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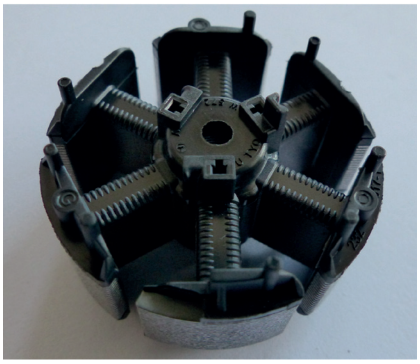
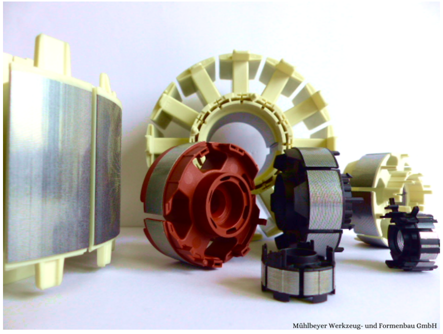
Injection mold for the production of stator insulation

In our modern world, when something rotates or moves at the push of a button, electric drives are usually at work. In industrial environments (machines, apparatus, chemicals, paper, material processing, textiles, food, stone/earth, plastics), electric motors make manufacturing processes effective and efficient. Electric motors have also become indispensable in transport (train, automobile, ship, aircraft), household appliances, farming and consumer goods. Even during the production of electric drives in large-scale series production, electric motors enable a highly effective and efficient manufacturing process that enables a very good price-performance ratio to be achieved.
The essential components of a simple electric motor are: Rotor (rotating electromagnet), stator, pole reverser or commutator (only for DC motors), brushes, coil and shaft. The rotor is the moving part of the motor and moves between the two poles of the stator.
Depending on the type of electric drive and the type of electrical winding, electric drives can be divided into two main components from the power generating point of view. The so-called lamination package serves to guide and locally concentrate the magnetic field lines. The electric winding generates the magnetic field.
The lamination stack of an electric motor consists of thin sheets of a soft magnetic material with thicknesses of approx. 0.10 mm to 1.20 mm, depending on the machine type and size. The two-dimensional shape of the rotor or stator is punched out of these sheets by means of punching tools. The sheets are stacked in axial direction and are electrically insulated from each other to minimize the influence of eddy currents.
The winding of an electric motor consists of copper wires of various types: stranded wire, flat wire, profile wire, fine wire, drilling wire, braided wire, bake varnis wire or standard wire with insulating layer and, if necessary, with lubricant coating. The wires are electrically insulated from each other and from the sheet metal package, regardless of the type of winding (distributed or concentrated winding). With regard to thermal load capacity, the winding insulation represents the weak point of the electric motor. Thermal materials have operating temperatures of up to 250 °C. At the same time, the copper conductors represent by far the largest heat source due to current heat losses. This means that the power density depends on the thermal load capacity of the insulation and on the ability to dissipate the heat loss.
For conducting the electricity, the insulation materials are just as important as the conductor materials. The large number of available insulation materials makes the selection as well as the summarizing presentation very difficult. This is partly due to the various requirements, such as high dielectric strength, high tracking resistance, good thermal conductivity, high temperature resistance, good chemical resistance, high mechanical strength and low costs. Since these goals are difficult to reconcile, specially adapted insulation materials are selected according to priority.
The insulation materials used have a direct influence on thermal conductivity, voltage reliability

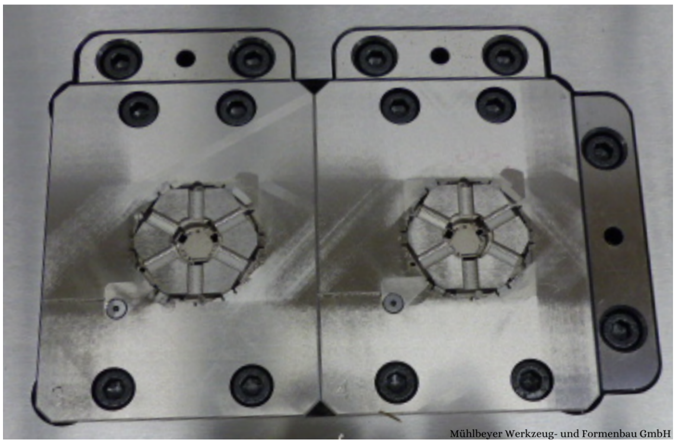


1/ Plastic-coated stator (PPS)

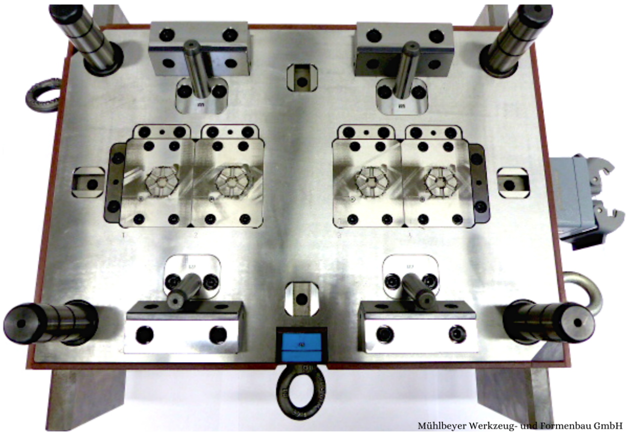
2/ Plastic-coated rotor



3/ Different plastic-coated stators

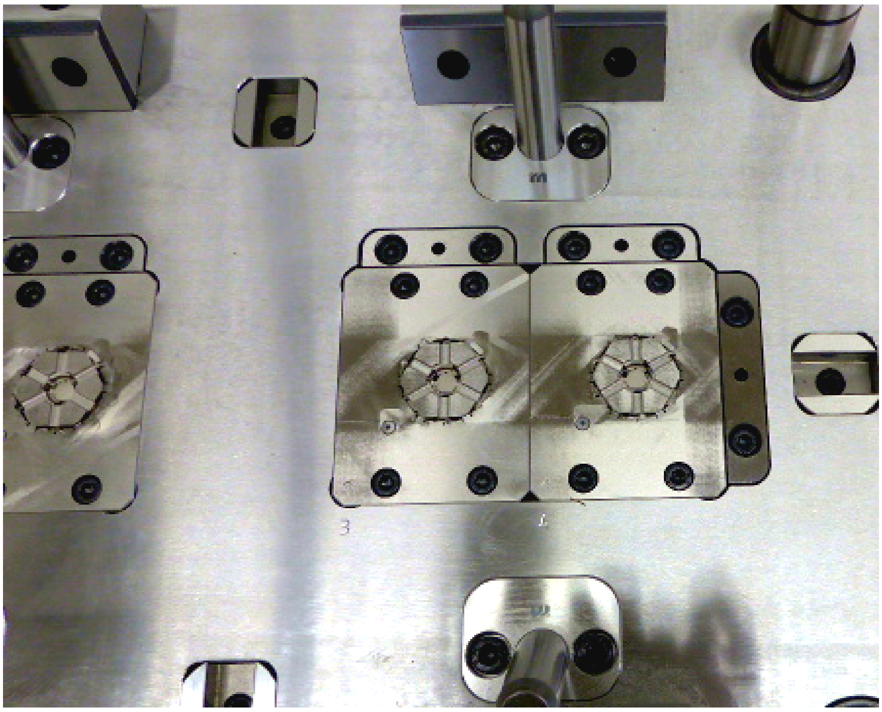


4/ Injection mold 1-fold nozzle side for plastic-coated Stator



5/ Injection mold 4-fold nozzle side for plastic-coated Stator

and especially on the geometric design of the motor. Thus, insulation thicknesses and creepage distances have to be provided by design.
The load-compatible design of the electric motor's insulation system must be observed. Among other things, the voltage distribution under different operating conditions must be analyzed and various insulating materials must be characterized.
In the case of plastic-coated stators/stator segments, in addition to the slot insulation and the base plate for the installation of the stamping package, technical functions such as track ribs for wire transitions, pole pocket insulation, plug shafts for contact parts, deflection pins, passages for wire guides, pole shoe inner flanges, clearances for screw heads, inlet and outlet slots are also incorporated.
The plastic selected for the insulation of the stator segments, the stator, the rotor or the fan impeller essentially influences the design costs of the injection mold. A plastic, such as a polyamide (PA), which requires a mold temperature of 80 - 100 °C, causes far lower costs than plastics, such as polyphenylene sulfide (PPS), which requires a mold temperature of approx. 150°C, or such as polyetheretherketone (PEEK) and polyetheretherketone (PEK), which even require a mold temperature of 240 °C and more. At high mold temperatures, standard components such as sensors, actuators, magnets for inserts, complete all-round insulation of the injection mold, the hot runner, more complex slides (burr formation), etc. become significantly more expensive.
Furthermore, the corrections for the plastics PPS, PEEK and PEK are much more complex, since the viscosity (burr formation on the spotting surfaces) is higher than for PA. The burr formation can lead to partial discharges in high-voltage insulating bodies or even wire damage, winding errors. With compounds such as glass fiber or mica, the flow behavior is negatively influenced. Therefore, an injection molding simulation (mold flow analysis) should be performed if possible, if a faulty design due to wrong assumptions should be avoided. Possible error patterns of the injection molded part could be: incomplete injection, weld line defects, etc. In the simulation, additional flow aids, overpourings, multiple connections etc. can be introduced and simulated if necessary. Flow aids are additionally introduced at those



6/ Main use of an injection mold for plastic-coated stator
(Pictures: MÜHLBEYER Werkzeug- und Formenbau GmbH, Bad Friedrichshall, Germany)

points that do not influence the function of the electric motor. This can be e.g. at the groove insulation surface in the direction of the center inner yoke ring, which is not touched by the winding. Flow conductors can also be realized by means of holes with a diameter of a few millimeters through the lamination stack of the rotor or stator. These flow conductors support the material flow of thermoplastics and promote the complete filling of thin-walled sections.

In the injection mold, compensation of the punch package tolerances must always be taken into account (up to 0.8 mm) in order to ensure the process. Due to the winding technical design, smallest geometries (e.g. radius 0.1mm) are necessary to deposit the winding wire. The surface roughness is required for the inclined winding / grooves and prevents the winding from slipping. Of course, this requires that the plastic insulation material also does this.

Inserts such as permanent magnets, sheet metal packages, ... need to be precisely positioned in the injection mold, their position must be clearly defined during injection molding. The higher the positioning accuracy of the inserts, the lower the imbalance. This means that the asymmetrical distribution of the rotor mass is advantageously reduced. The reduction in unbalance in turn has a positive effect on the efficiency of the electric drive, while at the same time reducing noise and component wear. Furthermore, the precise positioning of the sheet metal stack or the base body in the injection mold can improve the tolerance chain in radial, circumferential and longitudinal direction.

Further challenge in the construction of the injection mold is the definition of a functional flow chart for the injection mold. This ensures the function and position of the inserts. The wire guidance must be guaranteed. The different overall heights of the stators and rotors due to different sheet metal stack heights must be realized by means of a mechanical height compensation in the injection molding plant. The injection point or injection points must also be determined so that complete filling and low distortion of the plastic coating are ensured. A complete filling is essential to eliminate any possibility of dielectric failure during operation. A further challenge for the injection mold design is the partly required cleanliness of the outside and inside of the yoke ring. Here, too, design measures must be taken. The processing of the individual components of the stator or rotor injection molding tools is always a challenge. For example, in our recently built tool, which is used for the production of rotors and stators of electric motors, magnets have been inserted in addition to the stamping packages. This required molds made of a material that is not magnetic. This is why MÜHLBEYER chose the non-magnetizable material ferrotitanium for this tool. During the first attempts to mill this material, which at 48 to 53 HRC is not particularly hard but is very wearresistant due to its titanium carbide and austenite structure, the milled chips welded together in the milling cutters. Therefore, special milling cutters had to be used for ferrotitanium. Additional clamping devices were also built, because magnetic clamping technology fails in all manufacturing technologies for the steel material.

Our tool technology for plastic-coated lamination stacks and inserts is an added value for customers in the field of stators and rotors for electric motors (current-excited or permanently magnetized).
We offer injection molds for technically sophisticated assemblies and components made of high-quality thermoplastics, thermosets and elastomers for the automotive, railroad, wind power, drive, electrical, control, air conditioning, plant and automation industries:

- Stator insulation - overmolded with plastic, stamped lamination packets for electric motors e.g. with the plastics PET (e.g. Rynine), HTN (e.g. Zytel), LCP (e.g. Zentite, PA46 with up to GF50 (e.g. Stanyl, PPS with up to GF50 (e.g. Fortron), Peek etc.)
- conventionally overmolded rotors and segmented rotor disks (for lightweight engines)
- Plastic components for electrical motor insulation
- Blower wheels, diagonal impellers, impellers - radial and axial, one-piece compact impellers made of plastic, high-precision and low-balance impellers for automobiles, household appliances and technical articles, technical housings and covers

One of our focus areas is the construction of overmolding tools for stator insulation and rotor insulation. The advantages of overmolding technology compared to conventional paper insulation are

- only one injection mold is required for the entire insulation (slot insulation and face insulation, end plates with numerous additional functions)
- improved thermal conductivity
- facilitated motor winding
- cost efficiency

Additional advantages for secondary overmolding of stator teeth after application of the winding

- Contour for sealing the winding wires
- no damage to the insulation
- high winding density with small dimensions
- additional fixation of the winding + heat dissipation with suitable high heat conductive plastic (PPS, Peek etc.) through second plastic coating

We offer injection molds for:

- twisted and non-twisted external rotors for stators/rotors with overmolded Plastic insulation (punch package height up to approx. 90 mm, thin-walled insulation 0.50 mm)
- twisted and non-twisted internal rotors for stators/rotors with overmolded Plastic insulation (punch package height up to approx. 90 mm, thin-walled insulation 0.50 mm)
- single or double overmolded stator segments, so-called stator teeth
- Stators with overmolded ball bearing / sintered bearing
- Stators with switching disk and cover cap for perfect coordination of the individual components to ensure optimal and automated assembly