

Manufacturing and thermal properties of steel–carbon fibre/polyetheretherketone (CF/PEEK) hybrid shafts using laser-assisted in-situ consolidation

Zequan DING, Congcong LUAN, Xinhua YAO, Lingyu CHENG, Yuyang JI, Chengcheng NIU, Ningguo DONG, Kai ZHAO, Zhibin RUAN, Jianzhong FU

Cite this as: Zequan DING, Congcong LUAN, Xinhua YAO, Lingyu CHENG, Yuyang JI, Chengcheng NIU, Ningguo DONG, Kai ZHAO, Zhibin RUAN, Jianzhong FU, 2025. Manufacturing and thermal properties of steel–carbon fibre/polyetheretherketone (CF/PEEK) hybrid shafts using laser-assisted in-situ consolidation. *Journal of Zhejiang University-SCIENCE A*, 26(10):917-930.
<https://doi.org/10.1631/jzus.A2400437>

Research background

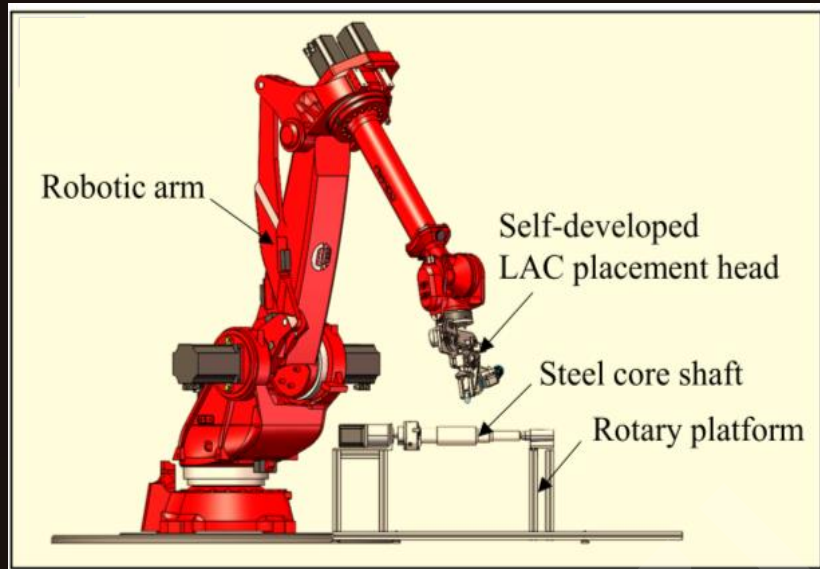
Thermal deformation of rotating machinery

The shaft thermal deformation of rotating machinery (such as precision machine tools) seriously affects the accuracy, and about 40%-70% of the manufacturing error is generated. Traditional methods such as passive cooling, thermal structure optimization design and thermal error compensation are effective, it still urges controlling thermal deformation from the design source.

Carbon fiber reinforced Polyetheretherketone (CF/PEEK) material properties

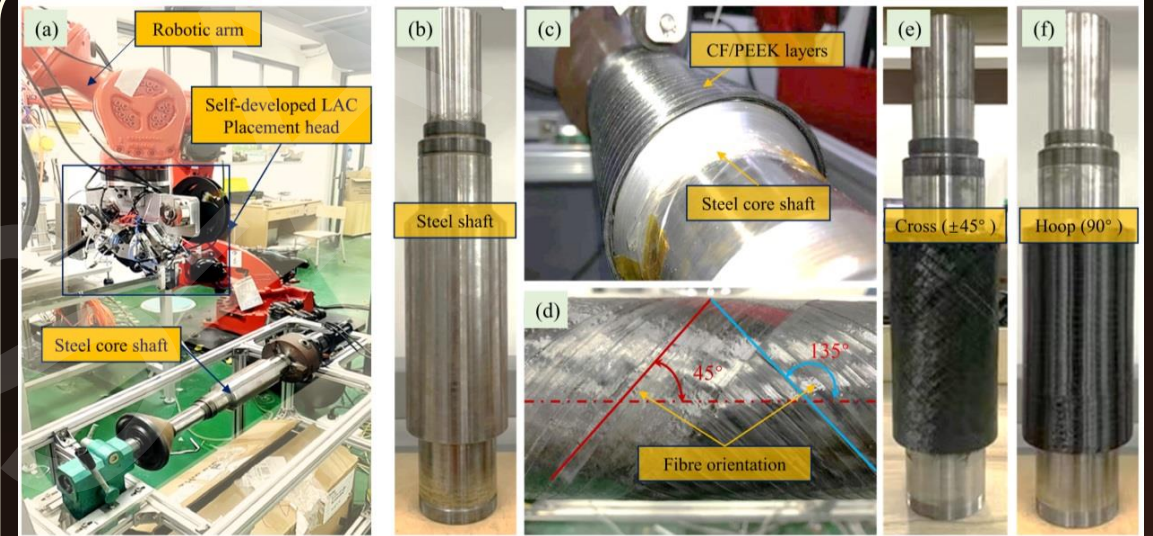
CF/PEEK (carbon fiber reinforced polyetheretherketone) has high thermal stability, negative thermal expansion coefficient and high rigidity, which is an ideal material to improve the axial thermal properties, but its high melting point and viscosity bring challenges to manufacturing.

Research innovation



The laser assisted in situ consolidation (LAC) process and equipment were developed to solve the interface bonding problem caused by peek high melting point and viscosity, and realize the close connection between steel and CF/PEEK.

Laser-assisted in-situ consolidation (LAC) process



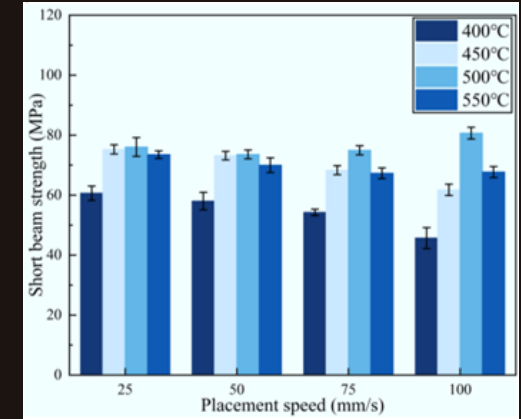
A self-developed deformation/temperature measurement platform was established to study the surface temperature distribution and thermal deformation characteristics of steel CF/PEEK hybrid shafts with different fiber orientations in detail, providing theoretical support for the design of hybrid shafts.

Influence of fiber arrangement on thermal deformation of hybrid shaft

Optimization of process parameters

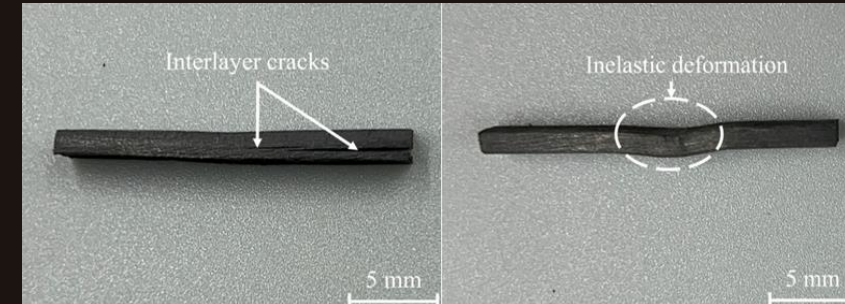
Determination of optimal parameters

Through the short beam shear (SBS) test, the optimal parameters were determined as the laser heating temperature of 500 °C and the placement speed of 100 mm/s. At this time, the SBS strength of CF/PEEK reached 80.7 MPa.

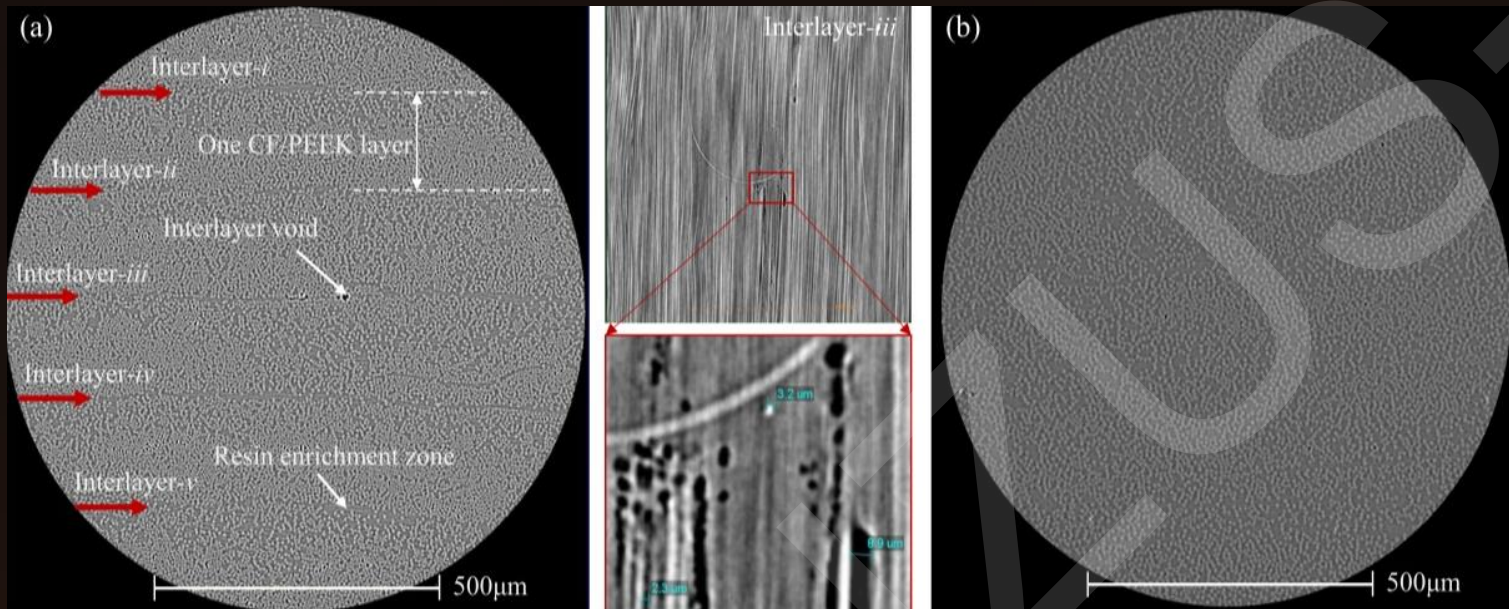


Failure mode analysis

Two failure modes were observed: interlayer cracks (SBS < 65 MPa) and inelastic deformation (SBS > 65 MPa), the latter related to higher SBS.



Internal quality inspection



Before optimization

After optimization

Porosity detection

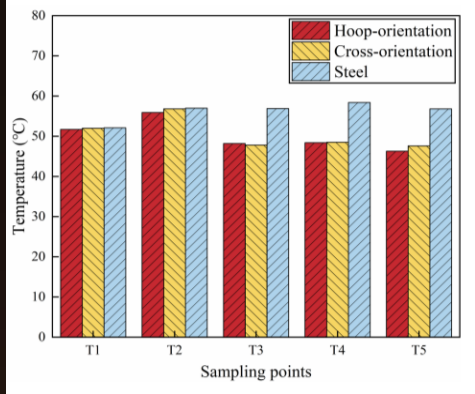
The internal defects and porosity of CF/PEEK samples were detected by X-ray tomography. Before optimization, there were defects such as uneven distribution of resin fibers and interstratified voids. Under the optimal parameters, the porosity of the sample was only 0.01%, and there was no obvious resin enrichment area, so the quality was reliable.

Thermal characteristics of hybrid shaft

01

Surface temperature distribution

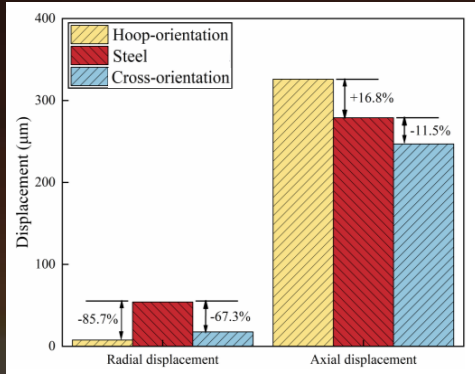
Compared with the steel shaft, the surface temperature of the steel-CF/PEEK hybrid shaft was significantly reduced, and the temperature of the CF/PEEK coverage area was reduced by 14.7% -18.2%. The surface temperature distribution of the cross fiber orientation axis was more uniform.



02

Thermal deformation characteristics

Compared with the steel axis, the axial deformation of the cross fiber orientation hybrid shaft was reduced by 11.5%, the radial deformation of the circumferential fiber orientation hybrid shaft was reduced by 85.7%, and the cross fiber orientation hybrid shaft was reduced by 67.3%.



Conclusions

Advantages of hybrid shafts

The steel CF/PEEK hybrid shaft performs well in inhibiting thermal deformation, significantly reducing radial and axial deformation, and improving the accuracy and stability of rotating machinery.

Process reliability

The results of LAC process parameter optimization and internal quality inspection show that this process can produce high-quality mixing shaft, and has broad application prospects.