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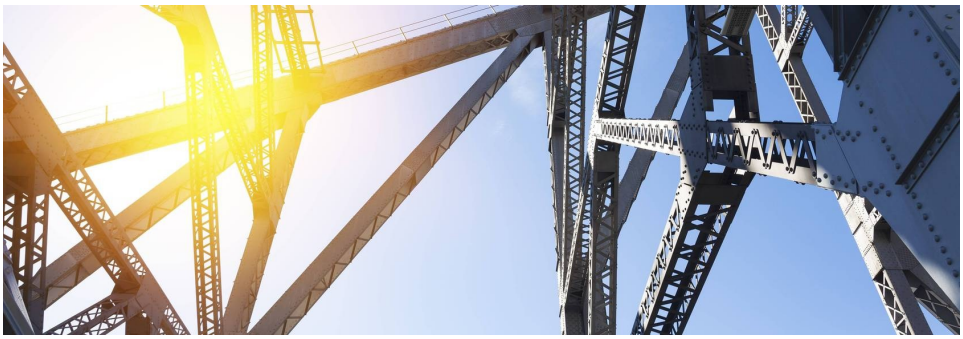
Metallurgy as a driver of the industrial revolution



The metallurgical industry's achievements in the mid-eighteenth century – the introduction of coal and coke – made it possible to increase iron output, as well as to reduce production costs and the prices of metal products for consumers. The accessibility of raw materials made the rapid development of engineering possible. Great Britain became the country where the machine revolution began.

Historically, only charcoal was used to

cast iron

, as both a heat source and reducing reagent . The need for iron was rising, while the amount of local wood was limited. In the mid-seventeenth century, England imported charcoal first from Sweden, then from Russia. Great Britain eventually became dependent on imported raw materials from these countries. Therefore, the salvation and the main innovation in the metallurgical industry from the industrial revolution era was the replacement of charcoal with coal and coke.

Young workers

Precursor

First, mining coal was less labour intensive than felling timber and converting it into charcoal. Second, charcoal has a combustion temperature of up to 1,300 degrees, while coal's is up to 2,100 degrees. Third, there was simply more coal available than wood, which was becoming scarce. Curiously, in modern terms we would call this a regression of sorts, switching from sustainable to unsustainable development. In other words, the renewable fuel (wood) was replaced by a non-renewable fuel.

The first person believed to have attempted to use coal in blast furnace smelting was the English metallurgist Dud Dudley in the 1620s. However, his experiments were of purely scientific value and brought no benefit to either the inventor or metal consumers. Dudley discussed his accomplishments in general terms in the book “Metallum Martis”. The book contains the earliest surviving geological map in the world. According to historical sources, Dudley’s smelting experiments were paid for, among others, by the entrepreneur Sir Clement Clerke.

First a sponsor and then a student of Dudley’s, Clerke too became a pillar of the global industrial revolution and the

modern metallurgical industry

. His primary achievement was the practical experience of using a reverberatory furnace (cupola) . The peculiarity of such a metallurgical furnace is that it isolates the material being processed from contact with the fuel (keeping coal impurities from migrating to the metal) without interfering in the material’s contact with gases. Sir Clement Clerke and his son built reverberatory furnaces in 1678 near Bristol and began to smelt lead and copper using coal, as well.

Assembly of the open-hearth furnace in 1935.

Darby Dynasty

The main protagonist of the revolutionary changes that took place in the metallurgical industry and mechanical engineering was the dynasty of Abraham Darby: grandfather, son and grandson. However, there are some secret connections here, as well. Historians believe that the great-grandmother of Abraham Darby I was Dud Dudley’s sister.

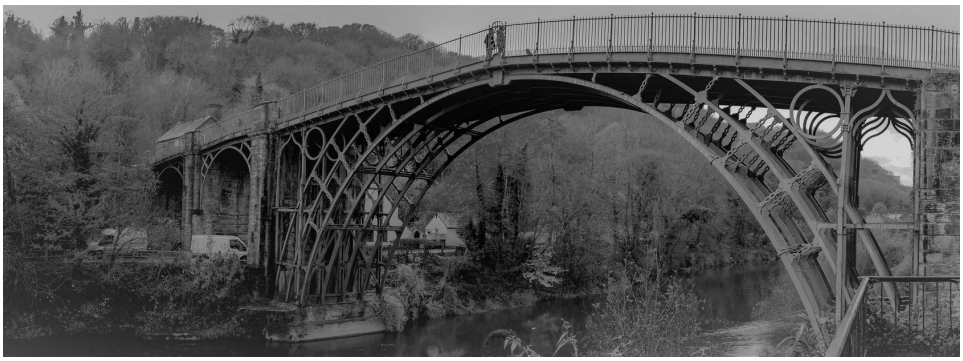
There is also a surprising theory that Darby I has brewers to thank for his main discovery: using coke in blast furnace production. In his early twenties, he got a job as a brewer’s apprentice at a malthouse. Around that time, British brewers began to switch from the traditional charcoal-based malting technology. They discovered how to make a better, harder fuel with fewer impurities: coke. It was obtained by heating coal without air.

At the age of 30, Darby I rented a dilapidated blast furnace in Coalbrookdale, which is in an area rich with iron ore. He refurbished the furnace and within several months brought it to blast; in the first year, he sold more than 80 tonnes of cast-iron utensils and other hardware to metal consumers. Over time, the entrepreneur noted a coal seam that simply surfaced right next to his factory. In 1713, Darby I himself made coke from coal, mixed it with charcoal and peat, put it in a blast furnace and smelted cast iron. Thus began a new era in the metallurgical age.

His son, Abraham Darby II, came up with the idea of using only coke in smelting. This happened in 1735, five years after he took the helm of the family ironworks at the age of 19. Under his guidance, the Coalbrookdale foundry became the absolute leader in pig iron production in Great Britain and for many years was the only company that smelted using exclusively coke. Meanwhile, throughout the country, iron became increasingly inexpensive and affordable. The use of metallurgy in industry to produce parts and machine tools became more widespread. And they, in turn, improved the degree of metal processing. The wheels of the industrial revolution turned faster and faster!

As for Abraham Darby III, he also took over the family ironworks at the young age of 18, entering history as the

builder of the legendary and innovative Iron Bridge.



Darby Cast Iron Bridge

Iron Bridge

A bridge was needed to connect the industrial town of Broseley with the mining town of Madeley and the industrial centre of Coalbrookdale, where the Darby family smelted iron from local iron ore and coke. Abraham Darby III was commissioned to cast and build the bridge out of iron. He agreed, estimating the cost of the project at 3,200 pounds sterling, the equivalent of 380,000 pounds sterling today. Shares were issued, a massive advertising campaign was launched in the press, and the funds needed were raised. There are no known documents detailing what the project actually cost. However, modern records indicate that the estimated cost was almost doubled and that the actual cost was 6,000 pounds sterling (more than 700,000 pounds today). Darby III contributed the missing funds, despite owing large debts to contractors. Within ten years of opening in 1781, the bridge became profitable and was earning the shareholders 8% a year. However, Darby III himself would be repaying his debts for the rest of his life.

The length of the new cast-iron bridge was 60 metres and the length of the central span was 30 metres. No one in the world had the experience of building such large infrastructure objects from iron! Therefore, the bridge features design elements inherent to wooden structures (for example, specific types of joints). Almost 385 tonnes of iron were used on the bridge. It consists of 1,700 parts, all of which were individually cast to match each other. They lack standard sizes and the discrepancy between “identical” components of the bridge is several centimetres.

Of course, compared with steel or wrought iron, cast iron is not an ideal construction material due to its brittleness and relatively low strength. In several cases, bridges and buildings made from cast iron failed rather quickly. However, the first Iron Bridge remained in use until 1935, when it was closed because it could no longer withstand the increasing cargo traffic.

Today, the English Heritage Trust – a charity organisation that manages more than 400 historic monuments, buildings and places in the UK – is undertaking a conservation project estimated at 3.6 million pounds sterling to restore the Iron Bridge to its original state.

Metal consumers

Demand for the metallurgical industry’s products combined with sufficient capital and energetic entrepreneurs quickly made Great Britain a world leader in the metallurgical industry. In 1875, it already accounted for 47% of global production of pig iron and nearly 40% of steel.

Many metal-consuming industries benefitted from the beginning of active development of the metallurgical industry and the reduction of pig iron production costs. As mentioned, the production of nails, hinges , wire and other hardware gradually became cheaper.

Steel mill construction

These metallurgical products began to be widely used to manufacture industrial equipment. New machines made it possible to better process iron, which, in turn, was used to make machine tools. Before their appearance, metalworking was carried out manually, using hammers, files, scrapers and saws. Manual labour was very expensive and time-consuming, and the precision of the parts suffered greatly. This led to the use of metallurgy in industry being minimised.

In this context, it is worth mentioning the boring machine that John Wilkinson developed in 1774, seven years before the Iron Bridge opened. By the way, Wilkinson was both a supplier of raw materials for and the chief proponent of the bridge's construction. However, planning and milling machines were not invented until the early nineteenth century. Therefore, it is not surprising that the lack of serial production of metal parts is considered a serious drawback of the metallurgical products from the time of the industrial revolution.

Technological advances in the metallurgical industry were also vital for the development of rail transport. The first British railways were built and paid for by the owners of the coal mines that they served. Loads were transported by horses or gravitation, while cast iron plates with grooves were used as tracks. In 1767, Richard Reynolds invented the type of rails that we know today. The first public railway using cast-iron rails was built in 1799 in Surrey (it began operating in 1803). Around the same time, the first passenger rail transport began. It was only after 1800 that the conversion of cast iron into soft iron (puddling) and rolling mills became widespread in the metallurgical industry.

Also noteworthy was the use of metallurgical products in times of hostilities. Thanks to the Napoleonic wars and increased demand from the military, as the main consumer of metal products, from 1793 to 1815, British production of iron grew four-fold and Great Britain became the largest centre of Europe's metallurgical industry. Today, the UK ranks 22* in the world in terms of iron and steel smelting.

* data by WSA, 2018