Topics

Ultra High Modulus Steel Reinforced with Titanium Boride Particles

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THE OBJECTIVE

Many machine parts are designed to have the optimized dimensions in order to ensure a necessary rigidity under actual stress conditions. It is difficult for conventional structural steels to achieve any further weight reduction of the parts while maintaining their rigidity, because of the fixed Young's modulus of about 200GPa.

Since a rotating part also requires high-speed and low-vibration characteristics, Young's modulus is the most important material property for the resonance frequency.

The purpose of this study is to develop a high modulus steel which has an excellent specific Young's modulus, and also has both practical mechanical properties and manufacturing availability.

THE CONCEPT AND ART

A high isotropic Young's modulus in metallic materials is achieved only by incorporating reinforcing phases with a higher interatomic binding force. Binary carbides or borides of the transition metal elements are the most likely candidate phases. However, a thermodynamically unstable phase often reduces the Young's modulus by transforming into a ternary compound or producing a large amount of solid solution of the matrix elements. Especially, for steels, low modulus carbides are known to be stable, and there has been reported no dramatic improvement in Young's modulus by incorporating the hard phases/particles into steel matrix.

The authors have verified titanium boride (TiB_2) to be the best reinforcement for improving the Young's modulus of steels because of its thermodynamic compatibility with the carbon-free steel as well as its low density and high Young's modulus[1-2]. An unique manufacturing process has also been developed in which fine TiB_2 particles are synthesized using a low-cost raw material. With this, we have shown that the established processes are applicable in making TiB_2-reinforced High Modulus Steel (HMS) parts[3].

THE YOUNG'S MODULUS OF DEVELOPED HMS

Fig. 1 shows the relationship between Young's modulus, specific Young's modulus and the TiB_2 content of the HMS having the Fe-17Cr alloy matrix, compared with calculated values. These values continuously increase with increasing TiB_2 content and agree well with the calculation. This means that TiB_2 maintains its own Young's modulus (550GPa) in the matrix and effectively contributes to the improvements. Furthermore, the specific Young's modulus is improved more remarkably because the average specific gravity becomes lower by incorporating low density (4.53g/cc) particles.

For the conventional melting and casting method, the HMS containing lower than 25vol% TiB_2 would be manufacturable, and it is above 40vol% in the sintering process. Such an "Ultrahigh" Modulus Steel has a Young's modulus over 300GPa, and the specific value is greater than double that of conventional steels.

A cast or sintered HMS bar is hot-worked to make machine parts with the necessary mechanical strength. **Fig. 2** shows examples of the trial parts. The final development is now being promoted with the aim of establishing manufacturing conditions to satisfy the necessary properties for these parts.

References

1) Tanaka K.,Oshima T. and Saito T.: Tetsu-to-Hagane, **84**-8(1998), 586
2) Tanaka K. and Saito T.: J. Phase Equilibria, **20**-3(1999), 207
3) Tanaka K.,Oshima T. and Saito T.: Tetsu-to-Hagane, **84**-10(1998), 747

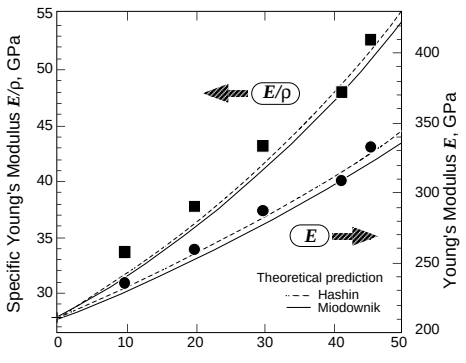

Fig. 1 Change in Young's modulus of HMS vs. TiB_2 content.

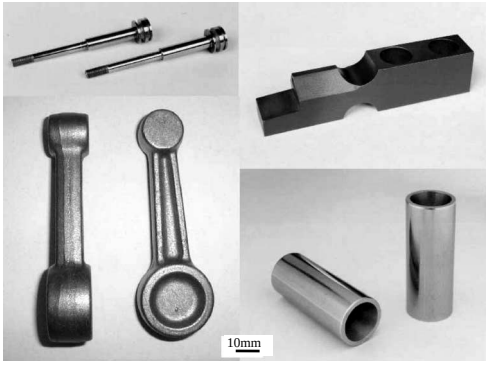

Fig. 2 Trial HMS parts.

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