News Release

March 30, 2023

SANYO SPECIAL STEEL

Overcoming Trade-off Between Hardness and Toughness
Innovative High-carbon Steel TOUGHFIT™ Is Commercialized

— Contributing to carbon neutrality through innovation in heat-treatment and high functionality of parts —

Sanyo Special Steel Co., Ltd. has commercialized high-carbon steel TOUGHFIT™, which contributes to achieving a carbon-neutral society.

TOUGHFIT™ overcomes the trade-off of "hard but brittle," which has been thought to be a disadvantage of high-carbon steel, by optimizing the alloy composition and the heat-treatment condition. This is an innovative high-carbon steel that has high hardness and high toughness at the same time.

Using TOUGHFIT™ as materials for wear resistant parts and powertrain parts for automobiles, construction machines, and industrial machines can contribute to a reduction in CO_2 emissions through simplifying hardening heat-treatment and making parts smaller and lighter.

We will expand the applications of TOUGHFIT™ to a wide variety of fields to meet the needs of customers who are aiming for carbon neutrality.

■ Innovative technology that overcomes the characteristic trade-off

High-carbon steel containing 0.6% or more carbon obtains a surface hardness of 700 HV or higher through hardening heat-treatment such as quenching and tempering, and also exhibits excellent wear resistance and fatigue strength. It is used for powertrain parts as typified by various wear resistant parts and gear shafts. On the other hand, hardness and toughness have a trade-off relationship, and increasing hardness (strength/wear resistance) decreases toughness (crack resistance and shock resistance) or it is simply expressed as "hard but brittle," which has been a serious disadvantage of high-carbon steel.

The business-academia cooperative team consisting of Sanyo Special Steel, Komatsu and Osaka University (Note: Nagoya Institute of Technology has taken over this part and is currently working on the research) has focused on the fact that hard parts made of high-carbon steel are likely to generate cracks along crystal grain boundaries (intergranular fracture) inside the steel and has conducted research to eliminate this problem. Consequently, this team found the alloy composition and the heat-treatment condition that strengthen the fragile crystal boundaries of high-carbon steel and additionally optimize the crystal grain structural condition, which led to commercialization of high-carbon steel TOUGHFIT™ that has overcome the trade-off between hardness and toughness. With a high hardness state of 700 HV after quenching and tempering, this steel exhibits approximately a ten times higher toughness value compared with conventional steel material with a similar hardness. (Figure 1)

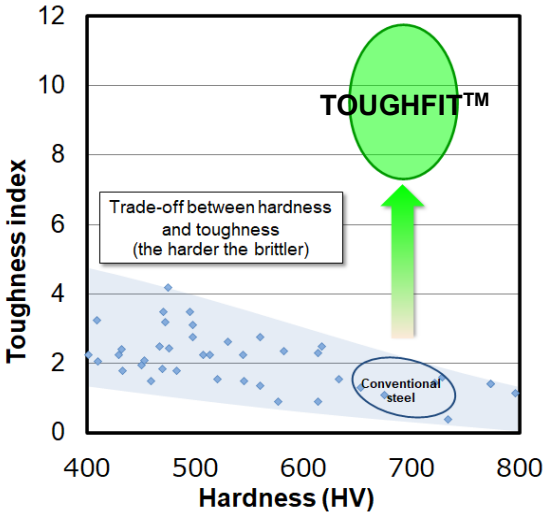

Figure 1: Relationship between hardness and toughness of steel

■ Practical use in the market: application to wear resistant parts for construction machines

Komatsu, one of the partners in the business-academia joint research on this steel, after various tests and verification procedures, put TOUGHFIT™ to practical use as a cutter ring material (Figure 2) for tunnel boring machines, which require high wear resistance and toughness. Since then, TOUGHFIT™ has demonstrated its excellent performance and the number of favorable use cases is increasing.

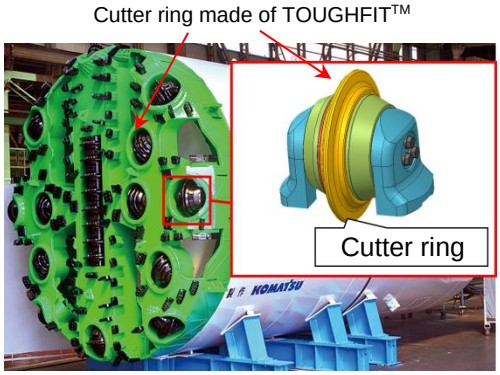

Figure 2: Appearance of Komatsu-made tunnel boring machine and a cutter ring form

Cutter rings for tunnel boring machines are required to have not only an extremely high hardness and wear resistance but also high toughness that ensures no fracture even when subjected to large impacts in order to cut through hard bed-rock and large amounts of sediment.

■ Future expectations for contributions to achieving carbon neutrality

- **Innovation in the heat-treatment of parts: reduction in CO_2 emissions by ridding the process of carburization**

In manufacturing powertrain parts such as bearings, gears and shafts used for automobiles, construction machines, and industrial machines, gas carburizing and quenching heat-treatment is often used to harden only surfaces of parts in order to secure impact resistance against a sudden shock and also to improve wear resistance and fatigue life that affect the service life of parts. However, the gas carburizing heat-treatment discharges a large amount of CO_2 when diffusing carbon into the surface of the part by the equilibrium reaction between the surface and carburization gas. For this reason, employing an alternative hardening heat-treatment method with reduced CO_2 discharge is called for in terms of carbon neutrality.

The hardness of TOUGHFIT™ can be increased without reducing toughness using the quenching heat-treatment (though hardening) without carburization. Applying TOUGHFIT™ will contribute to reducing CO_2 emissions in steel part manufacturing processes.

- **High functionality of parts: reduction in CO_2 emissions by making parts smaller and lighter**

Because applying TOUGHFIT™ with both high hardness and toughness improves the fatigue life of various powertrain parts, their sizes and weights can be designed to be smaller to improve gas mileage, which will reduce CO_2 emissions to contribute to achieving carbon neutrality.

Sanyo Special Steel will expand the applications of TOUGHFIT™ as a powerful solution to meet the social needs when people strongly desire to achieve carbon neutrality steadily.

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