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Rotor Shafts in Modular Design for Electric Trucks

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Modular Rotor Shafts in Electrified Trucks

With a view to lightweight design, Hirschvogel has developed a modular, multi-part hollow shaft concept for power ratings in the range of 140 to 360 kW. A holistic approach was taken, which not only reduced weight, but also optimized the manufacturing process and saved resources.

As a rule, lightweight design solutions bring advantages in terms of consumption and resources. Particularly in the commercial vehicle sector, a weight-reduced electrified powertrain can increase the available payload or the vehicle range. In the case of vehicles that require a design with several traction motors, this weight advantage is multiplied accordingly.

The rotor shaft, as a central component of the electric motor, must be able to withstand high rotational speed, have low imbalance and demonstrate high strength due to the loads that occur during operation. For power ratings in the range of 140 to 360 kW, Hirschvogel has now developed a multi-part concept for rotor shafts. The goal was to achieve a modular design and optimize weight. Hence, the forging was given a near-net-shape geometry and hollow semi-finished products were used in the area of the rotor seat. Compared to a solid shaft design, weight savings of up to 9 kg can be achieved, depending on the component type. The modular concept allows different component designs to pass through the same manufacturing process, resulting in production that is more efficient and uses fewer resources.

In practice, this is accomplished by a three-part component design, consisting of two end pieces and one center piece, **FIGURE 1**. The forged and pre-machined end pieces are joined to the tubular center piece by means of a laser welding process and then fine-machined.

With this design, different power ratings can be achieved by varying the length of the center piece. The parts used for the end pieces largely match each other, differing only slightly in terms of machining, **FIGURE 2**.

On the one hand, this keeps development times low; on the other hand, the use of matching end parts minimizes the number of tools needed. As the measures implemented for this shaft clearly demonstrate, the aim for all rotor shaft types is to find synergies

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in the development cycle for attaining sustainable process design and thus to pursue a holistic approach across all processes. The factors influencing development in this regard are outlined below.

HOLISTIC APPROACH

When designing the process for the new rotor shaft concept, a holistic and sustainable approach was taken, **FIGURE 3**, which forms the basis for future developments. This is because, alongside technical considerations, other aspects such as rising raw material prices, supply bottlenecks and scarcity of resources are playing an increasingly decisive role in component development. Thus, it is not only important that the functional product requirements are fulfilled, but also that material use is designed with maximum efficiency across the entire process chain. In addition, it is necessary to find the optimum process from the available options in terms of forging, heat treatment and machining.

One advantage of the new approach is that several production processes as well as different materials can be combined, depending on the customer-specific requirements. The aim here is to achieve the necessary component properties where they are actually needed. Thus, for components such as splines or gears that are subject to great stress and have high strength requirements, it makes sense in general to use high-strength alloys and suitable heat treatment processes. For less stressed areas, component-specific, cost-effective materials and less complex processes can contribute to resource efficiency throughout the entire process chain.

Furthermore, it is crucial to consider the entire value-adding chain, **FIGURE 4**. This is because early involvement in component design and development may make it possible to completely dispense with separate heat treatment steps. After all, the increase in strength by means of cold forging often already meets the required mechanical demands, rendering energy-intensive hardening processes unnecessary. In the specific application case, the early involvement allowed the variants to be developed as a modular concept.

Another effect is that the near-net-shape design of the forging can lead to a reduction in machining volume and thus material use. As alloyed quenched and tempered steels are often used for rotor shafts, this material saving not only leads to a resource-efficient process, but also offers potential cost reductions for the customer.

Last but not least, this holistic approach offers a flexible machining concept, involving optimum and sustainable utilization of production capacities and covering not only large series scenarios but also small and medium series production – in the commercial vehicle and passenger car sectors alike.

TWOFOLD FUNCTIONAL INTEGRATION

While the electric motor has clear advantages in terms of efficiency when compared directly to the combustion

FIGURE 1 Principle of the modular rotor shaft concept: three-part component design (© Hirschvogel)

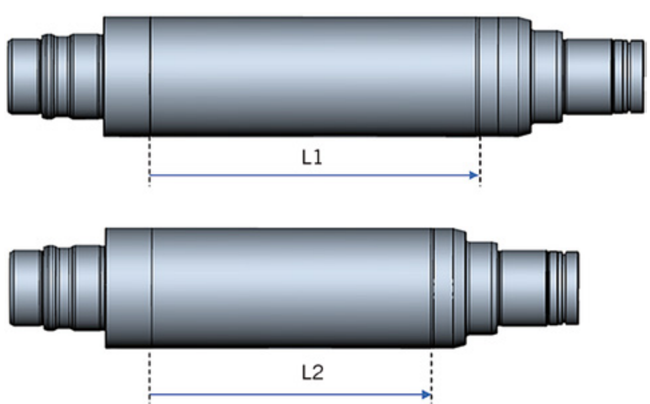


FIGURE 2 Variable length of the center piece for achieving different power ratings (© Hirschvogel)

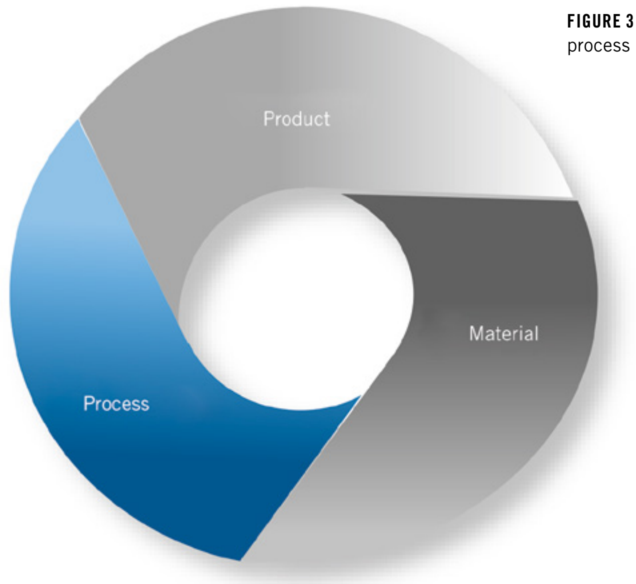


FIGURE 3 Core factors for holistic process design (© Hirschvogel)

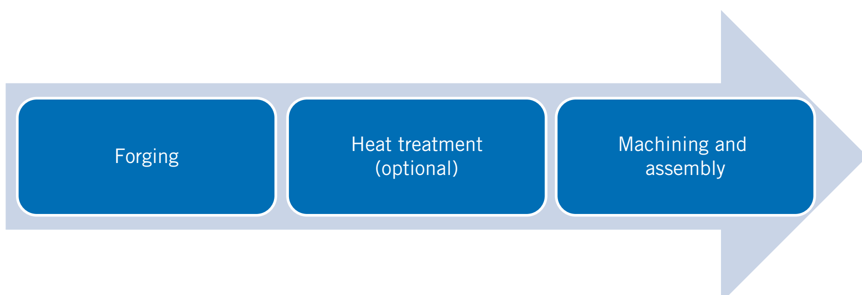


FIGURE 4 Diagram showing the core processes for rotor shafts (© Hirschvogel)

engine, there is certainly room for improvement in terms of range. The rotor shaft has a valuable function in two areas in particular, namely for motor cooling and for connecting the lamination stack.

An electric vehicle can be operated with high efficiency if the motor temperature is kept within the optimum range. For this reason, various cooling concepts have become established on the market in recent years. Internal rotor cooling is now strongly represented, **FIGURE 5**. This is based on the principle of using the assembly space available inside the rotor shaft to conduct the cooling medium through the shaft in a targeted manner and to dissipate the heat generated in the rotor. Due to the integrated cooling function, the rotor shafts increase the efficiency of the motor and therefore make an added contribution to sustainable mobility. Such cooling concepts are implemented in series production at Hirschvogel.

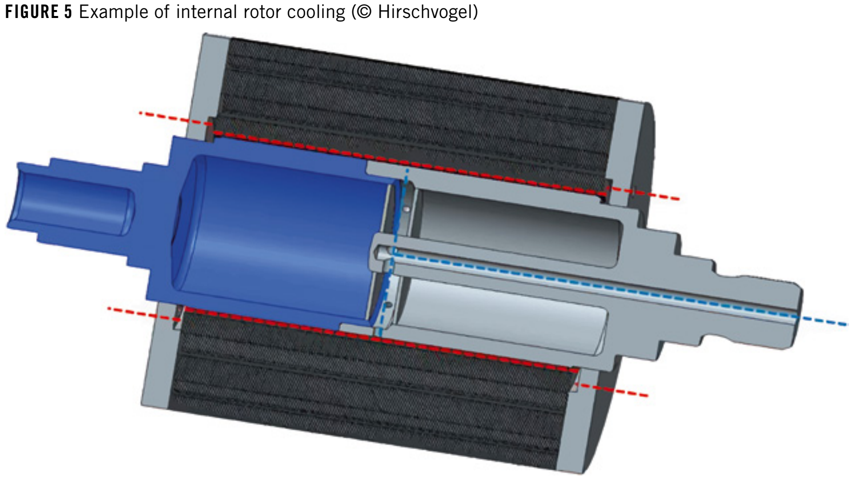
With heightened demands on motor performance (speed and torque), the connection between the rotor shaft and the lamination stack is becoming increasingly important in component design – both from a technical standpoint and in terms of manufacturing costs. The high-temperature joining processes predominantly used today are associated with significant manufacturing costs and plant investment. The StackFix cold joining process proposed by Hirschvogel [1], for example, can offer significant savings potential when it comes to manufacturing costs, while at the same time meeting high-performance requirements. Furthermore, it can both save energy and reduce CO_2 emissions. **FIGURE 6** shows the various design options for mounting the lamination stack to the rotor shaft.

CONNECTION TO THE REDUCTION GEAR

For the connection of the rotor shaft to the reduction gear, Hirschvogel offers all common spline and gear possibilities in a ready-for-assembly design. Internal or external splines can be manufactured by machining or forging, depending on customer requirements, **FIGURE 7**. A special capability is the forging of a spline in a blind hole – a process that would not be economically feasible using a machining operation in large series production. The forged spline offers additional advantages in terms of strength and, in some applications, can mean that separate hardening of the spline is rendered unnecessary thanks to process-related strain hardening.

Alternatively, instead of splines, a gear can be milled inhouse for the transmission connection. Already today, shafts are supplied to customers in a soft pre-machined condition. If required, these

FIGURE 5 Example of internal rotor cooling (© Hirschvogel)



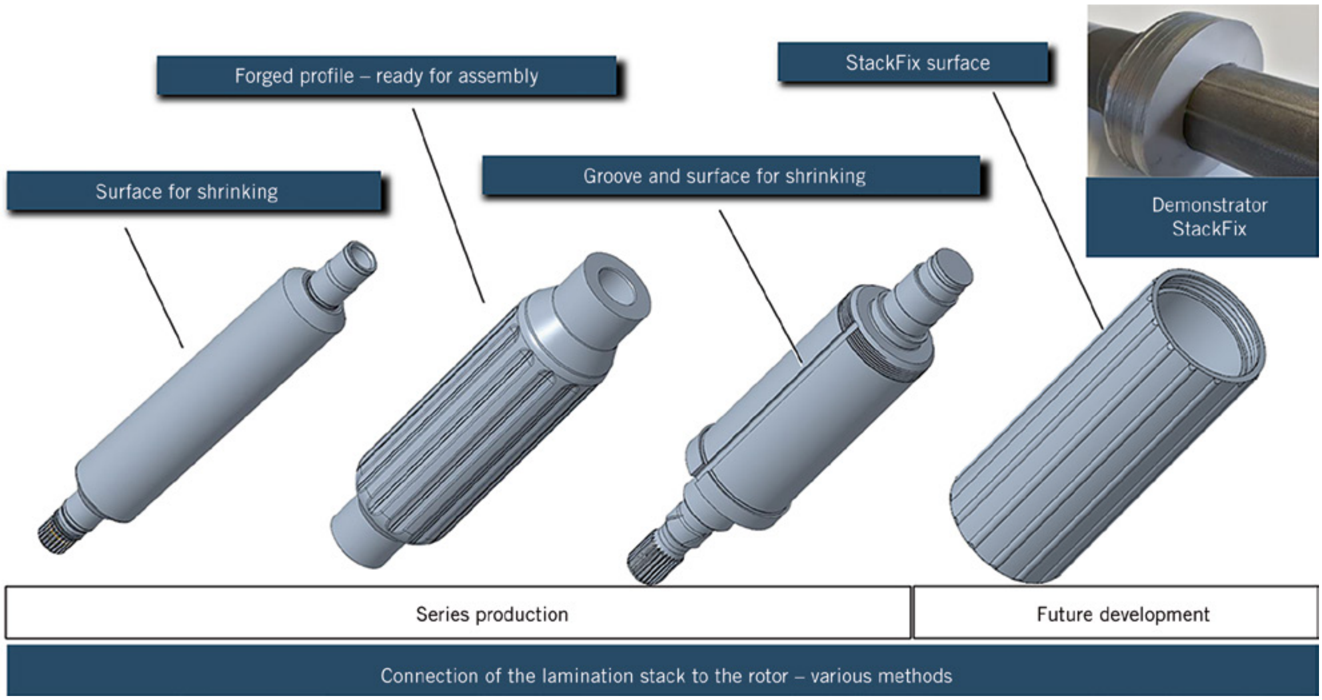


FIGURE 6 Connections between the rotor shaft and the lamination stack (© Hirschvogel)

FIGURE 7 Rotor shafts with different splines/gears for the connection to the reduction gear (© Hirschvogel)

components can also undergo heat treatment and hard finishing by means of grinding or honing to render them ready for assembly.

SUMMARY

Hirschvogel has developed a process by means of which ready-for-assembly commercial-vehicle rotor shafts can be designed in a modular way according to motor performance classes, produced in a resource-efficient manner and, as a lightweight design solution, used to achieve increased payload. In this way, depending on component type, weight savings of up to 9 kg have been achieved. The first truck rotor shafts already went into series production at the end of 2022.

REFERENCE

[1] Heizmann, J.; Linder, G.: Increasing Performance Through Forged Components. In: ATZheavyduty 01/2019, pp. 54-57

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