Unlocking the enigma of molten metal

Looking beyond the zeitgeist leads to higher quality steel.

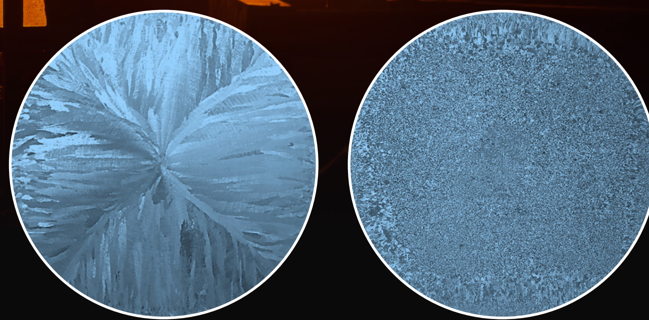
Shanghai University researcher, Qijie Zhai, never cared for trends. When the steel industry rapidly expanded in the 1990s in China, the fashionable research topic was working out how to remove impurities from molten steel. Zhai, instead, turned his attention to the way molten steel solidifies.

"At that time, some people said I didn't understand the zeitgeist," recalled Zhai, now a professor of ferrous metallurgy, and the director of the university's Center for Advanced Solidification Technology.

With extensive industrial and academic efforts, today, the problem of purifying steel is largely resolved. Poor control over the solidification of molten metals is now slowing the industry's progress in increasing efficiency, reducing waste, and improving product quality. After spending three decades singularly focused on the issue of metal solidification, Zhai's team is now well positioned to help steelmakers push past the problem.

Unlike water freezing to ice, it is very difficult to observe the formation of tiny crystals and their subsequent growth throughout hot, opaque liquid steel as it cools while moving through a continuous casting machine. To examine this process, Zhai first established a numerical model that allows him to calculate parameters such as the cooling rate and growth rate of crystals for a given casting process. Zhai then used the parameters to program a laboratory-scale thermal simulator, which can quickly produce small samples of steel with very close solidification structures to that cast at large scale. This can help reveal metal solidification processes and optimize the continuous casting parameters.

While working on the thermal simulator, the question of how to resolve homogeneity of steel billet also weighed on Zhai. Inspiration struck one day when he was preparing a hamburger for his daughter in the microwave. Without referring to the microwave's manual, Zhai heated a frozen burger bun for several minutes. While the bun defrosted, it also turned hard and dry, completely inedible. This sparked an idea in Zhai that perhaps microwaves could aid in metal solidification. While it turned out after a literature search that microwaves don't have the effect, Zhai discovered a report from MIT that electric pulses could be the solution.



The solidified structure of pure aluminum can be significantly refined by Pulsed Magneto-Oscillation (PMO) treatment.

Electric pulses help trigger the formation of numerous tiny crystals in the solidifying regions of molten steel that act as nuclei to refine solidification structure. But electric pulses are difficult to apply because they will be dissolved by the molten steel at a temperature of more than 1,500 °C. Zhai's team then invented pulsed magneto-oscillation (PMO) homogenization technique, which directs electric pulses into an induction coil near the molten steel with no restriction of its high temperature, and promote the nucleation and sedimentation of crystals. They fall, like rain, deep into the regions that remain molten, and refine the final solidification structure.

Today, thermal simulation and PMO homogenization techniques have been adopted by steelmakers such as Ansteel, Baosteel, Zenith Steel, Xinxing Pipes and Suzhou Steel. The thermal simulator helps identify optimal casting parameters before production begins and provides guidance for adjusting parameters if required to improve steel quality, Zhai said. Meanwhile, PMO-aided homogenization brings benefits, such as halving the energy requirement for casting, refining the solidification structure and uniform quality throughout a steel billet.

For Zhai, the steel industry's embrace of his research is the greatest reward. Eyeing needs in the industry, he is now working to use PMO-aided homogenization to enable continuous casting of high-alloy steels and to help reduce wastage when producing heavy ingots. ■

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