学 位 論 文 要 旨

Fabrication of Copper Plated Carbon Fiber Dispersed Iron Matrix Composites and Thermal Conductivity Calculation by Two-Dimensional Microstructure Images

(銅めっき炭素繊維を添加した鉄基複合材料の作製と二次元微細構造画像を用いた熱伝導率の計算)

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Carbon fiber (C_f) contacts and reacts with pure iron, and C_f requires electroless copper plating to protect C_f from being destroyed. Copper-coated carbon fiber (C_f -Cu) can establish thermal conduction channels in composite materials to accelerate heat transfer. The time of heat conduction accounts for 1/3 of the cycle of hot stamping die production of auto parts. The addition of C_f -Cu can accelerate the heat conduction of SKD61 (40CrMoV5) alloy, improve the thermal conductivity (TC) of the composite material, and quickly produce thinner and higher strength (≥1000MPa) auto parts, which can not only effectively reduce the weight of the car body, reduce fuel consumption, improve vehicle safety and comfort, and can reduce molding pressure, reduce deformation and wear, and prolong the service life of the mold. C_f -Cu is highly anisotropic, and its orientation has a strong influence on mechanics and TC. Controlling the orientation of C_f -Cu becomes the core of improving the TC of composite materials. The impurity atoms in the SKD61 (40CrMoV5) alloy, the voids created by the fabrication of the composite, the orientation and aspect ratio of C_f-Cu, and experimental errors all hinder heat conduction.

This study (Chapter 2) firstly explored the mechanical properties and TC of C_f -Cu/Fe composites. When the sintering temperature was less than 1100K, C_f -Cu was not destroyed and carbides were not formed. When the volume fraction of C_f -Cu in the composite increased from 20% to 30%, the relative density decreased sharply with the increase of C_f -Cu, and the mechanical properties and TC of the composite decreased. In Chapter 3, 5-25vol.% C_f -Cu/Fe composites were hot-rolled to align most of the C_f -Cu along the direction of heat flow and improve the TC of the composites. The mathematical model of C_f -Cu in three-dimensional space was established, and the relationship between the orientation of C_f -Cu on the two-dimensional section and the orientation in three-dimensional space was obtained. By 2D image analysis, the simulated TC of the composite shows good agreement with the measured TC. In Chapter 4, various factors hinder the heat transfer in 5-25vol.% C_f -Cu/Fe composites were investigated. By comparing TC calculated from ROM, EMA model, 2D image analysis, and steady-state method, the degree to which the voids, aspect ratio, and orientation of C_f -Cu and experimental errors affect TC was determined. The main factors hindering TC are the aspect ratio and orientation of C_f -Cu. For 20% C_f -Cu/Fe, the contact thermal resistance and the decrease of TC of negative C_f -Cu offset the increase of TC of positive C_f -Cu, and both the simulated and measured TC reached the maximum value, 68.89 Wm for $^{-1}K^{-1}$ and 71.02 $Wm^{-1}K^{-1}$, respectively. In Chapter 5, in order to improve the TC of SKD61(40CrMoV5) alloy, considering the void, aspect ratio, and orientation of Cf-Cu (Chapter 4), 2D image analysis (Chapter 3) was used to evaluate the TC of C_f -Cu/SKD61 (40CrMoV5) composite. Compared with the SKD61 (40CrMoV5) alloy, the TC of the C_f -Cu/SKD61 (40CrMoV5) composite was increased by 91%. This thesis lays the foundation for the study of C_f -Cu reinforced metal matrix composites TC. The TC of the composite material of SKD61 (40CrMoV5) can be effectively improved by adding C_f-Cu.