TKK Young Scientist Award in Technological Sciences

Forging the Great by the Smalls

By YAN Fusheng (Staff Reporter)

Prof. SUN Mingyue
Key Laboratory of Nuclear Materials and Safety
Shenyang National Laboratory for Materials Science
Institute of Metal Research
Chinese Academy of Sciences

The 2020 TKK Young Scientist Award in Technological Sciences went to Prof. SUN Mingyue from the CAS Institute of Metal Research (IMR), for his innovative technological breakthrough in metal forging, particularly the high-quality heavy forgings.

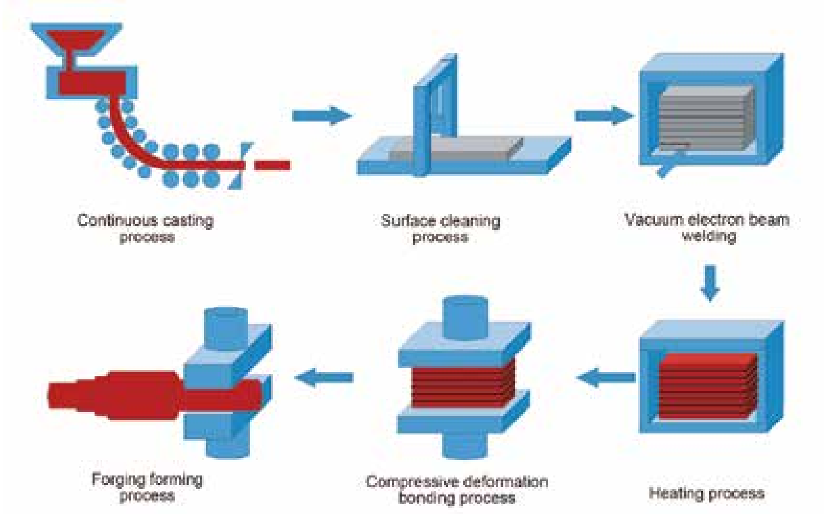
Electricity is the fundamental feed to keep a modern society running, which allows us to turn on the lights after sunsets, open our refrigerators for fresh food, switch on our air conditioners in the hot summer days, power assembly lines to make products; the fact is, we could not image a life, or an economy, without electricity.

To boost the economy and ensure over 1.4 billion people to have access to electricity, China has built diverse sources of power plants to harness heat, hydropower, or nuclear power for electricity generation.

When you walk into these power plants, you will find that they are all equipped with all sorts of bulky metal components (rotors, turbine runners, and pressure vessels etc.) that play indispensable roles. These bulky metal pieces usually serve under harsh conditions, which demands materials with superior physical and chemical properties that could withstand a huge amount or a high degree of radiation, pressure, temperature or corrosion.

Traditionally, these bulky metal pieces, or heavy forgings, are manufactured with bulk ingots that are made by pouring melted metals of more than 100 tons into a big pot and allowing it to solidify slowly. However, the size effect on metal solidification process can cause serious macroscopic segregation, shrinkage porosity and other inevitable defects, and the larger the ingot, the more severe the defects. These defects in heavy forgings, like cancerous cells within a normal tissue, can dramatically deteriorate a forging's mechanical property and thereby cut down its service life, thus posing a worldwide challenge for manufacturing high-quality heavy forgings.

To jump out of the box, a research team led by Prof. SUN Mingyue at the CAS Institute of Metal Research (IMR) first put forward a novel technology, which is termed additive forging, to manufacture high-quality heavy forgings. Inspired by the architecture, the additive forging technology uses small building blocks to form the great, like using the bricks to build The Great Wall.



The route of metal additive forging technology that can forge the great by the smalls. (Image by SUN's Lab)

In a typical go, small-sized slabs are used as the building blocks to forge the great. These metal slabs are of excellent quality due to the significantly reduced size effect. After surface cleaning, stacking, assembling, vacuum packaging, and then deformation by pressure-forging and multi-directional forging at high temperature, homogenized heavy forgings without interface traces can be successfully manufactured. This strategy opens a brand new way of metal forging through forging the great by the smalls.

Through in-depth investigation on the microstructural evolution and bonding mechanism of the interface, Prof. SUN attributed their success to two important behaviors that occur at the bonding interface. One is the dynamic recrystallization that is promoted by repeated deformation under high temperature and vacuum. The newly formed crystals act as rivets to bond the interface. The other contributing factor is that the oxides at the bonding interface can be completely decomposed during additive forging. The elimination of the extremely 'toxic' interfacial oxides significantly improve the mechanical properties of the forged piece, allowing the so-called 'seamless' bonding.

"In fact, shortly after we putting forward this new concept of metal forging, we faced many concerned doubts. A distinguished researcher once highly doubted that this method could be able to forge a solid bond between the slabs. In his opinion, the resultant forging,

The world's first nuclear power stainless steel giant ring (15.6 m in diameter) in one piece was manufactured by additive forging technology. (Image by SUN's Lab)

which just like multi-layer steamed bread, would be easily teared into pieces when serving under harsh conditions," recalled Prof. SUN in a public talk.

However, through a decade of efforts, they successfully applied additive forging to manufacturing hydroelectric alloy steel spindles, large pressure tubes and giant rings. In particular, they manufactured the world's first nuclear power stainless steel giant ring

The ring can easily accommodate over 150 persons standing apart with 1.5-meter spacing. (Image by the courtesy of SUN' Lab)

that is extremely well homogenized in one piece. The one-piece forging technology, in sharp contrast to the conventional approach which requires welding of multiple arched pieces, greatly enhances the ring's mechanical property and cuts the cost at the same time.

As stated by Prof. SUN in *Chinese Science Bulletin*, "this new technology of metal additive forging will play an important role in promoting the rapid development of high-end equipment in China and ensuring the independence and control of core materials for major equipment."