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Steel casting: the process

Continuous steel casting technology was introduced to the Ukrainian steel industry 60 years ago. Interestingly, the continuous casting machine (CCM) commissioned back then, on 30 July 1960 in Donetsk, was the first of its kind in the world. It produced 16.7 thousand tonnes of slabs in year one of operation, and production of 30 steel grades was developed over the first 10 years. Since then, CCMs have become an indispensable part of steelmaking worldwide.

Continuous casting spread amid a technological revolution in steelmaking. Even some 50-60 years ago, open-hearth furnaces (OHFs) dominated the industry, and the smelting process lasted for several hours until the steel had the required properties. In the 1970s, however, producers stopped installing OHFs and began replacing them with basic oxygen furnaces (BOFs) and electric arc furnaces (EAFs), which today account for almost 100% of global steelmaking capacity.

The type of furnace determines the choice of raw materials and composition of the metal produced. The new technologies also affected the number of conversions that liquid steel goes through before it becomes a solid finished product. Although CCMs play a dominant role in the

modern steel industry

, two other casting processes are also used:

- casting steel into ingots;
- making continuously cast merchant semi-finished products.

The process of smelting in OHFs was developed long before continuous casting technology. At the time, almost all OHFs would cast ingots. Liquid steel was first teemed into special ladles and then into moulds to form square, rectangular or round ingots. Steel can be cast into ingots using one of two methods: either top casting, where metal is poured into moulds one by one, or bottom (siphon) casting, where it is cast into several moulds at the same time. Siphoning helps to accelerate the process and improve the quality of semi-finished products. Ingots are then reheated and formed (under pressure) either in slabbing mills (if used as feedstock to make flat products, i.e. plates or coils) or blooming mills (to produce square, rectangular or round billets). Only after that are slabs, squares or rounds transported to rolling mills to make finished

rolled steel

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All of these stages take a lot of time and resources, for example, to reheat and form ingots.

These labour and energy-intensive processes improved dramatically after World War II. In the late 1940s and early 1950s, the first pilot vertical-type CCMs were commissioned, while in 1960, the first machine referred to above was commissioned in Donetsk. Continuous casting technology helped to channel liquid steel directly into the production of slabs, square and round feedstock, which can then be re-rolled into finished products. In the 1970s, radial and curved-mould continuous casters were invented, and they now represent the standard for the technology.

Interestingly the first Ukrainian CCM was operated in tandem with an OHF. However, most of the old steel shops did not have room for the new technology, so new continuous casters began to be widely used together with more efficient steelmaking installations. This meant BOF shops at large steel mills, or EAFs at mini-mills.

Almost all BOF and EAF steel is now cast using the following process: liquid metal is teemed into steel ladles, refined in ladle furnaces according to the required parameters, and then treated in tundishes in the continuous casting area. From the tundishes, metal flows into moulds, where it slowly cools and solidifies into a slab, or square or round shape.

Notably, secondary metallurgy is widely used in today's steel industry. This means that the metal acquires its final properties not through smelting (be it in an OHF, BOF or EAF), but in a ladle furnace. This significantly accelerates the smelting rate, increases production capacity and continuously feeds liquid steel into the continuous caster. According to worldsteel.org, in 2019, continuous casting produced 1.8 billion tonnes of steel goods worldwide and over 11 million tonnes in Ukraine.

What are the advantages of CCMs?

First, the finished products have better quality, physical and chemical properties, geometry, surface quality, and structure. Second, the yield rate improves dramatically: by 15-20%. Third, the costs of energy (gas and electricity) and consumables (refractory materials) are reduced. Fourth, all of these together lower the cost of producing semi-finished and finished steel goods.

Is continuous casting technology so good that it does not have any flaws? Nothing is perfect, of course. Among its disadvantages are lower scrap recovery, which means more work for a mill's procurement department, and higher technology costs. For instance, a new slab caster and related equipment cost Metinvest's Ilyich Steel US$150 million. Such investments are recouped through incremental volumes of high-quality products.

The construction of CCM no. 4 at Ilyich Steel began in September 2016. Austria's Primetals Technologies supplied the equipment, which, alongside a two-strand caster, included a ladle furnace with a modern gas cleaning system, a water treatment plant with reverse osmosis, a filter compensating system and other components. The unit allowed Ilyich Steel to increase its steelmaking capacity and fully meet the needs of the hot strip mill (HSM) 1700 for high-quality concast material.

The new caster can produce some 2.5 million tonnes of cast slabs with a size range of 170-250 x 900-1,550 mm a year. As such, Ilyich Steel can reduce its exports of pig iron and focus on manufacturing high value-added products.

The commissioning of the unit in early 2019 marked an important milestone in modernising Metinvest's steel mills.

According to

worldsteel.org

, around 97% of steel today is cast using CCMs. In Ukraine, while the share is somewhat lower, it continues to grow: from 40% in 2008 to 60-70% in 2020, as most domestic producers stopped ingot casting.

Today only two steel mills in Ukraine do not use continuous casting technology, the largest being Zaporizhstal. They operate twin-bath steelmaking furnaces, which are actually extensively upgraded OHFs. Last year, Zaporizhstal produced over 4 million tonnes of steel. All of the steel is cast into ingots, which then go through slabbing and rolling mills to become finished products, which are in demand both in Ukraine and worldwide.

Is it worth combining OHFs with continuous casting at Zaporizhstal? Most likely, this will not be needed. For several years, Metinvest has been exploring the possibility of building a new BOF shop in Zaporizhia. The plan is to implement an even more sophisticated version of continuous casting: compact strip production. This technology features a whole range of equipment uniting several process stages (conversions). Basically, the plant receives liquid metal and produces hot-rolled flat steel. This process is even more efficient and environmentally friendly than continuous casting, which is already the industry standard both in Ukraine and worldwide.