PRESS RELEASE

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Electric motor housings reliably enter large-scale production

The number of vehicles with electric drives being produced is increasing alongside the importance of electric mobility. Although electric motors per se are nothing new, the automotive industry is currently entering uncharted waters in terms of both their use as means of propulsion for vehicles and their large-scale series production. Being a technology partner to its customers, MAPAL has devised a number of innovative machining systems, including some for the complex machining of electric motor housings.

MAPAL provides innovative solutions for machining tasks

Design variant and performance requirement - these two keywords point the way in the development of electric motors.
The development of electric motors is clearly moving towards integration. Modern designs encase the electric motor, power electronics and gearbox in one central housing. When used as drive systems in vehicles, electric motors need to maintain their performance across a wide range of temperatures. Weight and efficiency play a major role. Highly automated, large-volume production that is as cost-effective as possible is another factor in the automotive industry.

Scalability of the requirements

Internal combustion engines have been optimised to suit these criteria for decades. Things that are commonplace for these engines and related components are now presenting new challenges when it comes to components for electric motors. Comparing an electric motor housing to a grearbox housing illustrates this fact: The housing for an electric motor needs to be manufactured within much tighter tolerances than a gearbox housing, as accuracy is pivotal in determining the efficiency of the motor. Furthermore, the electric motor housing usually has much thinner walls than a conventional gearbox housing owing to its integrated cooling

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channels. There are also bearing bushes pressed into some of these housings. This results in mixed machining, which is not easy to master.
Although these aspects can often be managed without too much difficulty in prototype production, they present a real challenge in large-scale production. That applies not only with regard to ensuring compliance with all tolerances, but also in terms of process costs. In addition to the bearing bore, machining the stator bore is especially challenging with its a large diameter and considerable depth.

How the machining approach affects tool design

Due to their bell-like shape, the thin-walled electric motor housings are prone to natural oscillation. For this reason, and because of casting-related stresses in the part, particular attention needs to be paid to the clamping setup and the various machining operations. During clamping setup for the part, it should be ensured that the radial forces are low so that the eventual outcome of machining, especially the cylindrical form, is not negatively affected.

Whereas the radial stock removal at the bore entrance is roughly 0.5 mm, the draft angles caused by casting result in material build-up measuring up to 13 mm in diameter forming at the bottom of the bore. This results in significant machining forces acting on the part and the tool, and these need to be taken into account in process and tool design.

Moment of tilt: a limiting factor

It is not unusual for stator bores to measure up to 300 mm in diameter. Machining this type of bore cost-effectively therefore calls for large tool diameters and long tool projection lengths. At such proportions, both the weight of the tool and its moment of tilt have a decisive impact on the machining process and can be limited by the requirements of machine tool and tool gripper. The tools should therefore be made as lightweight as possible.

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One possible means of reduce weight and moment of tilt comes in the form of special tool designs, for example with innovative, additive manufacturing methods and the resulting ultra-lightweight designs. This not only enables customisable cooling channel design, but also allows enormous amounts of weight to be saved as a result of the geometric freedom that it opens up and the option to have hollow interiors.

Multi-machine approach recommended

Thanks to the weight savings, it is possible to devise machining approaches for smaller machine connections, such as the HSK-A63. After all, only comparably low-weight tools with large diameters can be machined on less powerful equipment. Meanwhile, to make it easier to machine large diameters on machining centres with smaller tool connections, it is possible to reduce the number of teeth on the tool and thus the machining volume or the cutting torque. However, that comes at the expense of cycle time.

These options are particularly important because most of the existing machining centres in the automotive industry are fitted with HSK-A63 connections. One way of meeting the new requirements for parts for electric vehicles is to retrofit existing machine pools accordingly. A multi-machine approach is recommended for many machining processes. With smaller spindles, it is possible to work more flexibly and up to 15% more quickly than with HSK-A100 spindles. In ideal cases, machining centres with HSK-A63 connections should be used for all-round machining; for machining stator bores, however, machines with HSK-A100 connections are preferred. In each case, the connection on the machine side has a fundamental impact on tool design. That is because the number of teeth on the tool in question is chosen on the basis of the maximum possible torque and cutting power. As a general rule, the greater the number of teeth, the shorter the cycle times and the more powerful the machine and spindle need to be.

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Requirements to the machining process

Machining of the housing is ultimately subject to tight tolerances with regard to

the concentricity of the bearing and stator bores,

the perpendicularity of the bores to the reference surface

the roundness and cylindrical form of the stator bore and bearing seat.

In addition to the tolerances, the Al-Si alloys usually used for electric motor housings impose particular requirements on the machining process. Depending on the composition, machining these alloys can sometimes produce very long chips. However, these are undesirable for any machining process and must be avoided as they may result in wear on the part and tool as well as an increase in torque or the temperature of the part. The temperature of the chips is usually in excess of 100 degrees Celsius, and the heat needs to be extracted along with the chips. To meet this requirement reliably, MAPAL has used the finite element method (FEM) to develop special chip guiding stages and chip breaker geometries.

Another challenge involved in highly accurate housing machining is that of parts becoming distorted due to differences in temperature. These are far from rare owing to the thermal expansion characteristics of aluminium. For example, when the temperature changes by 5 °C, a solid shaft with a diameter of 219 mm will expand by 0.026 mm. That may not seem very much at first glance, but it is actually quite a lot given the tolerances that need to be complied with during machining. This expansion roughly corresponds to the full diameter and shape tolerance of an electric motor housing. Fluctuations in temperature can be reduced if an emulsion cooling lubricant is applied or, in some cases, via the appropriate chip removal if minimum quantity lubrication is used. Adjusting cutting parameters and feed rates is another option.

Tool design

MAPAL has developed various designs for tools that meet the aforementioned requirements which are used on a daily basis. These include lightweight and yet stable tools in welded design that are highly suited to machining the thin walls of the

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housing. For the welded designs, the tool body takes the form of a tube. One of these tools weighs just half as much as a conventional boring bar. The carriers for the cutting edges and guide pads, if applicable, are welded on and support each other by means of connecting ribs. This minimises the risk of chattering. It also ensures that support is provided in the event of interrupted cuts. The bending section modulus is excellent thanks to the tubular design and the stabilising ribs. Despite long projection lengths and large diameters, the tools are highly accurate. To achieve this, the MAPAL specialists use extensive analyses based on the finite element method (FEM) to investigate coolant distribution, machining forces, torque and moment of tilt.

The machining process and the tools are custom-designed to suit the dimensions, machine pool and clamping setup in question. This helps to minimise the cutting forces working on the part. The process of machining the stator bore is split into three stages – pre-machining, semi-finishing and fine machining.

Pre-machining: Vorbearbeitung: High material removal rate with economic machining values

In most cases, the machine tool is the critical factor in the design of the tool for pre-machining the stator bore. In the machining process that MAPAL recommends, the first choice is a boring tool with cartridges and PCD-tipped indexable inserts. This tool is that it achieves a high material removal rate very quickly and thus cost-effectively because it allows work at high cutting speeds and feed rates. However, using this tool requires a machine with high maximum torque and power to match.

If such a machine is not available, the alternative is to pre-mill the stator bore. MAPAL offers an ISO helix milling cutters with PCD-tipped indexable inserts for this very purpose. Although this tool can also be used to work with very high cutting speeds and feed rates, the machining time is much longer than it is with boring on account of the longer machining stroke.

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Semi-finishing and finishing: Ensure highest precision

In designing the tool for semi-finishing, MAPAL also focuses on the torque and power of the machine. This stage of machining involves pre-machining the complex contour definition of the electric motor housing so that finishing the complete contour including chamfers and radial transitions is possible in one machining step. For this stage of machining, MAPAL recommends a precision boring tool with PCD-tipped ISO indexable inserts.

The final stage involves machining the stator bore to micron precision with a fine boring tool, also a welded design. The PCD-tipped indexable inserts are finely adjustable, which helps to maximise accuracy. The tool is fitted with guide pads to provide the best possible support in the bore.

Bearing bore: Challenge of mixed machining

With some types of housings for electric motors, a steel bushing is pressed in for the bearing for the rotor shaft. The seat for the bushing is machined first and a bushing is pressed in the further course of the process. Because of the tough requirements for the concentricity of the bearing and stator bores, both bores are then fine machined with a combination tool. This involves one stage of the tool being used to machine the steel bushing and the rest to machine the stator bore out of aluminium at the same time. This is referred to as mixed machining and presents tool manufacturers with a number of challenges. Firstly, the steel chips need to be kept reliably away from the aluminium area. Otherwise, there is a considerable risk of damage to the surfaces of the component and the PCD guide pads on the tool. And secondly, the two materials differ in a fundamental way and have to be treated differently – in the choice of cutting speeds or the estimated end of the tool life.

A special chip guiding stage, the appropriate coolant supply and open chip spaces of the MAPAL machining solution ensure that the steel chips are reliably conveyed forwards. The aluminium chips, however, are routed backwards by means of a

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specially designed flushing mechanism. The MAPAL tool is also fitted with a protective plate that ensures that the steel chips are kept in the front area (see picture below, tool 3).

But how to work with the differing cutting speeds and tool lives? The specialists recommend 800 m/min for machining aluminium and 200 m/min for steel. And whereas PCD-tipped cutting edges can be used to machine aluminium on 6,000 to 8,000 aluminium parts, the tool life of the cutting edges, usually Cermet, for machining steel is at 250 to 300 parts. Indexable inserts are the solution in this case. Both insert types can be replaced on-site and can be fully used to the end of the respective tool lives.

Machining options for deep bores with large diameters: MAPAL solutions 90 percent faster

MAPAL recommends to machine large diameters with boring and fine boring. Besides, there is yet another option for machining stator bores: finish boring. In the application example, two finish boring tools with one PCD-tipped insert each for roughing and finishing machine a stator bore with a part length of 200 mm, a target diameter of 220 mm and a blank diameter of 215.7 mm. The productive machining time is around five minutes.

In the machining process recommended by the MAPAL specialists with boring and fine boring, the tools feature eight and four PCD-tipped cutting edges. Instead of five minutes, machining takes just under 0.48 minutes and is therefore much more efficient. The system with three different machining steps is already being used in practice and delivering good results. The required, tight tolerances for concentricity, roundness and cylindrical form are reliably maintained to within just a few micrometres even in large-scale production.

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Captions:

As a technology partner to its customers, MAPAL offers innovative machining solutions for complex machining of the electric motor housing.

Special chip guiding stages and chip breaker geometries ensure a process-reliable breakage and removal of the chips.

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Numerous analyses were carried out during the development of welded designs as a fine boring tool.

MAPAL covers the entire process for the complete machining of electric motor housings.

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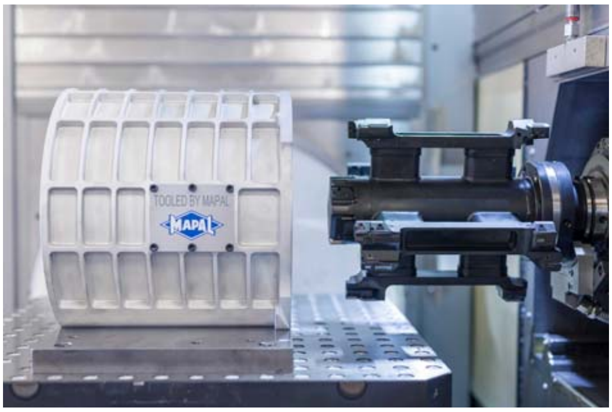
MAPAL recommends a process with three steps for machining the stator drilling – pre-machining, semi-finishing and fine machining.



Using a fine boring tool as a welded design, the main bore of the central housing is machined to an accuracy of a few µm.

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