 times. This fact suggests that the industrial structure shifted from the secondary industry for which the cost survey is executed mainly, to the tertiary industry and maintenance oriented structure. It has to be emphasized that the cost of corrosion still

Table 4. Cost of corrosion in the national economy of Japan

	1997 (Billion yen)	1974 (Billion yen)	Ratio of 1997/1974
GNP (1990 base constant price)	514343	148170	3.47
Corrosion cost (Uhlig method)	3937.69	2550.93	1.54
%GNP (1990 base constant price)	0.77	1.72	0.45
Corrosion cost (Hoar method)	5258.2	1038.1	5.07
%GNP (1990 base constant price)	1.02	0.70	1.46
Corrosion cost (I/O method)	9694.72		
%GNP (1990 base constant price)	1.88		

occupies a large portion in the national economy. It could be concluded that a conservative estimation for the cost of corrosion is in the range between 0.77% to 1.02% of GNP at 1997, and if the indirect cost could be counted properly, the range might be in 3-4% of GNP.

3.5 Proposal and strategy for improving the cost of corrosion

In the report, the future development of the corrosion engineering and science was discussed, responding to the change in the industrial structure which is manifested in the study. Maintenance technology for the infrastructure, the role of the corrosion prevention technology in the energy conservation and environment oriented society, the strategy towards the minimum corrosion cost, education by using the information technology, and organizing the corrosion experts are discussed in the report.

3.6 Members of committee on the cost of corrosion in Japan

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The symbol of "*" indicates the chairman of SC. Affiliation at the end of March, 2001 was shown.

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