Iron, the hidden element: the role of iron and steel in the twentieth century

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The annual Hatfield Memorial Lecture, given at The University of Sheffield and organised in collaboration with the Royal Society and The Institute of Materials, honours the special contribution made to the steel industry by William Herbert Hatfield, a native of Sheffield. Professor Boom from Corus Group plc – the company formed as a result of last year’s merger of British Steel and Hoogovens – gave the 47th such lecture, appropriately enough as the twentieth century drew to a close.

Alexandre Gustave Eiffel, Henry Bessemer, Andrew Carnegie, Alfred Krupp: all well known to the general public at the end of the nineteenth century, and all involved in some way with iron or steel. Where are their late twentieth century equivalents? Most of us would struggle to name spontaneously four figures strongly related to steel whose names are known to the man and woman in the street. People are hardly aware of the fact that the availability of iron and steel is crucial to almost every application, every feature, that shapes the quality of modern life. Iron and steel are so basic to society that they are taken for granted and hidden – sometimes literally, but more often figuratively.

The world 100 years ago

Economic and social changes at the end of the nineteenth century were marked by developments that can be attributed to the steam engine, in its stationary form (in factories) or moving on railroads, canals, rivers, or oceans. In most ‘developed’ countries the railway network had to a large extent been completed. (Note that the French use the expression chemin de fer, the Germans use Eisenbahn, and the Italians ferrovia – all meaning ‘road of iron’. In contrast, the British use railway, the Americans railroad, and the Dutch spoorweg, thereby denying, or hiding, the fact that rails are made of steel.) The railway infrastructures included some fine examples of advanced construction technology in iron and steel, like the Forth Bridge in Scotland, with a length of 2.46 km and two 521 m spans, then the longest bridge in the world.

Small scale domestic production of goods was substituted by mass production in mechanised factories. A striking example of this is found in textiles. Cities were growing fast, notably by the addition of thousands of small houses for factory workers. A labourer’s life was of low quality. There were no sewage systems and hardly any facilities for health and personal care. Heating was inadequate. Oil for heating was just being introduced at the end of the nineteenth century: coal and wood were the fuels that really mattered. Food was expensive and of low nutritional value. There was a great need for mechanisation of agriculture to produce the amounts of food required for human and animal consumption. Transport from the farms to the cities had to be arranged.

But the first signs of a New World appeared, some of which were shown at the famous Paris World Exhibition of 1887–89. For example, the cast and forged iron house, a demonstration of the best of iron technology from Russia (Fig. 1). The 300 m high Eiffel tower stole the show: note, however, that the Eiffel Tower is made of iron, not steel. The tower was a demonstration by the engineer Eiffel of the feasibility of using iron for large constructions, a proof to the world of new possibilities. British engineers such as Telford and Brunel had realised more complicated work: in fact, the Eiffel tower was a monument to the past rather than to the future. It was intended to survive the exhibition for only a couple of years, but today it is still the symbol of Paris.

1 Iron house originally exhibited at the Paris World Exhibition, 1887–89, now on display in the city museum, Yekaterinburg
From iron to steel
Henry Bessemer was a great inventor; he triggered the steel revolution in Great Britain at the end of the nineteenth century with his converter process. By blowing air through low phosphorus iron in a refractory lined vessel, low carbon steel could be produced in large quantities in short production times. Subsequently, Sidney Gilchrist Thomas adapted this process to convert high phosphorus iron, very important to European producers. The open hearth process, developed by Friedrich and Wilhelm Siemens and Émile Martin, was a next step in the large scale production of steel. The material, production processes, and facilities were there; steel was ready to play a major role in the twentieth century.

What was the importance of Bessemer's and Siemens' findings? Steel, a low carbon iron alloy, is ductile; it is 'tougher' and 'stronger' than cast iron; and it can be made in large quantities at an economic price far exceeding the possibilities of forged iron. This contributed greatly to the victory of steel over iron; whereas in the second half of the nineteenth century iron and steel were applied to a comparable extent, the twentieth century saw applications mainly of steel. The Forth Bridge, for instance, was one of the very first large bridges in steel. In fact the Iron Age turned silently into the Steel Age, unnoticed by the majority of mankind.

The early twentieth century
During the early decades of the twentieth century, steel plants and steel companies were established throughout the world. In 1901 United States Steel Co. was founded by Andrew Carnegie. US Steel contained Carnegie's interests in numerous small, mainly Pittsburgh based, steel companies and was introduced to the New York Stock Exchange in that year, the first steel producing company to be so listed. US Steel soon became the largest integrated steel producer in the world, owning iron ore mines, coal mines, railways, and shipping companies. Its power and success became so overwhelming that the US authorities started an antitrust investigation in 1910. In that year the company controlled 80% of the US steel market. By the time the investigations and the court hearings were finished, 10 years later, the situation had drastically changed and the market share of US Steel had dropped to 40%. The judge did not accept the charges, because of this drop in market share and because monopoly price setting was not proven. Carnegie, being a businessman rather than an inventor, made a lot of money out of steel. He used it wisely and with great charity to support science and technology and to reward those who had showed heroic behaviour in saving others. Carnegie lived in two centuries, but was mainly active in the nineteenth.

Also in 1901, Yawata Steel was founded as a state owned company on the island of Kyushu in southern Japan, and it produced the first iron ever made by the blast furnace route in Japan. Kyushu coal and local iron sand were used as raw materials for iron and steel production. Yawata Steel is one of the predecessors of Nippon Steel, now one of the world's largest steel companies.

In 1903 Friedrich Krupp GmbH was founded in Essen, Germany. A steel producer in the heart of the Ruhr area, famous for foundry products such as cannons, the family business, founded about 100 years previously and considerably expanded by Alfred Krupp, now became a publicly quoted company under his son, Friedrich. Krupp rapidly introduced Bessemer technology (Fig. 2).

This happened in a country that was industrialising at a high pace (Fig. 3). In terms of iron production, it can be seen that the UK, the creator of the Industrial Revolution, led industrialisation in the nineteenth century. France was picking up slowly, and Germany was rapidly increasing iron ore production. Coal and ore were available in Silesia, the Ruhr area, and in Alsace and Lorraine, which had been acquired from France in 1871. In Germany the Second Industrial Revolution began, triggered by coal, iron, and steel and by the chemical and electromechanical industries.

Steel permits equipment for large scale

![Graph](image-url)
generation and use of electrical energy to be built (to be exact: copper and iron). Without steel there can be no economic production of electricity: although iron does not conduct electricity very well, it guides the bulk of electrical power - transformers and generators need electrical steels. Electricity was easily transportable and could take over the role of steam engines as power sources. Germany led this new technology. There was also the development of sewage systems and other water ducts using iron or steel pipes. Transport of gas for domestic lighting and cooking was done through 1 inch steel 'gas pipes': steel as distributor of health and welfare for all classes of society.

The first metal carriages or motor cars were designed and built. Henry Ford Motor Co. in 1903. Mass production of automobiles started with the success of the Model T Ford in 1908. Henry Ford was elected businessman of the twentieth century by Fortune magazine. Without large quantities of steel of reliable quality, available at low prices, he could never have achieved this. I select him as the first name connected to steel in our century.

Large ships were being built in steel. We all recall the 'Titanic', one of three sister ships built around 1910 for the White Star Line to compete with the already famous 'Lusitania' and 'Mauretania' of the Cunard Line - ships that set the measure for a whole branch of industry. The UK led the world with its famous shipyards such as Vickers in Newcastle and John Brown on Clydeside. The recent movie about the tragic maiden voyage of the 'Titanic' focused the attention of the public on matters such as steel quality and joining technology. The other ships were also unlucky: both the 'Lusitania' and the 'Mauretania' were later victims of war.

**War: a boost to technology**

History has shown that large scale wars generally provide a boost to technology - long before the word even existed. The First World War was the first in which steel was available in large quantities. It was used for weapon systems, such as *Dicke Bertha* (Big Bertha) made by Krupp, a cannon with a range of 100 km that was used *inter alia* to fire on the steel city of Liège. It was named after Bertha Krupp, only child of Friedrich. Tall warships, made from Heavy armoured plate, were constructed with heavy artillery aboard, introducing the term 'battleship'. Armoured cavalry wagons with steel caterpillar tracks were introduced and became known as military tanks.

Historians claim that none of these developments significantly affected the course of the First World War. No, the real tragedy of the tremendous losses of young soldiers is to be attributed to the machine gun and the thousands of kilometres of barbed wire at the front lines - hidden weapons made from steel. An irony of history, given the theme under consideration, is that the decisive battles on the Belgian front were fought along the river Yzer, the Flemish word for iron.

The First World War made it evident that steel had become essential to national economies. This was felt particularly in the Netherlands, which because of its belligerent status had been isolated and deprived of foreign strategic supplies (any material in which it was not self-sufficient, including all metals) from 1914 to 1918. The experience boosted private initiatives to found a steel industry in the Netherlands. There had been attempts before, but during the nineteenth century the prevailing opinion was that such activities were out of place in a traditional trading nation without the necessary sources of iron ore. In fact, it needed a war to make people realise that the country could no longer do without a steel industry.

**Hoogovens**

Just before the end of the war, in 1918. Koninklijke Nederlandsche Hoogovens en Staalfabrieken NV was founded, a company that later became known as Hoogovens, the Dutch word for blast furnaces. At the chosen site near IJmuiden (Fig. 4), a small port on the North Sea coast some 25 km west of Amsterdam (chosen after that city had provided some additional capital), the necessary raw materials were not readily available. Neither was skilled labour: the people in the area were strawberry or bulb growers or worked at sea as fishermen or sailors. Nevertheless, these people were hired and trained. Technology was imported from Germany; German Meisters, experienced ironmasters from the Ruhr area, trained the personnel.

Blast furnace ironmaking started in early 1924. Despite the lack of experience, Hoogovens soon built up a reputation as a producer of high quality pig iron and became renowned for its marketing policy. The annual production capacity of over 0-25 Mt of pig iron, though quite modest by present standards, far exceeded the needs of the local market. So, right from the beginning the intention was to export a substantial part of the iron produced. This was a brave approach indeed, given the import and tariff barriers that existed then in Europe. But the management found a way out of this problem, setting up an international network of agents who sold directly to foundries and steelworks. By doing so, Hoogovens gained an advantage over its foreign competitors; whereas they sold only via traders and had no direct contact with their customers. Hoogovens supplied exactly what it found its customers wanted. Thanks to its favourable geographical location it could sell at very competitive prices.

In fact, Hoogovens' marketing expertise proved to be its greatest asset. Whereas, during the crisis of the 1930s, iron and steel producers all over the world were forced to cut production and even to withdraw from export markets, Hoogovens

![Hoogovens site near IJmuiden (c. 1925)]
managed to maintain a constant production level. In that period it was the world's largest exporter of pig iron - though at rock bottom prices. The modest income from that business proved sufficient to keep the company running.

**Interwar period**

The first decade after the First World War saw strong growth of industrial production in almost all industrialised or industrialising countries. The motor industry and the machine industry expanded. Tremendous growth in applications of electricity called for a corresponding infrastructure, whereas the growth of all kinds of transport made numerous civil works necessary: roads, bridges, ports, and so on.

From a technical point of view, the shipbuilding industry reached maturity. Its further sophistication became a driving force for the development of new steel grades. Large, fast ocean liners could now be built for the intensive Atlantic passenger trade. These subsequently became genuine prestige objects, competing for the Blue Riband, the award for the fastest transatlantic crossing. In the UK, for example, the 'Queen Mary' and the 'Queen Elizabeth' were built to designs that allowed the British to regain the Blue Riband from competitors such as the French, the Americans, and the Italians.

In the USA, the first household appliances came onto the market. The first washing machines appeared in 1920, soon followed by refrigerators. They became very popular; the American kitchen, with many pieces of equipment made out of steel, became a dream for millions all over the world. Consumers, not just governments, were asking for steel products.

On the other side of the globe the USSR, created after the 1917 revolution, first had to struggle with a civil war. After consolidation and after the death of Lenin, a plan for large scale industrialisation was developed. It was launched by Joseph Vissarionovitsch Djugashvili, who changed his name first into Koba and then into Stalin ('man of steel'), my second nomination as a name of the twentieth century strongly related to steel.

Stalin called for industrialisation in 1925 as the base for his economic policy. The goal was socialism, the method was planning, the instrument was the five year plan. Stalin was almost obsessed by the role of heavy industry, in particular by Big Steel. He was in a hurry; the USSR was on the 'March for metal'. He ordered the construction of a huge steelplant at Magnitogorsk, the 'magnetic mountain' in the Urals. Here, surrounded by empty steppe, iron ore resources were available.

The region, however, was hardly suitable for human life, but this was of minor concern to the Communist authorities. Active construction started in 1928. Unskilled labourers were moved to the site from almost everywhere. Forced labour by convicts was used. Both men and women worked on all aspects of the construction, including heavy labour.

The Soviets wanted the best technology, so they had the plant designed by the US engineering company Frey, which had also designed the largest steelworks at that time, US Steel's Gary Works, built on the marshes of South Chicago. Once the giant project had come on stream, the Americans were asked to leave and Magnitogorsk was declared a closed town, as was the old metal industry centre Yekaterinburg. This centre of mining and metals industry since the early eighteenth century was renamed Sverdlovsk, and was meant to be another nucleus of the Soviet metals industry. Foreigners were no longer allowed to visit those cities.

The Magnitogorsk plant became the biggest steel producing site in the world. Stephen Kotkin, in his book 'Steeltown, USSR', wrote:

> It was one of the symbols of the October Revolution itself; of the rise of backward peasant Russia to the status of an industrial and military superpower.

In this way steel became almost a synonym for advance, for presumed or expected prosperity. Malenky, in his book 'The metallurgical combine of the future', wrote:

> Metal is not produced simply for its own usage ... Metal draws all industry along with it, all spheres of human life ... Metal is the basis of modern civilisation.

At the same time steel became a route to power. Politicians quickly realised that control of the essential industries – starting with the iron and steel industry and, on its tail, the military industry – paved the way to gaining control of the whole country.

In the meantime, the Western economies had collapsed following the Wall Street Crash in 1929. The steel industry suffered badly and passed into a difficult period. It was a labour intensive industry and the effects on employment were dramatic. However, the crisis produced only a slackening in technological development, which accelerated again during the Second World War. In Germany, the National Socialists attacked the employment problem by rearmament. This is reflected in the steep rise of crude steel production, shown in Fig. 5, output at the outbreak of war in 1939 was more than four times that in 1932.

**Second World War and its aftermath**

During the Second World War steel was a matter of life and death for the combatants. The Atlantic lifeline between the USA and the UK was of paramount importance to Britain. Submarine action resulted in vast losses of allied merchant shipping, which had to be replaced. To this end the USA designed an assembly line to build 'Liberty' cargo and T2 tanker ships. From 1942, over 2500 Liberty ships were built; it took about 60 days to produce one ship. This high rate was possible because of technological developments that allowed welded joints to replace the usual plate and rivet construction. The steel industry was able to supply enough material with the right properties to produce this immense number of ships, steel thus creating the aorta between the USA and the UK.

However, some 'Liberty' ships were lost without enemy action; in 19 reported cases they even broke in two. Metallurgical investigations showed that crack formation in the steel plates was the cause. In the traditional rivet and plate construction this would not be disastrous, but in a fully welded construction it was. (Incidentally, the joints in the 'Titanic' – mentioned earlier – were of the rivet and plate type, making crack formation an unlikely reason for its sinking after hitting the
Impact tests were designed to map the brittle behaviour of steel grades. New grades were developed for low temperature conditions. The lesson was learnt the hard way, but in the end physical metallurgy provided the solution.

The success of the Russian tanks in the battles of Stalingrad and Minsk was largely attributed to the steel produced at Magnitogorsk.

The Second World War brought considerable technical advances. It procured for the USA the position of undisputed economic world leader. However, many countries that had been occupied, or that had used their last resources to defeat the enemy, emerged in a desolate state, hindering reconstruction and political stability. Winston Churchill warned early on against the upcoming threat of Communism. In a telegram dated 12 May 1945 to US President Harry Truman, he used the expression 'Iron Curtain' for the first time. Subsequently, in his famous speech at Westminster University in Fulton, MI, he said:

From Stettin to the Baltic to Trieste in the Adriatic, an iron curtain has descended across the Continent ... In front of the iron curtain which lies across Europe are other causes for anxiety ... The Communist parties or fifth columns constitute a growing challenge and peril to Christian civilisation ...

Through his popularisation of the term 'Iron Curtain' and through his iron will to defend freedom and democracy, his name is also closely connected with iron in the twentieth century.

In 1947 George Marshall, the US Secretary of State, announced an extensive European Recovery Program with a target of making impoverished European countries self-supporting again within four years. Major focal points were the rationalisation of agriculture and restoration of production in essential sectors of the economy. In principle, Marshall Aid was coupled to cooperation between countries to create a stronghold against Communism, but this proved to be a bridge too far at that time. Whereas the USSR rejected the offer and forced countries under its influence to do the same, most Western European countries reacted favourably.

The Marshall Plan was launched at a time when the Dutch government was changing its industrialisation policy, shifting the focus from import substitution to restoring the balance of payments and creating employment. This implied stimulating capital intensive industries. The government — contrary to its traditional point of view — was willing to participate in the Hoogovens expansion plan, if the capital required came from Marshall Aid. Though the plans met with opposition from (more industrially advanced) neighbours like France and the UK, financial support under the Marshall Plan was granted at the end of 1949. Mainly US equipment was installed. HM Queen Juliana officially inaugurated the complete set of new facilities (hot and cold strip mill and tinning lines) in 1953 (Fig. 6). In fact, this marked the completion, 35 years after the launch of the company, of the original plan of its founders: an integrated steelplant. From the Dutch point of view Marshall Aid was crucial in shaping the future of our steel industry.

For Germany the change in policy was of utmost importance. The Allied Occupation Force had put a dismantling programme in action, especially in the British sector where about 90% of the Germany steel industry was located. The first intention was to limit German steel production to a mere 10 Mt/year, but this was abandoned as the Cold War intensified.

A major impetus for the Marshall Plan was the US Government's wish to counteract the threat of Communism in Europe. Subsequently, the same policy was adopted towards its former enemies in Asia. Initially, the USA intended to restrict the development of Japan. Under the 'reparation policy', steel production would be lowered to 2–3 Mt/year. The Korean crisis produced a change of policy: the USA sent engineers to teach the Japanese steelmaking. The Americans, most of them from US Steel, were excellent teachers — and the Japanese were even more eager students. The first stage consisted of the introduction of new technology. In the second stage steel manufacturing was improved with discipline and patience, applying the 'total quality' approach developed in the USA by Deming. This resulted in such an advance (in the third stage) that other countries began to import Japanese technology. In Asia, Korea and China especially adopted Japanese technology. In Europe, The Netherlands, Italy, and France were leaders in importing Japanese steel manufacturing technology, soon followed by the UK. This advanced technology made possible higher productivity per man hour, thus greatly reducing the numbers employed in the industry (Fig. 7). In the 1980s, the five big Japanese steel manufacturers took...
financial interests in almost all US steel producers and began to export new technology to the USA.

In the 1950s, the French Foreign Minister Robert Schuman, another twentieth century man of steel, launched an initiative for European cooperation. His aim was to stimulate ‘world peace’—la paix mondiale—by which he meant preventing new conflicts between France and Germany. The Treaty of Paris was signed in 1951 and its first manifestation, the European Coal and Steel Community (ECSC), was formed the next year: steel in the role of joining different nations and different cultures. ECSC formed the backbone of the later EEC end of today’s EU. The member states of ECSC contributed through a levy per tonne of steel produced. Part of the funding raised was used for social measures and for regional reconstruction of the industry; part was used by ECSC to organise a common R&D plan (Fig. 8). This has led to the present high technological level of the iron and steel industry in ECSC, benefiting customers, stakeholders, and also the environment and energy conservation. A network of specialists, researchers, and managers from industry, RTOs, and academia has been established.

The end of the Iron Age?
According to Sze and Feldman, the Iron Age ended in 1968 (Fig. 9). In that year, the number of scientific publications having iron as the subject was equalled by the number of publications about silicon, since when silicon has forged ahead—clearly the glory days of iron belong to the past as far as scientific journals are concerned.

Was it coincidental that around this presumed end of the Iron Age the UK Labour Government nationalised the British iron and steel industry? British Steel Corp. (BSC) was formed by incorporating the 14 largest steel companies in the UK. The highest production level reached was 26 Mt in 1970, the total maximum capacity being 33 Mt/year. The energy crises of the 1970s led to rationalisation and reduction of the labour force. In 1988 British Steel was privatised, under a Conservative Government led by Margaret Thatcher, the ‘Iron Lady’ and my final selection as a name of the twentieth century strongly related to steel. Subsequently privatisation also took place in Italy and France.

In 1972 a challenging and alarming report appeared, ‘Limits to growth—a report for the Club of Rome project on the predicament of mankind’, by Dennis Meadows, a professor at the Massachusetts Institute of Technology and leader of the System Dynamics Group.10 His group developed a mathematical model to predict the future availability of resources. Energy, food, water, space, and other vital resources would, they inferred, become scarce in the near future. The concept of exponential growth was explained and its intrinsic danger was made clear. This danger had to be turned into a global challenge. In this report, steel consumption was used as a measure of national prosperity; a clear relationship between gross national product and steel consumption per capita was established for the USA (Fig. 10). Over 80 years, the consumption of steel in the USA rose from 50 to 700 kg/head, a factor of 14, and gross national product per head from US$800 to US$3600, a factor of 4.5 (note the saturation effect).

Taking this observation a little further, steel consumption was considered as a measure for the stage of development of a nation. Developing countries such as China and India were found at the lower end of the curve, whereas the former FRG, Sweden, and the USA were at the upper end (Fig. 11). With steel consumption so strongly related to prosperity, the future availability of iron sources would be of paramount importance to developing countries. Here the Club of Rome was not alarming in its conclusions. Steel was not considered a big problem; iron ore is abundantly available. Moreover, the mathematical formulae of Meadows did not incorporate much recycling. Only the recycling potential of steel, more or less securing future availability, was mentioned. Resources of other metals such as tin, however, were predicted to be completely exhausted within a few decades.

In 1973, just a few months after the publication of the Club of Rome report, the world was faced with an energy crisis, followed by a second one in 1979. A sudden rupture of all trends was experienced. Nations in control of natural oil and gas sources proved able to exert control over the industrial world simply by disrupting the supply of these fossil fuels. At first, the steel industry profited from this dramatic oil crisis as new sources were sought. Steel provided the means and boundary conditions for drilling and dragging, for exploration and exploitation, for distilling and refining, for transport.

9 The silicon age (1968–): after Sze and Feldman2

10 The system dynamics group of Meadows consisted of Dennis Meadows, the lead author, William Behrens III, the lead co-author, Donella Meadows, the model developer, and Jorgen Randers, a math model developer. The book was published in 1972 by the Club of Rome (St. Andrews University, Scotland).
storage, and distribution. Drilling in the North Sea provided prosperity to Scotland and Norway where offshore supply bases were set up. Exploitation of natural gas generated prosperity for the Netherlands. Distilling and refining initially brought employment. Storage in tanks of huge steel tanks provided strategic reserves. Mammoth tankers, built of steel in Japan and later in Korea, were used to transport crude oil. Transport of sour gas was made possible by development of special steel grades for large diameter pipes. The steel industry was able to deliver pipelines for Alaska and Siberia that could withstand severe Arctic conditions. Steel wherever you look, hidden and yet visible to those who realise its importance.

The alarming words of the Club of Rome and the two energy crises made clear that energy intensive industries like the iron and steel industry faced a great challenge. The introduction of new technologies such as continuous casting of slabs, blooms, and billets, direct rolling of hot slabs in the rolling mill, and maximising use of production gasses and surplus heat has brought tremendous energy savings. Since 1975, the average energy consumption per tonne of steel for the European steel producers that are members of Eurofer has been reduced by almost 40%. The best technology available gives even higher energy reduction figures for individual plants.

When the effects of the energy crisis hit the European steel industry, the economic and social roles of the ECSC again became apparent. A production quota system was announced and controlled by the ECSC authorities. After long deliberations a state of emergency was declared and a reduction of production capacity agreed on in 1983. In 1986 the reductions in production capacity had reached 13% for the former FRG, almost 20% for Belgium, roughly 20% for Italy, about 23% for France and the Netherlands, and 24% for the UK.

This had an impact on employment (Fig. 12); in the EU the number of jobs in the iron and steel industry fell by more than 60% between 1975 and 1993. The labour force in the UK suffered most. The emergency measures for the steel industry in the ECSC were withdrawn in 1988.

The ECSC Treaty will expire in 2002. Given the success of collaboration in R&D, the European steel industry is seeking a way to continue the shared research in iron and steel to improve its position in the marketplace.

### Changing materials market

Although steel is still the major construction material, its relative role in the materials market place is changing incessantly. It is clear from Fig. 13, showing saturation in global crude steel production, that steel is not following the growth in world population and thus steel consumption per capita is falling. However, this reflects increased materials competition and technological improvements in the manufacture and application of steel. Far less crude steel is needed to manufacture products that have high customer demands. Certainly plastics have become a threat to steel, but to form plastic products steel moulds are needed: steel shaping the competition. Aluminium has become another serious competitor, notably because of its light weight and visual presence in high tech applications such as aircraft and aerospace vehicles. But no aerospace production is possible without the steel machining equipment, the cranes and heavy lifting equipment in the factories, and the steel frameworks of the large hangar type buildings, let alone the transport to the launch platform and the launching equipment itself. Aluminium wings keep aeroplanes airborne, but steel landing gear guarantees a safe landing. However, these steel items do not share the glamour of the other metals.

Steel is fighting back and has recently shown its great innovative potential in lightweighting of vehicles. A group of 35 steel manufacturers joined forces under the umbrella of the International Iron and Steel Institute in the Ultra Light Steel Automotive Body project. By combining innovative holistic design and the improved properties of newly developed steel grades, it was proven that the weight of the body in white could be reduced by 25%. Stiffness, crash resistance, and other required properties were equal to those of conventional designs or better.

A further striking example of how the development of new steel grades has enabled advances in technology is found
in civil construction and notably in bridges. Today’s record holder for single span suspension bridges is the 3910 m long Akashi Strait Bridge, one of three links between the Japanese islands Honshu and Shikoku. It has a central span of 1990 m carried by two 1-1 m diameter cable bundles. But perhaps the greatest achievement of all is the middle link, which is a sequence of three linked suspension bridges (Fig. 14).

In June 1999 British Steel plc and Koninklijke Hoogovens NV announced a merger to form Corus Group plc, based in London. Corus is a splendid example of the role of steel in the materials market: not on its own, but together with other metals, establishing a profitable position in a challenging global marketplace. With a new market approach, a sound international manufacturing base, and a highly capable product application focused R&D organisation, the company will set the tone in the materials market of the next century. No longer is tonnage the important parameter; customer focus, market share, profitability, and shareholder values are decisive.

This approach differs fundamentally from the path inventors and steelmaking pioneers were able to adopt, as does the technical, economic, and social environment in which industrial operations are taking place. From being a motor and undisputed leader of economic development, steel has become an essential part of daily life in the knowledge-oriented society at the turn of the twenty-first century. In the same way, from being an almost universal construction material steel has become a member of a large family of materials, each with its own specific merits. But despite the introduction of many other materials, steel remains an indispensable basis of modern society – indispensable to such an extent that it almost seems ‘natural’ and that many of us never actively think of how far it has penetrated daily life, including arts and leisure. And so it undoubtedly will remain for many years to come.

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References

12 International comparison of employment in steel industry (1975–95): 1975 = 100% (Ref. 8)

13 World crude steel production in the twentieth century; source IISI
14 Part of Kurushima Kaikyo bridges linking Japanese islands Hunshu and Shikoko


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