Production and Technology of Iron and Steel in Japan during 2009

The Technical Society, the Iron and Steel Institute of Japan

1. Overview of the Japanese Iron and Steel Industry

In the first half of 2009, the Japanese economy experienced unprecedented difficulties resulting from the global financial crisis which began in the fall of 2008. However, beginning in the second half, the effects of government economic measures were felt, and the economy is now continuing to emerge from the worst period of the downturn. It was truly a year of recovery from crisis. Nevertheless, the yen remains high, deflationary tendencies are increasing, and the employment environment and other conditions are continuing to deteriorate, raising fears of a double-dip recession.

The Cabinet’s monthly economic report for January 2010 described economic conditions in Japan by saying that “The economy has rallied, but the recovery lacks self-sustainability. Moreover, as before, conditions remain extremely difficult, including the high level of unemployment”. The report goes on to say that, “Regarding the outlook for the future, although a difficult employment environment will continue, against the background of improvement in the economies of other countries and the effects of emergency economic measures, the improving tendency in the business climate can be expected to continue. On the other hand, it is necessary to note that the risk of downward pressure on the economy also exists, as seen in concerns about further deterioration in the employment environment and a possible downturn in the overseas business climate, the effects of deflation, and the like”.

The “Economic Review of FY 2010 and Basic Policy on Economic and Fiscal Management” adopted by a Cabinet resolution in January 2010 presents the following outlook: “The real growth rate of Japan’s gross domestic product (GDP) in fiscal 2009 will improve from the previous year because the takeoff point for growth was extremely low. However, growth is still expected to be limited to around minus 2.6%. Furthermore, the nominal growth rate, which is closer to the people’s real feeling of the economy, is predicted to decrease rapidly for the second consecutive year, at approximately minus 4.3%” (Fig. 1).

The Japanese steel industry also experienced a large drop in demand in the first half of 2009. In the second half, the effects of economic stimulus measures in various countries became apparent. Exports to China, Southeast Asia, etc. increased more than expected, supporting a gradual recovery in production conditions. However, because steel demand related to the construction market and equipment investment remains stagnant, the future outlook continues to be unclear.

In this environment, it is important that the steel industry continues to respond to global environmental problems, which is an area where it has committed great efforts to date, and responds appropriately to the increasing oligopolization of resource supplies in world markets. In both areas, it is necessary to implement strategies that are consistent with sure economic growth in cooperation with the government.

The following reviews iron and steel production and technology during 2009.

1.1. World Steel Industry

On January 22, 2010, the World Steel Association (WSA) announced that world crude steel production in 2009 totaled 1 219.71 million tons. The breakdown by country is shown in Table 1. Based on this information, the following features can be noted:

1. Recent world crude steel production peaked in 2007 at 1 345.82 million tons, and then declined by 1.4% in 2008, falling to 1 326.45 million tons. Continuing this trend in 2009, crude steel production recorded an 8.0% decrease last year.
2. In 2009, crude steel production declined in almost all main steel-producing countries due to the deterioration in world economic conditions. However, production increased in the No. 1 ranking country, China, and the No. 5 country, India. In particular, China’s crude steel production grew by 13.5% from the previous year. As a result, Chinese crude steel production for 2009, at 567.84 million tons, accounted for approximately 47% of total world crude steel production.
3. In both Japan and the main EU countries, the decrease from the previous year exceeded 20% in 2009. An even larger decrease was seen in the United States, where crude steel production fell by 36.4% from the
previous year. On the other hand, the decrease in Russia was only 12.5%, making it the world’s No. 3 ranking steel producing country. Similarly, the decrease in South Korea was also limited to 9.4%.

The following describes overview of the conditions in China and India, which recorded increases from the previous year. In China, production of finished steel products showed a temporary decreasing tendency due to the effects of the financial crisis of 2008. However, because the government immediately implemented publicly-funded economic stimulus measures, production for the year showed large growth, supported by firm growth in the automotive industry driven by the stimulus measures, and increased demand for infrastructure construction for the Shanghai Expo opening in 2010 as well as other projects. In particular, Chinese automobile production continued to set new records, as unit production in 2009 reached 13.79 million, for a 48% increase from 2008. This made China the world’s largest automobile-producing country. India also extricated itself from the effects of the 2008 financial crisis and has now resumed high economic growth, with a real GDP growth rate that is returning to its pre-financial crisis level.

In the main demand sectors for iron and steel, in construction, residential development is accelerating in response to housing shortages in urban areas, and government-led construction of infrastructure such as roads, and ports and harbors, is positive. In 2008, production of 4-wheeled vehicles was on the 2.32 million unit level, and India became the world’s eighth largest producer of automobiles. Production of steel products also increased in 2009, supported by increased demand in these sectors.

In contrast to this, although Europe and the United States entered the recovery process from the economic downturn which began in the second half of 2008, time will still be required before these economies return to their past levels (Fig. 2).

Due to these trends in the respective countries, the world crude steel capacity utilization ratio fell from a level exceeding 90% prior to the financial crisis which began in the fall of 2008 to approximately 58% at the end of that year, but had returned to a level above 70% at the end of 2009 (Fig. 3).

1.2. Japanese Industry

The Japanese economy was severely impacted by the financial crisis which began in the fall of 2008, but has finally shown a tone of gradual recovery since the second half of 2009. The following reviews the conditions in the Japanese steel industry in 2009.

1.2.1. Trends in Steel-consuming Industries

In the field of civil construction, orders received increased. In 2008, construction orders reached 13.79 million, for a 48% increase from 2008. This made China the world’s largest automobile-producing country. India also extricated itself from the effects of the 2008 financial crisis and has now resumed high economic growth, with a real GDP growth rate that is returning to its pre-financial crisis level. In the main demand sectors for iron and steel, in construction, residential development is accelerating in response to housing shortages in urban areas, and government-led construction of infrastructure such as roads, and ports and harbors, is positive. In 2008, production of 4-wheeled vehicles was on the 2.32 million unit level, and India became the world’s eighth largest producer of automobiles. Production of steel products also increased in 2009, supported by increased demand in these sectors.

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mained stagnant, as in recent years, not only in public works projects, but also in private sector civil construction. In building construction, the number of new housing starts continued to show minus results against the same month in 2008 throughout the year, with the trend in housing starts falling below 800,000 units on an annual base, in contrast to 1.04 million in fiscal 2008. In particular, building construction for mining and manufacturing industries and the commerce service industries continued to show large decreases.

In the automobile sector, in the first half, demand fell sharply from the previous year, but in the second half, production showed an increasing tendency as a result of the eco-car tax reduction and other factors. Domestic sales for 2009 were approximately 4.43 million units. On the other hand, exports of automobiles to the North American and European markets remained slow, decreasing from approximately 6.73 million in fiscal 2008 to around 3.62 million in FY 2009. Total automobile production declined to approximately 7.93 million units, falling below the 8 million level. In the industrial machinery sector, the trend of large decreases continued throughout the year in both the domestic and export markets. By application, in addition to large decreases in civil and building construction machinery, transportation equipment, and metal processing, machine tools, chemical industry equipment, which had shown a comparatively high level in the first half, fell below the previous year for the year as a whole. Electrical machinery also showed a declining tendency throughout the year in both the heavy electric and consumer electric areas. In shipbuilding, new ship orders, which had exceeded 20 million gross tons in FY 2008, had slackened to the level of 1.5 million gross tons/month at year-end, while work on hand at year-end also decreased from the level of approximately 64 million gross tons for FY 2008 to approximately 56 million gross tons for FY 2009.

1.2.2. Orders for Steel Products

Regarding orders for steel products, due to the above-mentioned trends in steel-consuming industries, total domestic demand for mild steel was on the level of approximately 3.5 million tons/month at the end of 2009, in spite of a gradual recovery, and was far from the level of more than 4.5 million tons before the financial crisis. Looking at the breakdown of orders, construction-related products remained on a low level, but manufacturing industries showed signs of achieving a plus result in comparison with the previous year. On the other hand, exports of mild steel continued in a plus condition in comparison with 2008, at approximately 2 million tons/month at year-end. Like mild steel, special steel continued to show a decreasing tendency in total domestic demand, while exports showed a large increase.

1.2.3. Iron and Steel Production

As announced by the Japan Iron and Steel Federation (JISF) on January 20, 2010, Japan’s crude steel production for 2009 totaled 87.53 million tons, which was a decrease of 26.3% from 2008, and was the lowest level since the 82.17 million tons of 1969. By steel type, production of mild steel was 71.41 million tons (−22.9% from 2008), while production of special steel was 16.12 million tons (−38.4% from 2008). Looking at the trend in production on a monthly basis (Fig. 4), in the first half of 2008, that is, before the financial crisis, the level of production exceeded approximately 10 million tons/month, but at the end of 2008, this had fallen 7.4 million tons/month. Subsequently, with the gradual recovery in 2009, production returned to the level of approximately 9 million tons/month at the end of 2009. Comparing production by the blast furnace route and electric arc furnace route, blast furnace production (pig iron) has returned to approximately 91% of its peak in 2008, while electric arc furnace production has been limited to approximately 62% of its peak. One factor in this is thought to be the effect of continuing stagnation in the civil building construction markets (Fig. 5). The crude steel production figure for the 4th quarter published by the Ministry of Economy, Trade and Industry (METI) was 26.72 million tons, and thus exceeded an annual rate of 100 million tons for the second consecutive quarter.
1.2.4. Trends in Raw Materials for Iron and Steel

The main raw materials for iron and steel are iron ore and coking coal. From mid-year, China's imports of both of these materials increased more than had been expected at the start of the year. As a result, maritime trade of iron ore reportedly set a new record exceeding 850 million tons. China now shows a strong tendency to select high grade imported ore and first class strongly coking coal from Australia and other countries, rather than low grade domestic ore and domestic coal. By year-end, with economic recovery underway in Japan and Europe, it was pointed out that raw material supplies would be tight.

The prices of iron ore and coking coal had continued to rise sharply every year since 2004, when world crude steel production exceeded 1 billion tons. However, in 2009, the annual contract prices of both decreased due to the decline in crude steel production caused by the deterioration in economic conditions. For example, according to one report, fine ore (price of Australian hematite ore to Japanese customers) decreased by approximately 30% from the previous year, and coking coal (price of Australian coal to Japanese customers) decreased by approximately 60% over the same period.

However, with the increase in crude steel production accompanying growth of real demand driven by economic growth in the Asian region, centering on China, and the recovery in economic conditions beginning in the second half of 2009, the prices of crude oil and scrap have already resumed their rapid increases, causing concern that the prices of iron and steel raw materials will also rise sharply once again.

In these conditions, the press has reported plans for a merger by large producers of iron ore, Rio Tinto and BHP Billiton, which would further the already-substantial oligopolization of raw material supplies (70% of iron ore is supplied by Rio Tinto, BHP Billiton (both Australian companies) and Vale (Companhia Vale do Rio Doce; Brazil), and Japan depends on Australia for 60% of its supply). This move has heightened concern regarding further oligopolization in the raw materials industry.

1.2.5. Trends in Steel Imports and Exports

Actual imports of iron and steel in 2009 totaled 4.61 million tons, which was a decline of approximately 42% from the 7.97 million tons in 2008. Imports of mild steel products decreased continuously from 3.71 million tons in 2008 to 2.49 million tons in 2009. By product type, in addition to wide hot-rolled coils, which are the largest item, imports of wide cold-rolled coils and Zn-coated steel sheets also decreased. By country, imports from the main countries of South Korea, Taiwan, and China all decreased. Imports of special steel products also decreased from 200 000 tons in 2008 to 180 000 tons in 2009.

Actual steel exports totaled 34.44 million tons, for a decrease of approximately 10% from 38.13 million tons in 2008. As the breakdown, exports of mild steel products decreased by approximately 15%, from 26.43 million tons in 2008 to 22.34 million tons in 2009. In comparison with the start of the year, exports showed a recovering tone for the year, centering on China and Asia. By product, exports of
Zn-coated steel sheets were sluggish, but exports of wide hot-rolled coils and plates increased. Exports of special steel decreased from 5.91 million in 2008 to 4.82 million in 2009 (Fig. 6).

Crude steel production in calendar year 2009 fell below the 90 million tons level for the first time in 38 years, since 1971, when crude steel production was 88.56 million tons. However, looking at results on a monthly basis, a gradual recovering trend is apparent, and signs of improvement in corporate profitability can also be seen. As factors in this improvement, in contrast to domestic demand, which remains sluggish, increased exports to China and East Asia are major factors. This suggests that international strategy will become increasingly important in the future.

2. Technology and Equipment

2.1. Technical Environment of Japanese Steel Industry

From 2008 into 2009, demand for steel decreased rapidly due to the stagnation in the real economy caused by the financial crisis. As a result, a response to a rapid decrease in production was unavoidable in the first half of 2009. Then, from mid-year, it was necessary to respond to the recovering tone of the economy. From the viewpoint of operating technology, technologies which enable large increases and decreases in production within a short period were required. In particular, in response to the production decreases at the start of the year, the individual relining schedules of blast furnaces were adjusted. Companies also implemented temporary shutdowns (banking), with which they had little experience in the past.

With regard to equipment technology, from the viewpoint of capital investment, published information from each steel company indicates that companies attempted to partially reduce investment, reflecting the economic circumstances from the beginning of the year, but carefully selected investments in blast furnace relining, investments related to the environment, and investments in measures to improve quality.

In the area of technical development, 2009 was the second fiscal year in the “COURSE 50” project, which is a large-scale national project in the field of iron and steel technology that began in FY 2008 with the aim of drastically reducing CO2. Also in FY 2009, “Development of Innovative Steelmaking Process for Strengthening Resource Response Capabilities” (METI) was adopted as a new project. (For details, see Sec. 3.)

Regarding the Japanese government’s science and technology policies, the Fourth Science and Technology Basic Plan, which is scheduled to begin in FY 2011, is now under study, and in 2009, the government announced a program called “Green Innovation” for global warming countermeasures (“Green Policy Innovation”; October 8, 2009, Council for Science and Technology Policy). In response to this policy, deeper discussions are now underway in forums such as the “Council on Material Strategy” (council for the study of technical strategies in the field of materials by 12 materials-related scientific societies), which will make recommendations on the importance of material technology fields, including steel, for Japan and technical issues which should be addressed through industry-academia-government cooperation.

The following presents an overview of the main trends in technology by field.

2.2. Ironmaking

Pig iron production in 2009 was 66.94 million tons, or a decrease of 22% in comparison with 86.17 million tons in 2008. This decline was attributable to the large-scale reductions in production that began around the end of 2008. Productivity decreased to 1.73 ton/m3-d from 2.01 ton/m3-d in 2008.

Trends in blast furnace relining, shutdown, banking, etc. of individual blast furnaces are shown in Table 2. At the

<table>
<thead>
<tr>
<th>Date</th>
<th>Remarks</th>
<th>Blow-off blast furnaces</th>
<th>Blow-in blast furnaces</th>
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<tr>
<td>30-Jan</td>
<td>•Banking</td>
<td>JFE Steel Kawasaki No. 3</td>
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<td></td>
<td>•Relining from October</td>
<td>4359 (m³)</td>
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<td>7-Feb</td>
<td>•Relining after banking</td>
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<td></td>
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<td>4884 (m³)</td>
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<tr>
<td>28-Feb</td>
<td>•Banking</td>
<td>Nippon Steel Kimitsu No.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3273 (m³)</td>
<td></td>
</tr>
<tr>
<td>28-Feb</td>
<td>•Banking</td>
<td>JFE Steel Fukuyama No. 3</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>3223 (m³)</td>
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<tr>
<td>11-Jul</td>
<td>•10,001 days operation</td>
<td>Sumitomo metal industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(world record)</td>
<td>Wakayama No.4</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>2700 (m³)</td>
<td></td>
</tr>
<tr>
<td>10-Jul</td>
<td>•Change of furnace</td>
<td>Sumitomo metal industry</td>
<td></td>
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<tr>
<td></td>
<td>•Enlargement of inner volume</td>
<td>Wakayama No.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>from 2700 (m³) to 1700 (m³)</td>
<td>1700 (m³)</td>
<td></td>
</tr>
<tr>
<td>2-Aug</td>
<td>•Relining period 68 days</td>
<td>Nippon Steel Oita No. 1</td>
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<tr>
<td></td>
<td>•Enlargement of inner volume</td>
<td>5775 (m³)</td>
<td></td>
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<td></td>
<td>from 4884 (m³) to 5775 (m³)</td>
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</tr>
<tr>
<td>4-Out</td>
<td>•Re-start after banking</td>
<td>Nippon Steel Kimitsu No.2</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>3273 (m³)</td>
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Table 2. Relining of blast furnace in Japan.

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end of 2009, 26 blast furnaces were in operation, or a decrease of 2 BFs from the 28 in operation at the end of 2008. The number of blast furnaces with a blast furnace inner volume of more than 5000 m$^3$ increased by one, to 12 blast furnaces.

The pulverized coal injection ratio (PCI ratio) of blast furnaces in 2009 was seriously affected by the large reductions in production. As shown in Fig. 7, the PCI ratio decreased greatly from that in the previous year, averaging 107 kg/ton in 2009, while the coke ratio increased greatly, to an average of 397 kg/ton.

In response to sharp reductions in production from around November 2008, banking was carried out at Nippon Steel Corporation, Kimitsu Works, No. 2 BF, JFE Steel Corporation, West Japan Works (Fukuyama District) No. 3 BF was shut down, and the schedule for blowing-down of two blast furnaces was moved up (JFE Steel, West Japan Works (Kurashiki District) No. 3 BF and Nippon Steel, Oita Works No. 1 BF).

Subsequently, Nippon Steel’s Kimitsu Works No. 2 BF was put back into operation in October in line with the recovery in production.

After the schedule for the blowing-down of Nippon Steel’s Oita No. 1 BF was moved up, relining was carried out in a short period of 68 d, and the blast furnace was blown in again in August with its inner volume increased from the previous 4884 to 5775 m$^3$. As a result, Oita Works now has two blast furnaces with the same inner volume, marking the start of the “world’s largest-scale twin blast furnace system”. A state-of-the-art blast furnace operation control system (“3D-VENUS”, enabling monitoring of the condition of the blast furnace in 3 dimensions and real time; introduced simultaneously at No. 1 BF and No. 2 BF during the relining) and technology for prolonging the furnace life were introduced. A broad reduction in the relining period was achieved by adoption of various new construction methods, including “unitary removal” of the furnace bottom in the normal condition, that is, with the salamander left in place, and modular “advance cast house fitting”, among others.

JFE Steel’s West Japan Works Kurashiki No. 3 BF was shut down and relining began in October. This blast furnace was blown in again in February 2010. The inner volume was increased from 4359 to 5055 m$^3$, and a number of JFE Steel’s blast furnace relining technologies were adopted (adoption of high quality refractory against erosion, strengthening of the cooling equipment of the furnace refractory, proprietary 3 parallel top bunkers type bell-less top).

In July, Sumitomo Metal Industries, Ltd., Wakayama Steel Works No. 4 BF (inner volume: 2700 m$^3$) was blown down, and a new No. 1 BF with an inner volume of 3700 m$^3$ was blown in. At the same works, No. 4 BF established a new world’s record for blast furnace life, at 10001 d (27 years and 4 months) thanks to technologies for prolonging the furnace life, such as diagnosis of furnace life for prolonging furnace life, furnace repairs, etc. The new No. 1 BF has a pig iron capacity of 7500 tons/d. In this BF, the same high productivity/techniques for low reducing agent ratio operation as those at Sumitomo’s Kashima Steel Works No. 1 BF and No. 3 BF were adopted, and the techniques for prolonging furnace life used in the recently blown-down Wakayama No. 4 BF were also incorporated, aiming at a furnace life of more than 25 years. Because the new BF is a large-scale plant, Wakayama’s crude steel production capacity is now 4.5 million tons/year.

Regarding coke ovens, in addition to reductions in the working ratio (production ratio) corresponding to the large reductions in production at blast furnaces, hot banking was also carried out at some coke oven batteries. In new construction, at Sumitomo Metals’ Wakayama Steel Works, new No. 1 coke oven batteries (130 ovens in total), which prioritizes environmental measures, was constructed and put into operation, and No. 6 coke oven batteries were shut down. Simultaneously with this, one new unit of environment-friendly type coke dry quenching (CDQ) equipment was also constructed. In technology, Nippon Steel developed and introduced a technique of diagnosis and repair for coke oven batteries at its Yawata, Muroran, Kimitsu, Nagoya, and Oita Works. This technology comprises equipment for the diagnosis and repair of damage inside coke ovens under conditions including high temperature (1000°C), constricted space (width: 0.45 m), and large area (height: 6 m, depth: 16 m). In addition to dramatically improving efficiency, accuracy, and reliability in comparison with conventional repair work, this technology is also contributing to elucidation of the mechanism of coke oven wall deterioration. This technology was awarded the 55th Okochi Prize, “Okochi Memorial Production Prize”.

Regarding sintering machines, JFE Steel East Japan Works (Keihin District) developed and introduced techniques for hydrogen fuel gas injection into the sintered machine. With this technology, a hydrogen fuel gas (city gas) is injected onto the surface of the sinter material as a partial substitute for coke breeze in the sinter bed. Energy efficiency is greatly improved by maintaining the optimum sintering reaction temperature for an extended period of time, thereby reducing CO2 emissions by approximately 60,000 tons/year.

2.3. Steelmaking

The condition of steelmaking operations in 2009 is shown in Table 3 (results of LD converter operation) and Table 4 (results of electric arc furnace operation). In LD converter operation, the production index decreased greatly. As with LD converter operation, the results of electric arc furnace operation also showed a large decrease in produc-
tion, centering on mild steel, and in the product mix, the ratio of alloyed steels decreased. Because the secondary refining ratio of electric arc furnace steel and the vacuum degassing ratio of LD converter steel were both high, the orientation toward high grade products seems to be firmly established.

The ratio of continuous casting steel in semi-final steel for rolling is shown in Fig. 8. For mild steel, the ratio continued to be 99.8%, while the ratio for special steel increased to 97.0%.

2.4. Plates, Pipes, and Shape Products

Steel Bar Equipment: At Sumitomo Metal Industries, Kokura Steel Works, the 3-roll final rolling mill at the Bar Mill was modernized to state-of-the-art equipment, and the rolling size was increased to 120 mm in diameter. In comparison with the existing equipment, the revamped mill features high rigidity, enabling use of higher rolling loads. As a result, the dimensional precision of large-sized bars is improved, and size-free production and concentration of rolling schedules have been realized, making it possible to increase the plant’s monthly production capacity by approximately 10%. At Daiwa Steel’s Mizushima Works, in addition to eddy current test equipment, improved dimensional precision and external appearance/surface quality of bar products were realized by combined inspection by surface inspection equipment using image processing technology in the final rolling process, and installation of optical profilers in the rolling and finishing processes.

Wire rod equipment: At JFE Bars & Shapes Corporation, Sendai Works, a number of improvements were implemented in the production line, including (1) conversion of the heating furnace fuel to LNG and modernization to a heating furnace with regenerative burners, (2) an increase in billet dimensions to 160 mm in square by adding two V-H type roughing stands, (3) installation of a thermal insulation table to minimize the fall and irregularity of temperature in rolled materials, and (4) stabilization of intermediate and final rolling by adding two 2-stand mini-block-type intermediate rolling mills. The revamped facility is operating smoothly.

Pipe Equipment: Sumitomo Metals’ Steel Tube Works (Amagasaki) constructed a new dedicated plant for 18% Cr and 25% Cr stainless boiler tubes which were developed for use in Ultra Super Critical power generation. At this production line, high efficiency, high accuracy heat treatment equipment and cold forming technology for high working ratios were introduced and are performing smoothly in mass production. At Nippon Steel’s Hikari Pipe and Tube Division, the small diameter, hot-rolled electric-resistance welding pipe line, where the hot stretch reducer (SR) process is applied, was modernized by adding 7 twist SR stands before the existing stands, thereby expanding the maximum wall thickness to 9.0 mm and the ratio of thickness to outer diameter to 33%. As a result, both inside dimensional accuracy and performance have improved.

Pipe Production Technology: Sumitomo Metals and Sumitomo Pipe & Tube Corporation developed a sequential forming method in which quenching (hardening) is performed simultaneously with 3-dimensional forming of pipes to arbitrary shapes. The development of this technology made it possible to achieve ultra-high strength (1470 MPa class) in structural materials with closed sections which are formed to arbitrary shapes.
2.5. Steel Sheets

Nippon Metal Industry Co., Ltd. (Nikkinko) carried out revamping work on the hot rolling line at its Kinuura Works with the aim of improving productivity/yield and quality, and began full-scale operation in September. The concrete contents of this modernization project were as follows: (1) Hydraulic actuators were introduced in the rolling roll holding section of the pair cross-type Steckel mill, resulting in improved roll cross setting accuracy and improved rolling stability by absorbing the impact of the rolling material at roll bite. (2) The crop shear before the finishing mill was changed from a conventional single straight blade type to a type using two bow-shaped curved blades with different orientations, achieving improved roll bite at the mill. (3) In the surface inspection section, an inspection device equipped with CCD cameras and an image processing function was installed before the coiler in order to improve quality control by performing full length inspection of both sides of 100% of products and preventing mass occurrence of nonconforming products.

JFE Steel decided to construct a new No. 5 continuous annealing line (No. 5 CAL) at West Japan Works (Fukuyama) to respond to higher quality in high grade steel sheets for containers and improve production efficiency. The line is scheduled to begin operation in the second half of 2010, and will contribute to improving competitiveness in the field of steel sheets for containers and reducing CO₂ emissions by improving energy efficiency. Accompanying the startup of the new line, JFE plans to shut down No. 1 CAL.

Sumitomo Metals applied a fine grain stainless steel spring material, which was originally developed for application to automobile gaskets, to metal diaphragms used in hydrogen compressors for injection of hydrogen into feed water in nuclear power plants as a countermeasure for fatigue cracking of these parts, thereby realizing a large improvement in the life of the diaphragm from a maximum of two months in the past to more than one year with the new material.

Nisshin Steel Co., Ltd. completed the construction of a new cold rolling mill for stainless foil at its Ichikawa Works in December. State-of-the-art technology was introduced in this mill, making it possible to respond to needs for high quality and high accuracy, including high foil thickness accuracy of below ± 1 μm, stable shape in wide products, etc.

2.6. Measurement, Systems, and Analysis

Sumitomo Metals’ Kashima Steel Works constructed No. 2 Resource Circulation Furnace, which is a facility of the world’s largest scale, with an annual steel dust treatment capacity of 400 000 tons. This furnace is a cylindrical rotary kiln-type furnace which separates and recovers iron and zinc using the carbon contained in the dust, and has been named the “Perfect Recycling System” because all recovered substances are utilized. The furnace has a direct-reduced iron production capacity of 220 000 tons/year and a zinc recovery capacity of 18 000 tons/year.

The same type of equipment was also installed at Osaka Steel Co., Ltd., West Japan Works (treatment capacity: 6 000 tons/year). On the other hand, Daiwa Steel Corporation, Mizushima Works installed smelting reduction equipment (treatment capacity: 120 000 tons/year) using an electric arc furnace, and began treatment of steel dust.

Nippon Steel established a system for recycling refractories in the iron and steel manufacturing process. Conventionally, the addition rate of spent refractories to new refractories had been approximately 10–20%. However, Nippon Steel established a recycling system which improves this to a maximum of 80% by developing a mass addition technique which considers expansion of applications focusing on the grade of the spent refractories and the particle size distribution of crushed raw materials obtained from spent refractories, and developing efficient recycling raw material regeneration equipment and recycling refractory production equipment, etc.

3. Environment

3.1. Government Efforts

The 15th Session of the Conference of Parties of the United Nations Framework Convention on Climate Change (COP 15) was held in Copenhagen, Denmark in December 2009. The results (Copenhagen Accord) of discussions over a 13 d period, after the schedule was delayed by 1 d, can be summarized as follows.

1) Emissions Targets and Mitigation Actions

(1) Interim Targets: Emissions targets for 2020 for the advanced nations (Annex I parties) and mitigation targets for the developing nations (non-Annex I parties) will be submitted to the Secretariat.

(2) Long Term Goal: As a guideline for long-term emissions reduction, reductions should be implemented “so as to hold the increase in global temperature to
below two degrees Celsius”. Although a one-half reduction by 2050 was not incorporated, “deep cuts in global emissions” are considered necessary based on the science, as documented by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.

2) Funding

(1) Short-term Funding: The “collective commitment of the developed countries is to provide new and additional resources approaching USD 30 billion for the period 2010–2012”.

(2) Long-term Funding: The developed countries “commit to a goal of mobilizing jointly USD 100 billion a year by 2020”.

3.2. Efforts of Japanese Steel Industry

According to the statistics of the Japan Iron and Steel Federation (source: November 2009, “Measures Against Global Warming by the Steel Industry in Japan”; total of actual values of companies participating in the Voluntary Action Plan), Japan’s crude steel production in FY 2008 was 101 334 thousand tons, or a decrease of 3.2% from FY 1990. As a result of positive implementation of energy saving measures, energy consumption in FY 2008 was 2 159 PJ, or a decrease of 11.5% in comparison with FY 1990. Furthermore, energy-originated CO2 emissions were 176.3 million tons-CO2 in FY 2008, or a decrease of 12.1% from FY 1990.

In November 2009, the Japan Iron and Steel Federation published a statement of the industry’s thinking on efforts, the directions aimed by the Japanese steel industry, and the concrete contents of efforts in “Measures Against Global Warming by the Steel Industry in Japan” (in Japanese), as presented in outline in the following:

1) Thinking on Efforts by Japanese Steel Industry to Address the Global Warming Issue

“The Japanese steel industry will endeavor to further improve its energy efficiency, which is currently on the world’s highest level. With Japan continuing to serve as a base for production and development, the industry will present to the world eco-processes, eco-products, and eco-solutions, while strengthening industrial cooperation with manufacturing industries, and thereby will contribute to the growth of the Japanese economy and creation of employment, while also grappling with measures for controlling global warming”.

2) Directions Aimed by Japanese Steel Industry

(1) Present to Mid-term: Eco-processes, eco-products, and eco-solutions

(2) Long-term: Development of innovative steel manufacturing processes

3) Concrete Content of Efforts

(1) Eco-processes: The Japanese steel industry will further improve energy efficiency in its production processes, which is already on the world’s highest level, by introducing advanced technologies to the greatest extent possible. (Target for 2020: CO2 reduction of approximately 5 million tons, preconditioned on crude steel production of 119.66 million tons)

(2) Eco-products: Development of high performance steel products, which are indispensable for building a low carbon society, and contribution to CO2 reduction in the stage where these are used in society as final products by supplying these products in the Japanese and international markets.

(3) Eco-solutions: Contribution to CO2 reduction at the global scale by transfer and dissemination of the outstanding energy saving technologies and equipment of the Japanese steel industry to the global steel industry. (The CO2 reduction potential of this technology/equipment is 340 million tons-CO2 worldwide, corresponding to approximately 25% of Japan’s total CO2 emissions.)

(4) Development of Innovative Steelmaking Technology: For the mid- to long-term period of 2030–2050, the Japanese steel industry is promoting a project for technical development of an innovative steelmaking process, COURSE50 (CO2 Ultimate Reduction in Steelmaking process by innovative technology for cool Earth 50; reduction of iron ore using hydrogen and separation/recovery of CO2 from blast furnace gas).

3.3. Efforts by Individual Steel Companies

Technical development in the above-mentioned COURSE50 project began in FY 2008. Last year, in 2009, the construction of a pilot plant with a scale of 30 tons/d for separation and collection of CO2 began on a site located in Nippon Steel’s Kimitsu Works.

In order to realize innovative energy saving in the ironmaking process and strengthen the industry’s use flexibility for low grade raw materials for steel manufacturing, in 2009, Japan’s New Energy and Industrial Technology Development Organization (NEDO) invited participation in a new research and development project, “Technical Development of Innovative Pig Ironmaking Process Technology for Strengthening of Resource Flexibility”. In response, four steel makers (JFE Steel, Nippon Steel, Kobe Steel, Ltd., and Sumitomo Metal) submitted proposals, and these four companies were selected as scheduled grant recipients in June.

In order to realize this project, JFE Steel has decided to construct a pilot plant for production of an innovative lump material, “Ferro-coke”, at its East Japan Works (Keihin District) at a cost of approximately ¥ 3.5 billion.

JFE Steel developed a new technology for the sintering machine, “Super-SINTER (Secondary-fuel Injection Technology for Energy Reduction)”, and has begun commercial operation. According to a trial calculation, this technology makes it possible to reduce CO2 emissions by a maximum of approximately 60 000 tons/year.

In June, Sumitomo Metals and Kashima Senko Co., Ltd. began commercial operation of No. 2 rotary kiln for dust recycling (No. 2 Resource Circulation furnace; in addition to “resource circulation”, R and C are also the initial letters of “Recycling and Creating”). As advantages of this process, recovery of iron by the RC furnace requires less energy consumption than production from iron ore, and the
recovered zinc is a higher grade material than natural ore.

Regarding recycling of steel dust, Nippon Steel’s Hirohata Works started operation of #3RHF and established a 100% recycling system. Nippon Steel is also involved in overseas development through a JV project with POSCO, among other efforts.

In addition to direct environmental improvements at steel works and other manufacturing plants, in 2009, all of Japan’s steel companies announced numerous new products which contribute to environmental improvement, including high strength materials such as plates, steel pipes and tubes, spring steel, and stainles steel, coated steel sheets with a heat reflecting function or antifouling function, etc. (see New Products).

4. Technology Trade and Development

4.1. Technology Trade

As a breakdown of technology trade in the one year period of 2009, Table 5 shows the results of a survey of the Sustaining Members of the Iron and Steel Institute of Japan (79 companies). Technology exports declined to 17 items from 41 in 2008. Technology imports comprised one item (also one item in 2008).

As export regions, Asia accounted for 41% of the total, followed by North America and Africa (18% each). By field of technology, the processing/heat treatment field accounted for 94% of the total.

Figure 9 shows the balance of technology trade in the steel industry up to FY 2008. The amount of compensation received for technology exports increased by 27% from the previous fiscal year, and the amount paid for technology imports also increased.

4.2. Research Expenditures and Number of Researchers

Figures 10–12 show the transitions in the following three items, according to the “Statistical Survey of Researches in

<p>| Table 5. Contents of technology export and technology import (term: January 1, 2009–December 31, 2009). |
|-------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Technical field</th>
<th>Trading area</th>
<th>Asia</th>
<th>North America</th>
<th>Central south America</th>
<th>Europe</th>
<th>Oceanic</th>
<th>Africa</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Raw materials &amp; Ironmaking</td>
<td>1. Pretreatment</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2. Blast furnace</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>B. Steelmaking</td>
<td>1. Hot metal treatment</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2. LD converter</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>3. Electric furnace</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>4. Continuous casting</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>5. Ingotsmeltng</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>6. Others</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>C. Shaping process</td>
<td>1. Bar and wire rod</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2. Pipe</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>3. Plate</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>4. Strand</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>5. Surface treatment</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>6. Heat treatment</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>7. Shaping</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>8. Welding</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>D. Other Operation Know-how (incl. Research related)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Iron &amp; Steel weeks in general</td>
<td>1. Feasibility study</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2. General operation</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>3. Others</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>7</td>
<td>(21)</td>
<td>3</td>
<td>(9)</td>
<td>2</td>
<td>(4)</td>
<td>2</td>
</tr>
<tr>
<td>Technical imports</td>
<td><strong>Total</strong></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1(0)</td>
</tr>
</tbody>
</table>

Note
Coverage: 79 sustaining member companies of ISIJ
Numbers in parentheses show the data from January 1, 2009 to December 31, 2009
1) Ratio of Research Expenditures to Sales
In all industries, the decrease in research expenditures was not particularly large in comparison with the decrease in sales. As a result, this ratio increased in comparison with 2007. In the steel industry, both sales and research expenditures increased; however, this ratio has bottomed out, having been around 1.00 for four consecutive years since 2005. Research expenditures in the steel industry set a new record high, at approximately ¥ 163.4 billion.

2) Number of Regular Researchers per 10 000 Employees
In the steel industry, there was a slight decline in this index, from 357 researchers in 2008 to 345 in 2009. On the other hand, the increasing tendency in all industries continued, and the total number of researchers set a new record at approximately 490,000 persons.

3) Research Expenditures per Regular Researcher
Although per capita research expenditures in the steel industry had been rising rapidly since 2005, this index was somewhat stagnant in 2008. All industries recorded a decline from the previous year due to the combined effects of reduced research expenditures and an increase in the number of regular researchers.

4.3. Trends in Research and Development Utilizing Public Funds
Among iron and steel-related technical development projects, topics completed in FY 2009 included (1) “Leading research of process technology for the expansive use of unusable ferrous scrap”, (2) “Development of non-catalytic coke oven gas reforming technology”, and others.

The main projects started in FY 2009 were (1) “Development of innovative iron making process technology for reinforcement of resources” (FY 2009–2011, production of inexpensive next-generation coke and development of blast furnace operation process using the developed coke; budget for FY 2009: ¥ 360 million), (2) “Advanced promotion for strategic use of nuclear technology” (FY 2009–2011, support for research and development of main nuclear power equipment and materials; budget for FY 2009: ¥ 1.6 billion), and (3) “Preliminary research on separation and recovery of phosphorus for strengthening of steel slag resource capabilities” (FY 2009).

The main continuing projects were (1) “Technology development of environmental harmonic iron making process” (FY 2008–2012, development of technology for reduction of CO₂ emissions from the blast furnace and development of technology for separation of CO₂ from blast furnace gas; budget for FY 2009: ¥ 1.12 billion), (2) “R&D project on fundamental technology for steel materials with enhanced strength and functionality” (FY 2007–2011, development of innovative welding joining technology for high grade steel materials and fundamental development of forging technology using advanced control; budget for FY 2009: ¥ 480 million), and (3) “Technology development of Advanced Ultra Super Critical Steam Condition” (FY 2008–2016).

Regarding iron and steel-related research/technical development topics being carried out utilizing public funds, the results of a survey of the main Sustaining Member companies of the Iron and Steel Institute of Japan are shown in Table 6. Many of these topics are in the environment/energy field and materials field.

5. Development of Human Resources in Technical Fields
The Iron and Steel Institute of Japan conducts various
types of training projects (Iron and Steel Engineering Seminars, Iron and Steel Engineering Seminar special courses, Advanced Iron and Steel Seminar) for the purpose of developing cross-industry core human resources in technical fields. In FY 2009, these various seminars were conducted as planned. Further, 2009 was the third year in the Student Iron and Steel Seminar program for university and graduate school students, which was begun in FY 2007. The second round (ironmaking/steelmaking course, materials course) of seminars for graduate students and support for plant tours by undergraduates was also held. The year 2009 marked the 200th Nishiyama Memorial Technology Lecture. The memorial lecture conference was held on the topic of “Progress of Iron and Steel Technology and Outlook for the Future—The View from the Top” with participation by top leaders from industry and academia.

On the other hand, in order to maintain Japan’s industrial competitiveness by closing the gap in human resources development between universities and industry and promoting cooperation between the two sides, an “Industry-Academia Cooperative Human Resources Development Partnership” was launched with the cooperation of the Ministry of Economy, Trade and Industry (METI) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT), and the issues and responses to human resources development in the materials field were discussed in the Materials Subcommittee of this organization. Based on the results, as a policy of METI, concrete educational program creation and trials by industry-academia collaboration are being developed, centering on the Japan Research and Development Center for Metals (JRCM), under a three year plan beginning in FY 2008. In FY 2009, educational trials involving lectures and seminars with students were actually carried out for a project on strengthening of basic education, an objective-based internship project, and a development management project, with the cooperation of steel companies and university teachers participating in the projects.

6. Technology Creation Activities in the Iron and Steel Institute of Japan

6.1. Technical Committees

In the Iron and Steel Institute of Japan, research on iron and steel production technology and communication of technical development issues centers on the Technical Society. The type and contents of these activities are shown in Table 7.

The Technical Committees which promote the activities particular to the Iron and Steel Institute of Japan hold Committee Meetings periodically to study and conduct active discussions on key issues at the present point in time as common and priority themes. In FY 2009, a total of 34

Table 6. Examples of public funded research projects for steel industry in Japan.

<table>
<thead>
<tr>
<th>Category</th>
<th>Subjects</th>
<th>Source of funds and commission</th>
<th>Beginning fiscal year</th>
<th>Ending fiscal year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Facility</td>
<td>Development of Innovative Melting Processes for titanium</td>
<td>NEDO</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>Strategic promotion of nuclear power technology application*</td>
<td>METI</td>
<td>2009</td>
<td>2011</td>
</tr>
<tr>
<td></td>
<td>Pre-study of phosphorus recovery from steel-making slag*</td>
<td>NEDO</td>
<td>2009</td>
<td>2009</td>
</tr>
<tr>
<td></td>
<td>The technological development of the innovative iron making process to enhance the flexibility of the resource</td>
<td>NRDO</td>
<td>2009</td>
<td>2011</td>
</tr>
<tr>
<td></td>
<td>Demonstration of CO2 adsorption by seaweed plating in Hokkaido using ground and fertilizer made from circulating materials in farming and industry</td>
<td>METI</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>Promotion of energy saving projects in the steel works*</td>
<td>NEDO</td>
<td>2009</td>
<td>2009</td>
</tr>
<tr>
<td>Elemental Technology</td>
<td>Future Power Electronics Technology project directed by NEDO</td>
<td>NEDO</td>
<td>2009</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td>Investigation of reursion-reversion heat devices*</td>
<td>JOGMEC</td>
<td>2009</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>Development of high strength austenite steel for main steam pipe of ultra super critical power plant</td>
<td>METI</td>
<td>2008</td>
<td>2016</td>
</tr>
<tr>
<td></td>
<td>Development of FCA steel usage to railway bogie frame*</td>
<td>MLIT</td>
<td>2009</td>
<td>2012</td>
</tr>
<tr>
<td>Others</td>
<td>Research survey on supply and demand trends of coke in Indonesia</td>
<td>NEDO</td>
<td>2009</td>
<td>2009</td>
</tr>
</tbody>
</table>

The subjects attaching asterisks (*) were translated by the ISIJ secretariat.

METI: Ministry of Economy, Trade and Industry
NEDO: New Energy and Industrial Technology Development Organization
JOGMEC: Japan Oil, Gas and Metals National Corporation
MLIT: Ministry of Land, Infrastructure, Transport, and Tourism

Table 7. Technology creation activities of technical committee, interdisciplinary technical committee, and research group.

<table>
<thead>
<tr>
<th>Technology creation activities</th>
<th>Content of activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Committee</td>
<td>The Technical Committees aim to improve on-site technical standard and to promote technological exchange for iron and steel production, as well as engage in extraction and research of technical topics in each field. 19 Technical Committees that encompass the entire spectrum of iron and steel manufacturing are active, and engineers and researchers of iron and steel companies as well as university researchers participate in the Committees. Meeting of the Committees is held once or twice a year, and Technical Subcommittees that focus on discussing technical topics are set as subordinate organization to carry out technology creation activities.</td>
</tr>
<tr>
<td>Interdisciplinary Technical Committee</td>
<td>To make technical examinations and surveys on future development and solution about interdisciplinary technological problems within the iron and steel industry and with other industries. Two Committees are active.</td>
</tr>
<tr>
<td>Research Group</td>
<td>To conduct the joint research on specific and important subjects for iron and steel industry based on the needs from industry and seeds from academia. As of end-February, 2010, 24 Research Group are active.</td>
</tr>
</tbody>
</table>
Committee Meetings (17 Spring Meetings, 17 Fall Meetings) were held, which was approximately the same as in FY 2008. A total of 2,667 persons participated (2,867 persons in FY 2008). A total of 61 university researchers participated in Committee Meetings, which was the same level as in FY 2008 (61 persons in FY 2008).

Furthermore, in the Technical Committees, industry-academia collaboration with the Academic Divisions is now firmly established, and the Technical Committees are encouraging exchanges, which includes participation by university researchers in Committee Meetings and joint planning with Academic Divisions.

Technical Subcommittees carry out common, priority study of designated technical issues. In FY 2009, 18 of these Technical Subcommittees were active. A total of 11 items were completed, including “Reducability analysis of CO$_2$ in model steel plant” (Heat Economy Technology Committee), and five new topics were begun, including “Maintenance management adopting risk based management and serious trouble of hot strip mill” (Plant Engineering Committee).

Plans aiming at activation of the Technical Committees were also implemented on an ongoing basis from FY 2008. These included lecture meetings for young engineers and plant tours/lectures meetings with other industries.

6.2. Interdisciplinary Technical Committees

Interdisciplinary Technical Committees study cross-field

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Research Group</th>
<th>Division/Committee</th>
<th>Group Leader</th>
<th>Research Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>Development of New Coking Technology for High Strength</td>
<td>High Temperature Process</td>
<td>Koichi Miura, Kyoto Univ.</td>
<td>2006-2009</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>Advancement of Sensing Technologies for Plant Safety Conditions</td>
<td>Instruction, Control and System Engineering</td>
<td>Satoshi Honda, Keio Univ.</td>
<td>2006-2009</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>Effective Use of Waste Heat in the Steelmaking Industry</td>
<td>Environmental and Energy Technology</td>
<td>Tomohiro Akiyama, Hokkaido Univ.</td>
<td>2006-2009</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>Control of Reduction Equilibrium in BF through Viscosity Arrangement of Iron Ore and Carbon</td>
<td>High-Temperature Process</td>
<td>Masakata Shimizu, Kyushu Univ.</td>
<td>2007-2010</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>Material Vision 2100</td>
<td>Social Engineering on Iron and Steel Industry</td>
<td>Atushi Inaba, the Univ. of Tokyo</td>
<td>2007-2010</td>
</tr>
<tr>
<td>8</td>
<td>C</td>
<td>Relation between Work-Hardening Behaviour and Microstructure</td>
<td>Microstructure and Properties of Materials</td>
<td>Kenji Higashida, Kyushu Univ.</td>
<td>2007-2010</td>
</tr>
<tr>
<td>9</td>
<td>C</td>
<td>Development of Innovative Mathematical Model of Blaat Puranace</td>
<td>Ironmaking/Coke</td>
<td>Tatsuro Arika, Tohoku Univ.</td>
<td>2007-2010</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>Agent-Based Emergent Synthesis of “Field Force” in Steel Plant</td>
<td>Instrumentation, Control and System Engineering</td>
<td>Hisashi Tanaki, Kure Univ.</td>
<td>2007-2010</td>
</tr>
<tr>
<td>11</td>
<td>C</td>
<td>Interaction of Biofilm with Steel Materials</td>
<td>Microstructure and Properties of Materials</td>
<td>Yoshitsugu Sato, Osaka City Univ.</td>
<td>2007-2010</td>
</tr>
<tr>
<td>12</td>
<td>C</td>
<td>Control of Non-Metallic Inclusion Properties in Solid Steel</td>
<td>High-Temperature Process</td>
<td>Shinys Kitanura, Tohoku Univ.</td>
<td>2008-2011</td>
</tr>
<tr>
<td>13</td>
<td>C</td>
<td>Standardization of Steel Tube Formability Test</td>
<td>Processing for Quality Products</td>
<td>Yutaka Miura, Kaga University</td>
<td>2009-2011</td>
</tr>
<tr>
<td>15</td>
<td>C</td>
<td>Process Simulation for D疏osphorization of Pig Iron by Multi-Phases</td>
<td>Steelmaking</td>
<td>Kimihisa Bo, Waseda Univ.</td>
<td>2008-2011</td>
</tr>
<tr>
<td>16</td>
<td>C</td>
<td>Research Group of Plant Management by Risk Assessment</td>
<td>Plant Engineering</td>
<td>Shinnenke Sakai, The Univ. of Tokyo</td>
<td>2008-2011</td>
</tr>
<tr>
<td>17</td>
<td>C</td>
<td>Green Energy Steelmaking</td>
<td>Environmental and Energy Technology</td>
<td>Yoshiaki Kashiyaya, Hokkaido Univ.</td>
<td>2008-2011</td>
</tr>
<tr>
<td>19</td>
<td>C</td>
<td>Control of micro- and macrosegregation</td>
<td>High-Temperature Process</td>
<td>Hisao Ikaya, National Defense Academy of Japan</td>
<td>2009-2012</td>
</tr>
<tr>
<td>21</td>
<td>C</td>
<td>Standardization of analytical methods for characterization of free-CaO in steel slag</td>
<td>Analysis Technology Committee</td>
<td>Tatsuhiko Tanaka, Tokyo Univ. of Science</td>
<td>2009-2012</td>
</tr>
<tr>
<td>22</td>
<td>C</td>
<td>Development of heat transfer model of run-out table in hot strip mill</td>
<td>Rolling Theory Committee</td>
<td>Hidetoshi Nakato, Tamagawa Univ.</td>
<td>2009</td>
</tr>
<tr>
<td>23</td>
<td>C</td>
<td>High Precision Process Control via Large Scale Database and Simulation Models</td>
<td>Instrumentation, Control and System Engineering</td>
<td>Yasuhiro Fujisaki, Kobe Univ.</td>
<td>2009-2012</td>
</tr>
</tbody>
</table>

(Note) Knowledge-intensive type (type C), technology development type (type B), search for new fields related to iron and steel (type C)
and inter-industry technical issues in activities limited to a period of within three years. The activities of the Interdisciplinary Technical Committee studying the common theme of "Technology for saving resources and energy in modern structural steel" began in FY 2009. This committee is carrying out survey research on environmental technologies (resource saving, energy saving/CO2 reduction) in steels for welded structures and steels for machine structural use.

The Interdisciplinary Technical Committee on Desirable Steel Materials for Automobiles completed its Phase V activities in FY 2009 and will advance to Phase VI in FY 2010. In particular, the priority issues are improvement of the power train as a main technology for CO2 reduction, technical development in connection with eco-cars, such as hybrid automobiles and electric vehicles, and identification of needs for iron and steel materials related to evaluation by Life Cycle Assessment (LCA).

6.3. Research Grants and Research Groups

Under the program of Grants for Promotion of Iron and Steel Research, 33 new projects were selected as grant recipients for FY 2010. Combined with the 29 items selected in FY 2009, a total of 62 projects are receiving support in FY 2010.

Among Research Groups, 24 groups were active in FY 2009. Of these, seven were terminated in March 2010. In FY 2009, seven new activities were begun in each of the knowledge-intensive (A type), technology development intensive (B type), and search for new iron and steel-related fields (C type) study groups. Six new study groups were selected as proposed projects for FY 2010.

In the Industry-originated Project Development Iron and Steel Research, one theme which was selected under this system in its first year was completed in FY 2008, and two themes selected in FY 2007 and two themes selected in FY 2008 are currently in progress. Unfortunately, no new themes were selected in FY 2009. However, one new item has been selected for FY 2010.

Acknowledgement

The authors would like to express their deep appreciation to the Japan Iron and Steel Federation and those concerned in the Iron and Steel Institute of Japan for their generous cooperation in all stages of the preparation of this paper.
“Production Technology Topics” present an outline of noteworthy achievements in technical development, new equipment, new products, etc. in 2009.

1. Sintering


JFE Steel Corporation

JFE Steel Corporation developed a technology for injection of hydrogen-based gas fuel in sintering machines, “Super-SINTER™ (Secondary-fuel Injection Technology for Energy Reduction)”, which makes it possible to greatly reduce CO2 emissions in the sintering process, and successfully applied this technology to a commercial sinter plant for the first time in the world. This equipment was put into commercial operation in January 2009 at JFE’s East Japan Works (Keihin District) and has continued to perform smoothly up to the present.

In order to produce high quality sintered ore, it is necessary to maintain the sintering temperature between 1200 and 1400°C. With “Super-SINTER™” technology, it is possible to extend the period in the optimum temperature by injecting a hydrogen-based gas fuel from the top side of the charged raw materials as a partial substitute for coke breeze. As the result, the energy efficiency of the sintering process is greatly improved, and it has been achieved to reduce CO2 emissions by a maximum of approximately 60,000 tons/year.

2. Blast Furnace

**Blowing Out the No. 4 Blast Furnace at Wakayama Steel Works After an Operating Life of a World Record 10001 Days**

Sumitomo Metal Industries, Ltd.

Sumitomo Metals conducted blowing-out of No. 4 blast furnace at Wakayama Steel Works on July 11, 2009. The blast furnace had been operating its third campaign since February 23, 1982, and achieved the longest life in the world (10,001 days). The operation was handed over to the brand new No. 1 blast furnace.

Although No. 4 blast furnace (2,700 m³) was initially designed to operate for 7 years, several technical skills made it possible to operate 4 times longer than the designed lifetime. Examples of the skills are shown in the following.

1) Stave replacement: In 1987, the replacement during the campaign was taken place, and it was first in Japan. No. 4 BF experienced 24 times of the stave replacement operation, and totally 821 staves had been replaced until the blowout.

2) Refractory brick replacement of the hot stove ceramic burner: the bricks that construct the ceramic burner were replaced during the campaign (2001 and 2002). The blast furnace operation was carried out with only 2 hot stoves out of 3 during the replacement.

3) Raw materials distribution control system replacement: main control system of raw materials distribution was renewed during the campaign (2002), although it had been said impossible unless the BF is blowout.

4) Brick erosion control at the bottom of the blast furnace: In addition to the all kinds of improvement in hardware, the heat flux was measured to monitor the brick erosion condition. It was made possible to control the brick erosion while keeping the high operation ratio by linking the erosion monitoring and the operational action together.

Sumitomo metals supplies techniques and support over the world, especially in the field of stave replacement.
The Relining of Oita No. 1 Blast Furnace
Nippon Steel Corporation

Nippon Steel’s relining of its Oita No. 1 blast furnace has been completed in 68 d, on schedule, and was blown in on August 2, 2009.

This relining project has many characteristic features: the world-class Oita No. 1 blast furnace (inner volume: 5 775 m³), now twin to Oita No. 2, is designed to make the sharing of operation, maintenance, and equipment know-how possible. The furnace also incorporates: the adoption of self-coating carbon blocks and copper staves for longer life; and state-of-the-art technologies for monitoring and controlling operations, with emphasis on greater visibility. The furnace’s construction also utilized a variety of new methods for drastically shortening the term of large blast furnace construction.

Particularly notable is the fact that, as the world’s first construction of this kind for a world-class large furnace, the construction term was considerably shortened by carrying out, en bloc, the furnace-bottom shell, still holding the remaining iron slag up to the level of its tuyeres and weighing over 10 000 tons (see Photo). Other contributing new methods included: the prior outfitting and carrying-in of the new cast house for tapholes, monolithic with the roof, along with the carrying-in of the walls, which together weighed over 3 000 tons; and the prior fitting and carrying-in of the new furnace-bottom carbon brickwork, weighing over 5 000 tons.

On the seventh day of blow-in, the furnace produced 12 000 t/d and, in about four months, 13 500 t/d, reaching a level equal to that of Oita No. 2 during high operation. At present, Oita No. 1 blast furnace continues to run smoothly at a level of 13 700 t/d, and will no doubt continue to raise our expectations for more than two decades of stable service into the future.

3. Heavy Plate

Steel Plates for Architectural Construction with Excellent HAZ Toughness in Large Heat Input Welding
JFE Steel Corporation

JFE Steel Corporation developed high tensile strength steel plates for architectural construction with excellent HAZ (Heat Affected Zone) toughness in large heat input welded joints, and reached 10 000 tons or more shipping in total.

These steel plates are mainly adopted for welded box columns of super-high rise buildings. Large-spans and multi-story designs are common features of the high-rise buildings recently being built mainly in urban districts. This requires the use of thick plates with high tensile strength.

On the other hand, based on the 1995 Hyogo-Ken Nanbu earthquake and other disasters, high toughness in welded joints in architectural steel frame structures has been strongly required in recent years from the viewpoint of seismic resistance.

The welding methods used in welded box columns are submerged arc welding (SAW) and electro slag welding (ESW), which are high efficiency large input welding methods. In this type of large heat input welding, reduced toughness had been unavoidable with conventional steels.

JFE steel developed a high-HAZ toughness steel plate by applying “JFE EWEL”, a technology for improving the toughness of the large heat input HAZ.

JFE EWEL integrates three element technologies: (1) optimum chemical composition design via the high-accuracy TMCP technology using Super-OLAC, (2) control of grain size in HAZ, (3) control of intra-granular microstructure in HAZ.
4. Cold Rolling Steel

Fine Grain Stainless Spring Steel Have Significantly Improved the Cycle Life of Compressor Diaphragm

Sumitomo Metals (Naoetsu), Ltd.

The stainless spring steel NAR-301L HS1, developed for automobile parts by Sumitomo Metals (Naoetsu) have made a remarkable achievement for equipment life in Tsuruga Power Station of the Japan Atomic Power Company.

The diaphragm-type hydrogen compressor is an important equipment used for suppression of the stress corrosion cracking (SCC) of reactor coolant system piping. Hydrogen injection into coolant is one of the anti-corrosion engineering by making corrosion potential of the piping less noble. NAR-301L HS1 was adopted as an improved material for the diaphragm, which is vital component of this compressor.

High fatigue strength is needed for the diaphragm material under the cyclic bending during the compressor actuation. Fatigue crack of the conventional diaphragm material usually occurs within two months, so frequently replacement of the diaphragm was needed.

NAR-301L HS1 has improved the cycle fatigue life of diaphragm to more than one year, and contributed to a continuous and stable operating of the equipment. High fatigue resistance of this steel is due to fine grain micro structure of 1–2 μm. This success shows the potential of NAR-301L HS1 for the new applications.

Nuclear power is the most effective energy source to reduce CO₂ emissions. It is hoped that NAR-301L HS1 will expand further new application to contribute to the realization of a low carbon society.

5. Shaped Steel

The World’s Longest Straight Web-type Sheet Piles of 38 m were Applied to Overseas Big Infrastructure Project for the First Time

Nippon Steel Corporation

The world’s longest straight web-type sheet piles of 38 m that Nippon Steel has developed were first applied to world-class big project, Incheon Bridge that connects Incheon International Airport to New Songdo City in Korea. They were used as steel members of cylindrical ship impact protections around main pylons and piers near the ship line. A lot of straight web-type sheet piles were interlocked with one another cylindrically, driven below the seabed and filled with crushed stones and sand inside the tubular structure. This structure called ‘cell’ resists ship impact as steel sheet piles cooperate with stones and sand.

The features of straight web-type sheet piles of Nippon Steel are the world’s longest length of 38 m (hitherto 25 m) and the world’s highest tensile strength at its interlocking sections up to 5 800 kN/m. There are two types of sheet piles with 9.5 mm and 12.7 mm web thickness. But the production of intermediate sizes between 11.0 mm and 12.7 mm are now being planned.

6. Steel Pipes and Tubes

Dry Surface Treatment Technology Applied to Premium Connection for Environmentally Safe Rig Operations

Sumitomo Metal Industries, Ltd.

Grease technology, commonly called “dope”, is universally used to protect and assemble Oil Country Tubular Goods. Extensive efforts have been made to design environmentally friendlier dopes by removing heavy metals such as Lead and Zinc. While these so called “green dopes” have reduced the impact on the environment, it missed providing the paradigm shift to “no application-no discharge”.

Sumitomo Metals Industries, Ltd. in partnership with Vallourec & Mannesmann Tubes developed a completely dry film system (“CLEANWELL® DRY”), applied on both pin and box members of a Premium Connection. The dry system functions include anti-corrosion performances and...
excellent lubricating performances. In June 2009, the Dry System was run successfully Offshore North Sea with zero reject. Beyond this success the Dry System will offer a large range of valuable side benefits to oil and gas developments, among which the reduction of well bore contamination, the simplification of pipe handling, the enabling of hands-free OCTG running and finally a safer working environment for rig personnel.

Development of a Low-noise and Low-vibration Method of Construction for High Load-bearing Foundations for Port Engineering Utilizing Steel Pipe Piles

Nippon Steel Corporation

Nippon Steel Corporation, jointly with the Port and Airport Research Institute and Chowa Kogyo Co., Ltd., has developed the RS Plus Method®, a new low-noise and low-vibration method for constructing high load-bearing foundations for port engineering utilizing steel pipe piles.

The new method makes it possible to construct a foundation of steel pipe piles in port areas even where measures against noise and vibration are required in relation to local residences and industrial facilities. Conventionally, foundations for structures were constructed under such conditions by the combined water jet and vibro-hammer method (the JV method), whereby pipe piles are driven into the soil while the soil is stirred with a water jet. Using the new method, piling work goes as follows: steel pipe piles are driven by the JV method; then, a large foot protection area of soil cement is formed by injecting cement milk at the lower end of each pile, where steel fins, called rib plates, are provided; and in addition, cement milk is injected to cover the sidewall of each pile. The new method is expected to reduce the total number of piles required because a pile installed in this manner has a higher load-bearing capacity than that of an impact-driven one.

The new method is characterized by:
1. Low noise and low vibration;
2. Rib plates on the sidewall at the lower end of the pile, which make it possible to form a large foot protection area, and which, in combination with a sidewall coated by soil cement, make the load-bearing capacity greater than that of an impact-driven pile; and
3. Easily installation through use of a cement milk pump, instead of the water jet pump used in the conventional JV method.

Instrumentation, Control Engineering

Fountain Pyrometer for a High Tensile Hot Strip Production

Sumitomo Metal Industries, Ltd.

Sumitomo Metal Industries, Ltd. (SMI) developed a new temperature measurement method (Fountain pyrometer) and associated control system, for hot strip cooled by water in cooling banks. Use of the Fountain pyrometer and control system achieved very precise temperature control of hot strip in the run-out table.

Recently, high tensile steel has been applied to lightweight cars as a measure to reduce CO₂. In order to stabilize material quality of a hot strip including high tensile steel, the temperature control in run-out table is important. But the accuracy of the conventional control was not good enough because the temperature of a hot strip couldn’t be measured in cooling banks that had much cooling water, which disturbs thermal radiation from the hot strip surface and the stable measurement of hot strip temperature.

SMI has developed Fountain pyrometer, which uses water purge to stabilize the optical pass of thermal radiation from hot strip surface. It was confirmed that Fountain pyrometers are reliable to measure hot strip temperature even in cooling banks where much cooling water exists. The range for Fountain pyrometer is above 360°C and its responsiveness is less than 20 ms. SMI also developed a new
control system to use the Fountain pyrometers.

Use of Fountain pyrometers and the control system achieved very precise temperature control of hot strip in the run-out table.

8. Testing and Analysis

Development of Evaluation Method for Local Strength in Spot Weld of Steel Sheet Using Small Specimen

Sumitomo Metal Industries, Ltd.

Application of high strength steel (HSS) sheet has recently been increasing for automotive bodies in order to realize lightweight and improve crashworthiness. On the other hand, there are cases where static and fatigue strength of spot weld of HSS are not superior to those of low strength steel sheet. In order to investigate a way to improve strength, it is important to evaluate the local strength of weld metal and heat affected zone (HAZ) in spot weld, where failure often occurs. However, the failure region is sub-millimeter and the conventional testing method cannot be employed.

To solve the problem mentioned above, Sumitomo Metal Industries newly developed tension testing and tensile-compressive fatigue testing techniques under axial loading for small specimen with a total length of less than 3 mm and a thickness of 0.2 mm. Using these techniques, the local strength of weld metal and HAZ in spot weld were successfully evaluated.

The local strength properties are applied to examination of the effect of the steel grade on the strength of spot-welded joint, and to development of a new analysis technique for evaluating crash performance of spot-welded components. These researches are expected to contribute to development of automotive structures with higher strength and reliability.

9. Environment

Recycling Technology for Refractories

Nippon Steel Corporation

Nippon Steel Corporation won the Award for 3R (Reduce, Reuse, Recycle)-Oriented, Sustainable Technology 2009, ‘Prize by Director-General, Industrial Science and Technology Policy and Environment Bureau, the Ministry of International Trade and Industry in Japan’ from Clean Japan Center on the Recycling Technology for Refractories.

Hundreds types of refractories with different compositions are used in steel making processes. However, simple recycling of used refractories degrades new (recycled) refractories in corrosion resistance typically as they contain impurities like slag or skull. It limits recycling ratio from 10 to 20%, and the others were used for roadbeds in steel works.

Nippon Steel has developed mass recycling technology of refractories, *i.e.* cascade use of refractories from high to low grade and blending technique considering particle size distribution of ground used refractories. In addition, purification (*i.e.* removal of slag and skull) of the used refractories was made possible by concentrated collecting and sorting system of the used refractories with effective regeneration and reproduction plants. It led to the usage of medium and fine grains that originally contain impurities.

These innovations enhanced the recycling ratio of the used refractories to new refractories up to 80%.

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**Fig. 1.** Comparison of small specimen and standard size specimen.

**Fig. 2.** Cross-section of spot weld and sampling location of small specimen.

10. Others

Kobe Steel’s Titanium Used in JAXA Transfer Vehicle

Kobe Steel, Ltd.

Kobe Steel, Ltd.’s Titanium Division has supplied titanium alloy forgings for the propellant tanks in the H-II Transfer Vehicle (HTV), which successfully docked with the International Space Station last autumn. The HTV was developed by the Japan Aerospace Exploration Agency (JAXA) to transport cargo to the space station.

Kobe Steel manufactured hemispherical titanium alloy forgings for IHI Aerospace Co., Ltd., which used them to make ball-shaped propellant tanks. The tanks provide fuel for the HTV’s orbital maneuvering thrusters.

Hemispherical shapes made of titanium are difficult to process. As the thickness of a hemispherical shape varies, maintaining the prediction accuracy of the shape is critical. When processing titanium, it is important to prevent the temperature from decreasing to maintain internal quality. Kobe Steel has a long history of supplying hemispherical shapes, including the pressure-resistant shell for the deep-sea submersible Shinkai 6500 in the late 1980s. Kobe Steel applied its accumulated analysis and production technologies in the manufacturing of the hemispheres for JAXA.

Plans call for the HTV to be launched once a year. Kobe Steel is contributing to Japan’s space industry through its high expertise in the plastic forming of titanium products.

New Matrix Type Cold Work Die Steel “DCLT”

Daido Steel Co., Ltd.

Daido Steel Co., Ltd. has developed DCLT (pronounced “DC Light”), a new matrix type cold work die steel. With the aim of contributing to a reduction in environmental burden and in die manufacturing cost, the amount of rare metals used in DCLT was decreased by 70% compared with conventional JIS SKD11 steel.

Many of the tool steels used for the manufacturing of dies contain such rare metals as molybdenum, vanadium, and tungsten. However, these rare metals are exhaustible resources, the amount of usage is expected to be lower from the viewpoint of reducing environmental impact. Also, since the recent onset of the financial crisis, a major challenge for die manufacturers has been to lower the cost of die manufacturing. Given that cold-work die steel can make such cost reductions possible, the demand for cold-work die steel has been increasing.

As a result of detailed research we conducted on the effects on hardenability and temper softening resistance of each alloying element, we were able to reduce the amount of rare metals used as DCLT alloy ingredients by 70% compared with SKD11 steel, while maintaining the required hardness of various plates for progressive die process. Furthermore, as a result of eliminating coarse carbides, machinability and toughness were improved for DCLT. These improvements can contribute to reduce die manufacturing cost and increased die life compared with SKD11.

Fig. 7. Titanium alloy hemispherical forging (1 000 mm dia.).