CompoTech
Carbon Composite Components

The benefits of composites for milling tools and spindles

A CompoTech Technical Article

Introduction

The use of carbon fibre-reinforced plastics (CFRPs) is very widespread in motorsports and the aerospace industry. The exceptional stiffness and lightweight of these materials make them ideal for enhancing the performance of Formula 1 cars and high-speed jet aircraft.

Less widespread is the use of CFRPs for the production of machine tools. The same properties that make these materials so popular in high performance applications can impart significant benefits in this arena too, especially for load-bearing and structural components, or for precision movements.

In particular, the use of CFRP parts can help to improve the speed and acceleration and deceleration of a machine tool, especially over extended distances. The accuracy and repeatability with which, for example, a tool set can be returned to exactly the same location, operation after operation, can have a significant impact on productivity and, through a reduction in weight, operating life.

To highlight the benefits of the use of CFRPs in such applications, CompoTech recently developed a steel-composite hybrid milling tool that, in testing, has been shown to perform faster and machine more accurately than conventional options. The tool also imparts improved surface roughness meaning that, in certain circumstances, it can perform the job normally requiring two steel tool sets, for rough and final machining. This increases milling productivity, decreases machining time and reduces machining cost.

The hybrid milling tool is produced by depositing carbon and graphite fibre onto a steel part using a process called robot assisted filament laying (RAFL). The steel body acts both as a mandrel and as a means of connecting the tool to the tool holder and the tool holder to the spindle. It also provides a means for the attachment of the tool to the milling teeth.

After fibre placement, the part is cured at room temperature to reduce the likelihood of any thermally induced stress. It is later machined to its final shape.

The reduction in weight, up to 40%, and the increased stiffness provided by the use of graphite and carbon fibres enhances the damping properties. As well as increasing the natural frequency of the tool, reducing unwanted vibrations in the machining process, it gives the tool greater stability.

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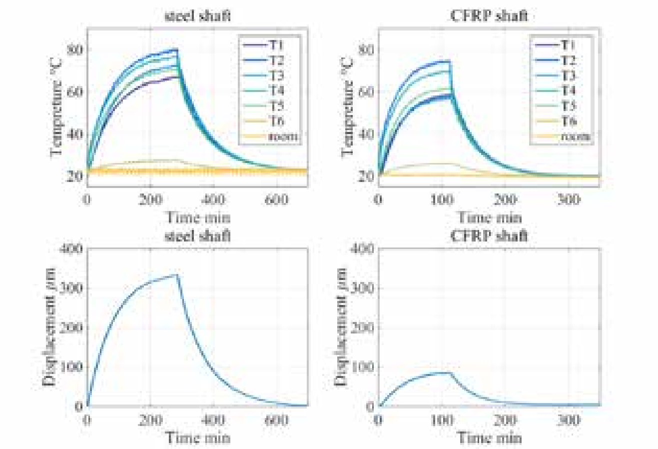
The low weight of the milling tool means that less energy is used in non-loaded positioning, while the lower inertia reduces peek energy in acceleration. Unfortunately, this can also reduce wear on parts of the machine, meaning that the lifetime of the machine and the durability of the tool tip can be increased.

CompoTech is also using composites to produce motor spindles. These are usually hybrids; steel is used for the bearing surfaces and threads and is combined with a composite laminate designed to modify a specific property of the tool, for example, its weight, stiffness or coefficient of thermal expansion in axial or radial direction (CTE). The CTE of the fibre is close to zero (in fact slightly negative), while the ability to lay the fibres in a specific direction in a laminate can be used to advantage by controlling the direction in which the part behaves as operating temperatures fluctuate.

Professor Atsushi Matsubara of the Department of Micro Engineering at Kyoto University in Japan has carried out a detailed study of the behaviour of such spindles with CFRP shafts. His recent research - currently submitted for publication - has yielded some encouraging results. It has shown, for instance, that the shaft of the hybrid spindle is 70% lighter in weight than a steel version of the same design and the spindle demonstrates 75% less displacement when heated to 70˚C.



Comparison of steel and carbon spindle. Temperature measure along the spindle and resulting displacement over time.

Furthermore, the damping behaviour of the composite spindle is 16 times better than the steel version.

In application testing, Professor Matsubara has also shown that the hybrid spindle accelerates to its maximum rotation speed of 18,000rpm 17% faster than a steel spindle, owing to its lower inertia. Finally, and most importantly for machining operations, the stability limit curves that he measured showed that twice the limit chip thickness could be safely achieved at a wider range of spindle speeds. The comparison of the two-stability limit curves for the steel and CFRP-shaft spindles clearly showed that the cutting depth could be increased from 5.5 to 10mm.

Carbon fibre is significantly more expensive than steel or aluminium, which might be enough to deter some machine designers from considering the use of CFRP parts. However, modern manufacturing methods and considered design can be employed to narrow this cost gap significantly.

As we have seen, the performance benefits of the use CFRP tools for machinery manufacturers can be significant, far outweighing any increase in initial cost over the lifetime of the tool.