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Highspeed production of traction motor stacks with bonding varnish (Backlack)

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Summary

Bonding varnish/backlack enables the production of lamination stacks with highest precision. Compared to interlocking and welding, bonding has no short cuts between the single sheets, thus, better magnetical properties and lower losses are the result. Today, stacks from bonding varnish/backlack are produced in highest quality for small and medium series. To make also large series viable the synchronization between stamping and stacking/bonding is necessary.

Keywords: asynchronous (induction) motor, motor, motor design, permanent magnet motor, powertrain

1 Introduction

The expansion of electric mobility will require traction motors in massive numbers, with consistent quality and lowest possible cost per unit. Efficiency is of the essence considering the constraints of available space in the vehicle. Although the basic principle of traction motors for electric vehicles is identical to other electric motors, designers must pay attention to the specific requirements for this application. This article elaborates on the production of rotor and stator cores which are components of traction motors. The basic methods of stamping laminations for electric motors are presented with a special focus on state-of-the-art joining technology like interlocking, welding, gluing, and using backlack to join the laminations to a full stack. Especially the use of backlack offers advantages in comparison to other methods but lacks efficient and automated production solutions. The paper intends to address such limitations and how to overcome them.

2 Methods

When we talk about stamping of motor laminations, we talk about three main tool & die technologies: single notch dies, compound dies, or progressive dies as shown in Fig. 1. The start is always from a coil material. Electrical steel is available in thickness of 0,35mm - 0,5mm for typical industrial motors. Progressive dies and compound dies convert the coil material directly into the lamination with a specific geometry, whereas single notch diesets work from a blank so that an intermediate step is required: a simple compound die is used to produce the blank out of a coil. Not to forget prototypes of motors are often laser-cut to reduce the time which it takes to produce a tool.

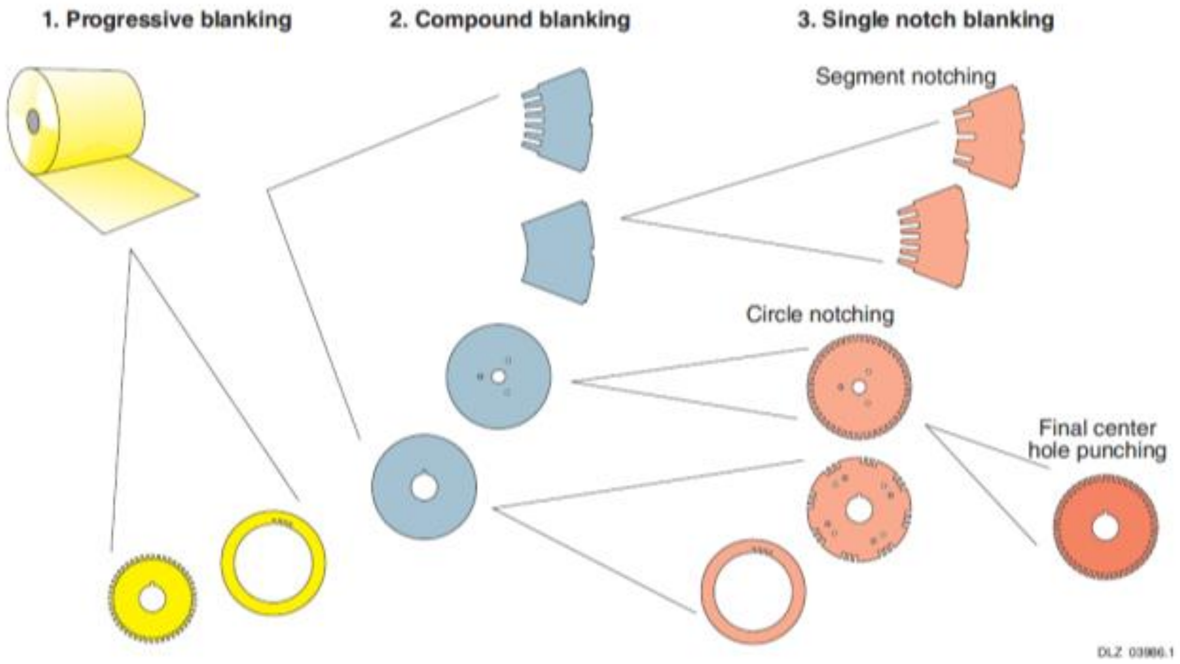

Figure 1: production processes for electrical steel sheets

To decide which method is commercially viable one must consider the size (diameter) of the stator and the required output. Small production volumes are predestined for single notch diesets whereas high volumes call for compound diesets for diameters above 600mm (stator diameter) and for progressive diesets below 600mm – see figure 2. It is obvious, that traction motors with its typical numbers and sizes are ideally produced by progressive diesets. However, pre-series of motors or high-end applications in small numbers may be viable for single notch operation.

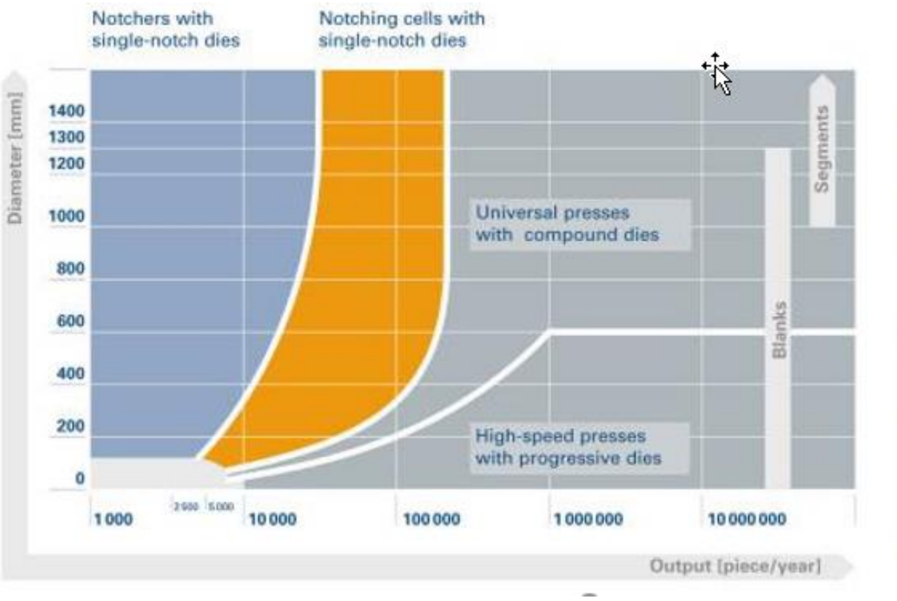

Figure 2: diameter/output ration to decide on production process

Once the laminations are cut out of the coil, they are single pieces which must be organized and joined to a stack by welding. Each lamination is isolated to each other by lacquer to avoid huge iron losses of the motors. Handling of the single pieces is troublesome, and many approaches have been made to make things easier. Welds also mean a shortcut inside the steel core as isolation is bridged over as illustrated in figure 3.

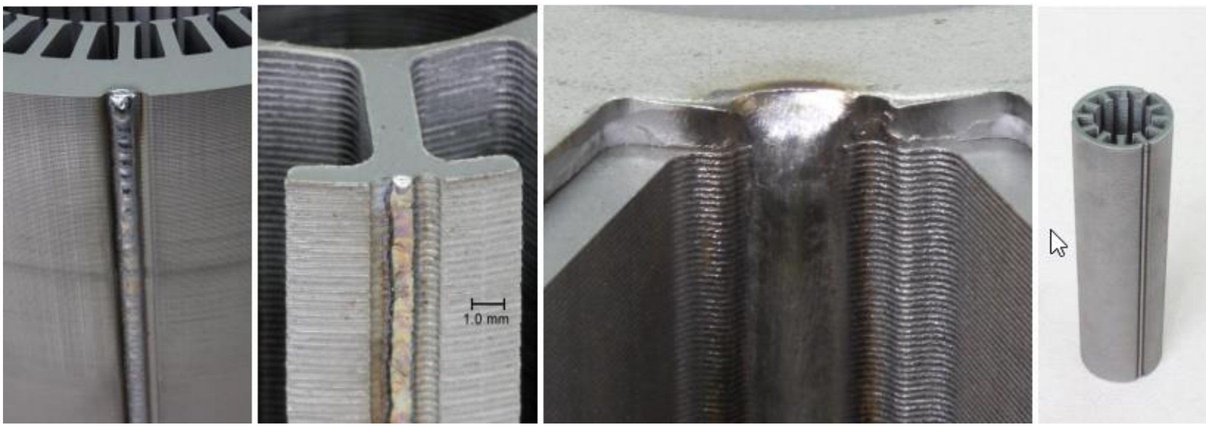

Figure 3 – welded motor cores [1]

The state-of-the art solution is the so-called interlocking which was first tried in the eighties of the twentieth century [2] – see Figure 4 - and improved since then to mass production. With interlocking progressive tooling small portions of the single lamination are pressed down into the underlying lamination in the die. This lamination has the same formed portion. This clinching keeps the stack together and when complete, the small portions of the first lamination of the next stack are stamped out so that the joining stops; the stack is finished.

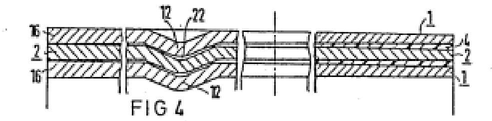

Figure 4: Interlock and interlocked stack [2]

The interlocking is a very productive and proven technology which offers high output, easy stack handling and wide variety of suppliers for production equipment and tool and die. However, one major disadvantage is imminent for this method, which is the shortcut between the laminations which deteriorates the magnetical properties of the motor [3].

In addition, there is a trend to improve the efficiency of the motor by using thinner gauges as the typical 0,35mm-0,5mm, e.g. down to 0,2mm. The very thin gauge makes it quite difficult to form the clinching dots in a reliable manner, resulting in not-ok-stacks, small joining forces and low stack density. Thus, interlocking comes to its limits when stamping traction motor cores.

Other joining methods such as gluing and backlack were (re-)introduced recently to overcome such limitations. Gluing is the application of an adhesive in the stamping tool before the rotor and stator parts are cut out. The stacks are joined by pressing the laminations on each other with the adhesive in between. Thus, the isolation stays undamaged other than with interlocking. Having the gluing integrated in the stamping tool is a compact solution. It is defined by the process window to apply the glue in a correct manner. However, this could lead to compromises between the integration of gluing into the stamping process and other parameters like output. In addition, the method is not commonly available but there are proprietary solutions developed successfully by stampers/tool & die companies.

In addition, the gluing is not a full-face joining as with backlack which allows for more delicate geometries of the laminations. Other advantages are that backlack has a higher thermal conductivity than air and the full-face connection reduces vibration and noise of the motor. In addition, no liquids will be absorbed into the much tighter stack joined with backlack.

Usually the backlack material is stamped traditionally in a progressive tool and joined afterwards by applying pressure and temperature to the stack in an oven. The handling of the single laminations is a hassle; thus, this method was applicable many years only for small and medium series but not for bulk production. New developments were made to integrate the bonding of backlack in the stamping process. First solutions were industrialized and are available but having two constraints, like gluing. One challenge is the process window for activating of the backlack in the stamping tool which may result in a reduction of stamping speed. The other challenge is the fact, that such integrated solution is tied to a defined raw material (supplier), i.e. the defined material cannot be replaced by material of another make.

3 Results

In this regard, Schuler has revisited the traditional way of using backlack with separate operation for stamping and bonding. The drawback of handling loose laminations is tackled by a fully-automated system to collect the lamination underneath the progressive dieset and bring them in a controlled and safe way to the bonding stations – see figure 5. These bonding stations are free-standing, redundant units which allow full process control on all process parameters like pressure, temperature, and time. The process is track- and traceable and allows for a wide variety of raw material. And the solution is commonly available as turn-key-system containing all processes from de-coiling of the raw material to the finished lamination stack but also as retrofit to existing machines.

Figure 5: Bonding stations

4 Discussion

The proposed combined system between a highspeed press and modular bonding stations can produce more than 500.000 bonded rotor and stator stacks per year. The modularity sets the flexibility to adapt to different part sizes, volumes, and ramp-up scenarios. So, investments can be aligned with the production volumes. Also, digitalization solutions are put in place, thus containing traceability of the process, process data archives, data analysis and applications for process improvements.

In short, traction motors benefit from cores joined with backlack. To produce such cores cost-effectively and with full process control the separate stamping and bonding process is proposed. Both processes are proven and commonly available but require a fully automated and digitized production system to connect. Design engineers of traction motors should familiarize themselves with the pros and cons of the available joining methods. Backlack is the way forward for joining cores of traction motors.

Acknowledgments

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Presenter Biography

Markus Röver, graduated in mechanical engineering at University of Aachen and in business administration at University of Hagen. He started at Schuler, the global leader in metalforming machinery, in 1995. Schuler is offering metalforming equipment with a special focus on machines for roducing motor laminations and battery cases.