Forging Iron

Iron and steel are perhaps the most useful materials in the history of industrialized society. They are responsible for tools, factories, machines, and many other fundamental components of civilization. Indeed, the widespread use of iron, and later steel (an alloy of iron and small amounts of carbon), made the Industrial Revolution possible.

Together, iron and steel account for 95% of the world's current metal production. Iron is the second most abundant element on Earth (next to aluminum). Most of our planet's core is metallic iron, but on the surface the iron reacts readily with oxygen to form rust, or iron oxide. Hence, very little pure iron is found in rocks, except in meteorites. The ancient Aztecs made implements of meteoritic iron long before Europeans brought the process of smelting to the New World; the Aztecs prized their meteoritic tools above gold.

Iron smelted from rock was probably first discovered in Asia between 4000 and 3000 B.C. in the ashes of fires built on outcroppings of red iron ore. Noting the presence of that reddish metallic substrance, people built bonfires against banks of ore exposed to prevailing winds. These fires were surrounded by boulders and fanned by bellows to increase the heat of the flame; later the people collected the lump iron puddled on the ground. From the metal thus extracted from the rock, they could make new weapons and tools.

Iron artifacts do not last a long time, thanks to extreme oxidation over the centuries, but small items have been found in Egypt's Great Pyramid of Giza (2900 B.C.). Around 1300 B.C., the Hittites, one of the dominant peoples of the ancient Middle East, worked with iron in an area of what is now Turkey. They discovered a "recarburization" process that forced carbon into the outer layers of iron, forming a crude steel. The Hittites' iron was superior to bronze for weapons use, and less expensive than stone for agricultural implements. The iron dagger found in Tutankhamen's tomb was made by Hittites, and later Rameses II asked the King of the Hittites to supply Egypt with iron. Also around this time, the Chinese independently created a blast furnace to remove metallic iron from iron ore.

The Greeks developed iron-making into a sophisticated art. Homer writes that Achilles received a ball of iron as a prize in an athletic conquest. The Greeks passed their knowledge to the Romans, who later carried the techniques throughout Europe. Old examples of Roman cast iron have been found in France, Great Britain, and parts of Eastern Europe.

In early iron-working, iron oxides are reduced when the ore is heated in a furnace. Chemical by-products, called slag, separate from the metal—but iron itself, with its relatively high melting temperature, solidifies around the pockets of slag into a hard spongy-looking mass. The smelter must reheat and hammer this mass several times to force out the inclusions of slag and mold the separated globules of iron into a single lump. The resulting metal is called wrought iron, which is relatively pure (less than 2% total impurities, and only about 0.3% carbon content) but is softer than bronze and does not hold an edge well.

Fashioning this wrought iron into various types of practical implements required the skills of the blacksmith, who became a vital figure in Europe around A.D. 1000. Blacksmiths attached themselves to various ruling groups, under whose patronage they developed their craft. The depth of their skill is evident in European iron armor of this period, in particular, the carefully forged helmets adorned with gold and brass, and other intricate and beautifully worked pieces.

In the 14th century, a larger and more efficient design for a blast furnace—known as the Catalan forge—was developed in Catalonia, Spain. A mixture of charcoal and iron ore was heated intensely for several hours in the forge, fanned by a vigorous blast of air frequently powered by a falling column of water, until the iron became an incandescent blob of metal. At the appropriate time, the smelter broke into the forge and removed the white-hot "sponge" of iron, hammering it to expel as much of the slag as possible. Iron production increased substantially after the invention of the Catalan forge. Its output, cast iron, was made into pots and pans, as well as weapons, especially large cannons.

The only adequate fuel for blast furnaces, however, was charcoal. Charcoal is produced by burning wood chips in a sealed oven that contains little or no air; most of the hydrogen, nitrogen, and oxygen in the wood escapes, leaving only a porous material consisting primarily of carbon, which burns well. Supplies of charcoal eventually became difficult to obtain as nearly all available forest land was chopped clear to satisfy increased demand. Many iron forges were able to operate only a few months of the year.

In 1709, Abraham Darby found a way to replace charcoal in iron smelting by using Britain's abundant coal supply. Previously, coal had never been suitable for iron working because of its high sulfur content, which contaminated the resulting iron. Darby found, though, that if he slowly preburned coal in the same manner wood was burned to make charcoal, the sulfur and other volatiles evaporated, leaving only a dense flammable mass known as "coke." Coke became a crucial alternative to charcoal in iron smelting worldwide.

The first method of making steel—which is much harder than wrought iron—was developed in England in the 1600s. In the "cementation process," wrought-iron bars were packed with charcoal in sealed clay boxes or jars, then heated for days; this step made the iron absorb a small amount of carbon on its surface, turning it into crude steel. Steel produced by this method often had its surface covered with blisters caused by carbon monoxide bubbles working their way to the outer layers; this effect gave cementation steel the nickname of "blister steel."

An alternative cementation method was to stack layers of high-carbon iron with low-carbon iron, heat them, and then hammer them together into a relatively homogeneous mass—this was the technique used in Syria during the Middle Ages to create the famous Damascus steel used in fine sword blades.

Other methods of steelmaking came into use, including the "crucible process" invented in the 1740s by the English instrument maker Benjamin Huntsman, who was trying to create a type of metal for a better clock spring. He decided to cut blister steel into small pieces, then melt the pieces in a closed clay crucible to improve the homogeneity of the carbon (which penetrated only the surface layers in cementation steel). Huntsman skimmed the slag off the melt, then poured the metal into a mold.

Crucible steel was a far superior product, used for making fine steels such as those used in cutlery. But Huntsman's process was expensive, the melts were small, and the work was labor-intensive.

Not until a century later, with the invention of the Bessemer process, was steel produced on a mass economical scale. The next Historical Note will discuss steel and various steel alloys developed in the 19th and 20th centuries.

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