Design of PCB Coils for Precision Engineering Linear Drives

Introduction

Aiming at high forces and low space requirements in linear direct drives, favorable heat transfer conditions and high copper filling factors of the coils are of central importance. For this reasons coils are mainly made of round copper wire and subsequently casted with epoxy or impregnating resins, to increase stability and thermal conductivity. However, there are alternatives such as coils with rectangular wire, casted coils or printed circuit boards (PCB) coils.

A commonly used drive in industry is the ironless linear drive based on the principle of the Lorentz force. Fig. 1 shows the design of a homopolar linear direct drive with permanent magnetic field and moving coil as armature.

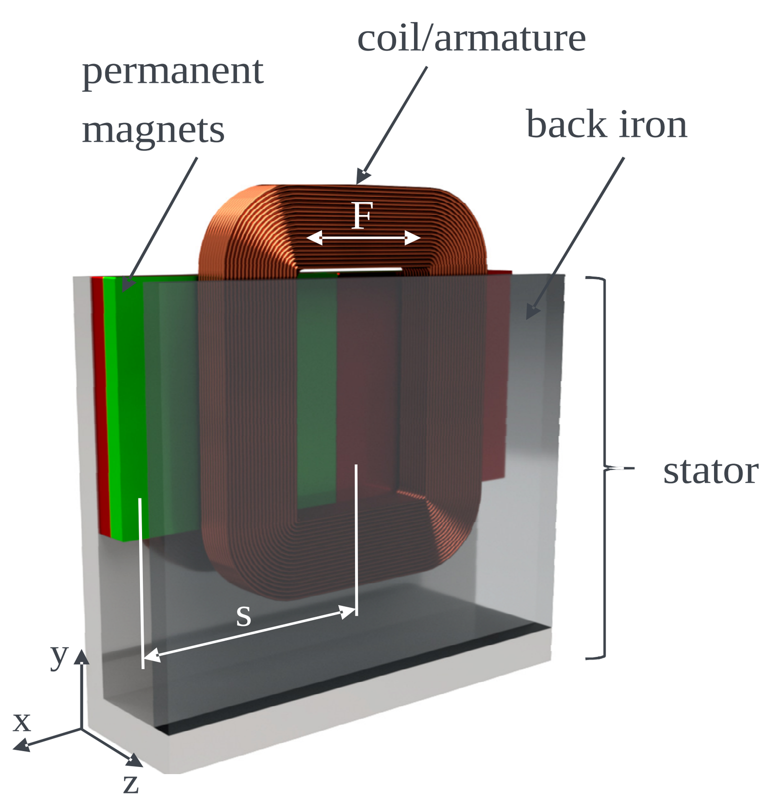

Fig. 1: Linear direct drive

Using an additional displacement measuring system and a closed loop control, high positioning accuracy and high dynamics can be achieved at the same time.

Foldflex PCB

The Foldflex PCB, a special type of PCB manufacturing, is first structured in double layer construction and sealed with solder-stop. Afterwards, the PCB is folded at intended bends and glued together in the last step to a multilayer PCB, as shown in Fig. 2.

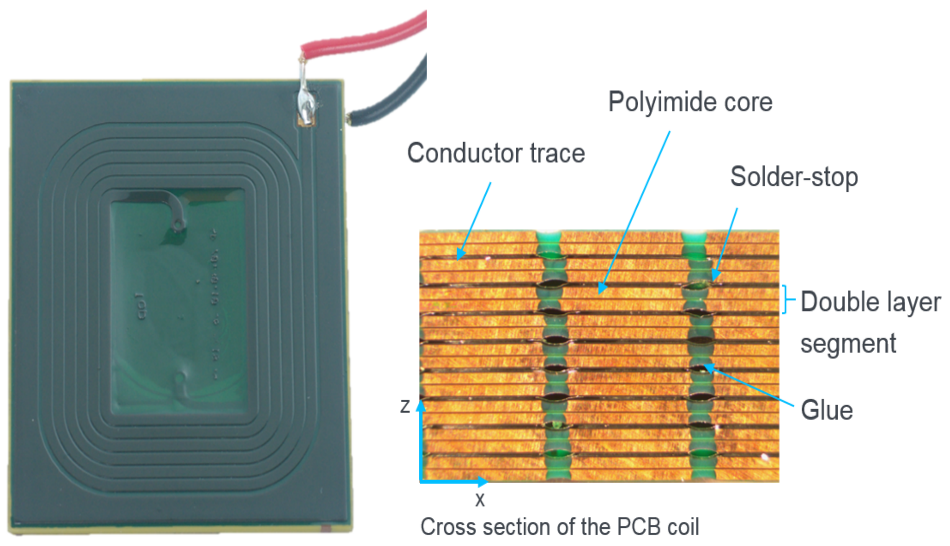

Fig. 2: Foldflex PCB coil

The PCB coil manufactured in this way, combines high mechanical stability with a high copper filling factor.

Optimization of the PCB coil

In contrast to round copper wire coils, a PCB coil has no air enclosures due to the manufacturing process. Based on the design rules of the PCB technology, an optimization, according to the copper filling factor, can be done. The workflow of a suitable PCB coil is shown in Fig. 3.

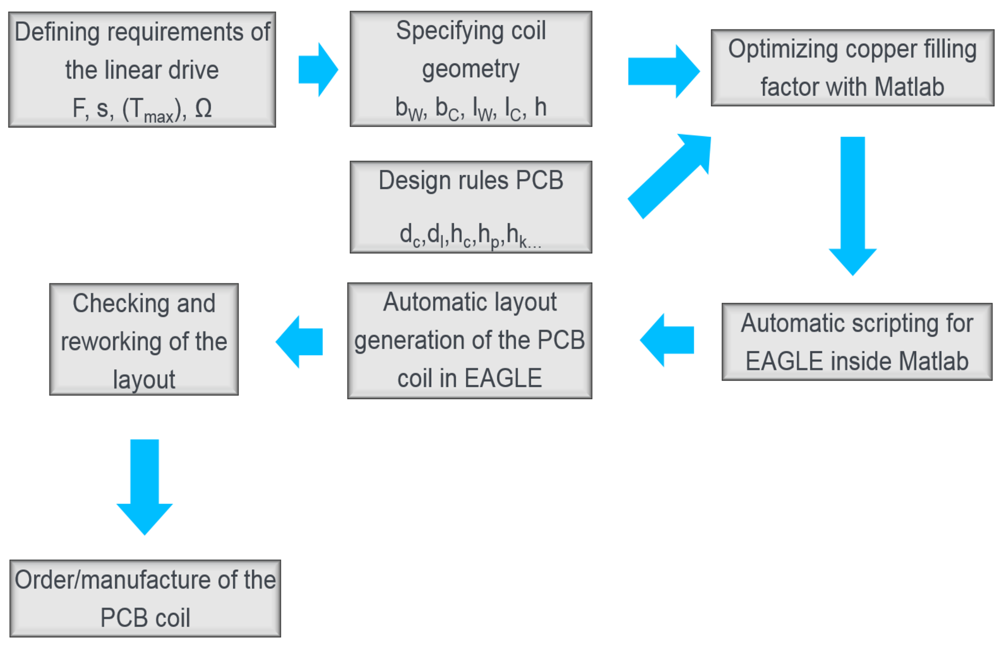

Fig. 3: Workflow – Design of a suitable coil for a linear drive

In a first step, the requirements of the drive, such as the required force *F* and the displacement *s,* as well as the optimum coil geometry, has to be determined. The geometry includes the outer dimensions of the coil, the dimensions of the coil window and the height. The design rules, such as the minimum distance between two conductor traces and the height of the copper layer, must be adapted to the PCB type, as well as the respective manufacturer's specifications. With the parameters of the coil geometry and the variables of the design rules the optimization can be done.
After the optimization, a script is automatically generated, in which the code for the PCB layout is contained. The script with the code can then be loaded into a PCB designer program e.g. Eagle, in which the layout is generated automatically. At the final stage of the workflow, the check of the layout, if necessary reworking of the design and the manufacturing or order of the PCB coil, needs to be done.

Comparison to standard coil

A coil of round wire is also optimized in order to compare it with the PCB coil. Due to the high air content of the round wire coil and the poor heat conduction of air, the two coils are difficult to compare. For this reason the round wire coil is cast with epoxy resin, with a thermal conductivity of 1 W/mK in a further step.
For the tests, the same current density is set to both coils. Therefore slightly different current intensities are reached due to the different number of windings.
Fig. 4 shows, that both coils represent approximately the same force-displacement characteristic. The flattening of the force at the beginning and end of the curve is caused by the reduction of induction at the edges of the permanent magnets of the drive. However, this behavior is typical for this type of drives.

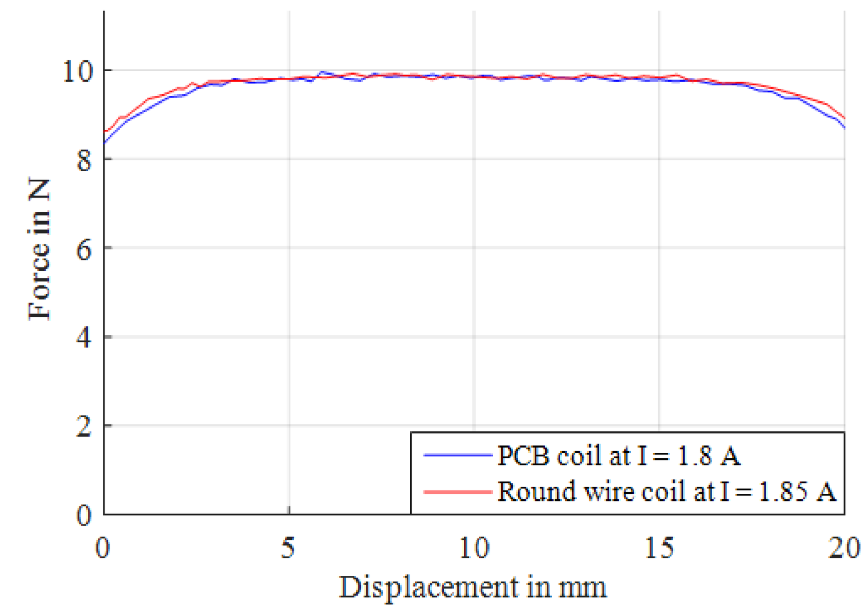

Fig. 4: Force-displacement characteristic

A second test under static load and with the same current density at both coils is set up, to obtain the temperature-time diagrams of the respective coils. The heating curves are shown in Fig. 5.

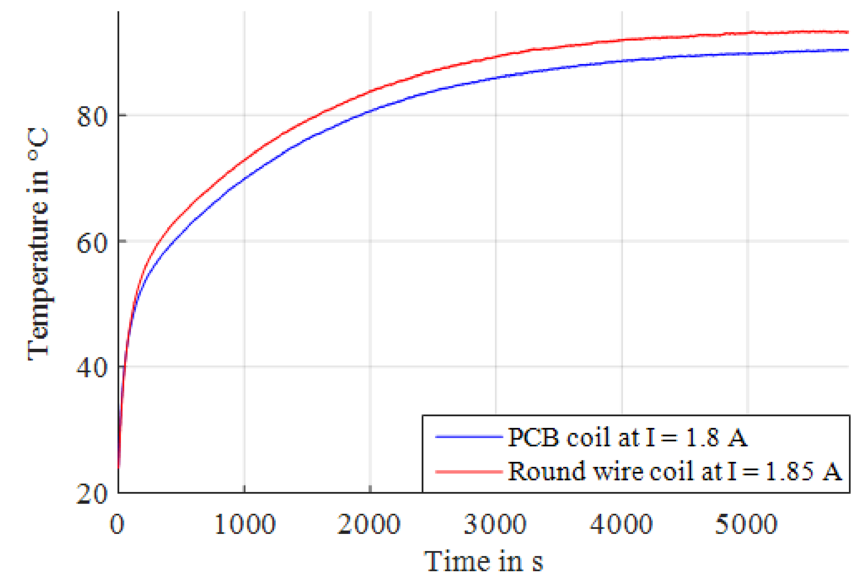

Fig. 5: Heat up curves

Both curve progressions are very similar. In the thermally stable state, the temperature of the PCB coil is 90 °C and is thus around 3 K lower than the temperature of the round wire coil.

Conclusion

The Workflow of the PCB coil is fast and effectively with a high degree of automation. Due to the high technical standards in PCB manufacturing, PCB coils can be manufactured very quickly, with high precision and repeatability.
The tests have shown, that the temperature of the PCB coil is lower, while the mechanical properties of the drive remain constant. PCB coils can thus increase the performance of drives.

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