Technical Presentation

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Magnetic Slot Wedges

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SPIndustries

Introduction

Magnetic slot wedges reduce starting current, improve cos phi and load current, and lead to reduced iron loss (core loss). Typical reduction of iron loss is in the range of some kW depending on the type of machine. This means a corresponding value of some thousand Euros, when calculating the machine prize. So it is obvious that additional costs for high performance slot wedges clearly pay off.

Conventional slot wedges are that weak that they often are not fulfilling the mechanical needs so that some companies are not using magnetic wedges any more.

The mechanical properties of SPInduwedge – a new generation of magnetic slot wedges – are surpassing that of conventional magnetic slot wedges (made out of laminated material) by far and it is to mention that they are in the range of non magnetic (i.e. unfilled) glass fiber reinforced material, some non magnetic material they are even surpassing. Hence these wedges are in the required stability range, which can be seen when comparing the mechanical data shown in this this folder. Furthermore there is no glass dust on the surface which is a great improvement in employment protection.

STANDARD SHAPES

Trapezoidal wedge, single edge wedge
Reaches far into the slot tooth, but has the advantage of fitting well in the slot, even when tolerances not achieved. It is the most typical wedge design (angle 60° or 70°) yet and when milling out of plates the most cost saving design.

Double edge wedge
Is less extending into the slot tooth, but more difficult and expensive to mill out of plates. If tolerances are not achieved they are not fitting well in the slot and must be discarded maybe.

MODERN SHAPES

Semicircular wedge
A wedge without sharp edges has electrical advantages and therefore this section shape was used in the past sometimes, but the milling process is complex and costly, and it was nearly impossible not to obtain a small edge.

Double edge wedge with flattened edge
This wedge is less weakening the slot tooth and not having a sharp edge has electrical advantages.

Trapezoidal wedge with a straight section
For some applications this shape is preferred, but difficult to mill out of plates, when the straight section is very small.

Trapezoid shape with rounded edges
The perfect shape if a trapezoid design will not be abandoned.

Unsymmetrical double edge wedge
Very similar to the design above but with no round section

Pedestal shaped wedge, Wedge with basement(s)
It is possible to add a pedestal to any cross-section shape. This type allows to insert as many magnetic material into the slot as possible and therefore to improve electrical properties even more. Another advantage is, that lateral buckling of the slot wedge is less likely because the pedestal is prohibiting this movement. Therefore this shape improves the safety further.

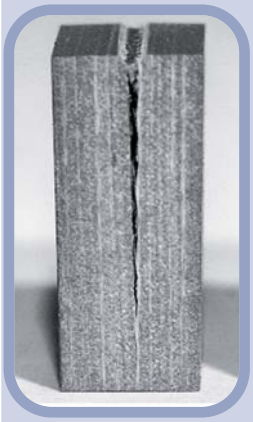
The pedestal on the ground fills the space between wedge and coil, where often spacers are used, which are no longer required, so that working time for producing and inserting spacers is saved and moreover the electric properties are increased because much more magnetic material is present. The pedestal on the top fills the place to the air gap.

New cross-sections shape

SPInduwedge can be manufactured in a great variety of shapes without thinking of additional production costs, because they are pressed and moreover some designs are even not possible with conventional milling process. See table on left side for possible cross-sections and feel free to contact SPIndustries to talk about pros and cons of new designs. Some considerations about slot section are not up to date anymore and therefore innovative designs should be considered to improve electrical properties and safety.

Technical evaluation of the properties of SPInduwedge

On the Vienna University of Technology an investigation was carried out to prove the stability of SPInduwedge and to compare the mechanical data with conventional magnetic slot wedges.
The results of this investigation are shown in the diagrams of this folder and in an descriptive 23-page booklet (Technical Report), which can be ordered from SPIndustries.
The superiority of the mechanical properties of SPInduwedge can be seen when looking on the values of delamination load which corresponds to the force of inserting the wedge with a hammer (diagram 1), flexural strength (diagram 2) and module of elasticity (diagram 3). Moreover SPInduwedge react different to forces which normally damage the wedge, which can be seen in picture 1 to 3. These very pictures proves the superiority of SPInduwedge.



Picture 4: left side: Conventional slot wedges show tearing on the cleavage test, sometimes the tear is propagating on the whole length of the wedge and the glass cloth is laid open. Subsequently this leads to complete destruction.

Picture 5: above: In the picture you can see a laminated magnetic slot wedge with poor adhesion between the layers, so that even small forces lead to delamination.

Picture 6: left: The fundamental difference of the slot wedges SPInduwedge to other wedges is not only the fact that they endure the highest cleavage forces (see values of delamination load in diagram 1) but also that a damage by a cleavage force leads to a completely different kind of fracture. The force effect, as seen in the picture, is deviated nearly in a right angle to the side. This means that the damage is limited to a small area and that the internal structure of the wedge remains intact. So the stability remains almost unaltered.

Delamination Load

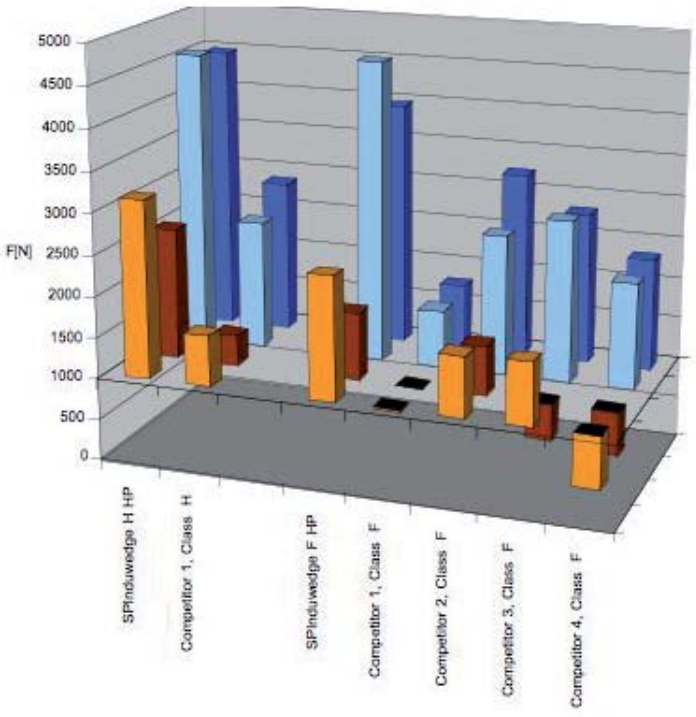


Diagram 1: Delamination Load

Delamination load obtained by cleavage test according to DIN 53464. In this diagram you can see the values of 4 different conditions: unaged and aged wedge at room and elevated temperature (23°C and 155°C).
Condition (1) is relevant when inserting the wedge with a hammer, condition (2) is relevant in an operating system. For comfortable interpretation the bars are starting at a force of 1000 N, so that values below 1000 N are bars pointing down. **SPInduwedge** shows the highest values at all conditions and therefore has the best cleavage protection, not only because of the high values of delamination load but also because of the different behavior to cleavage forces.

Flexural Strength

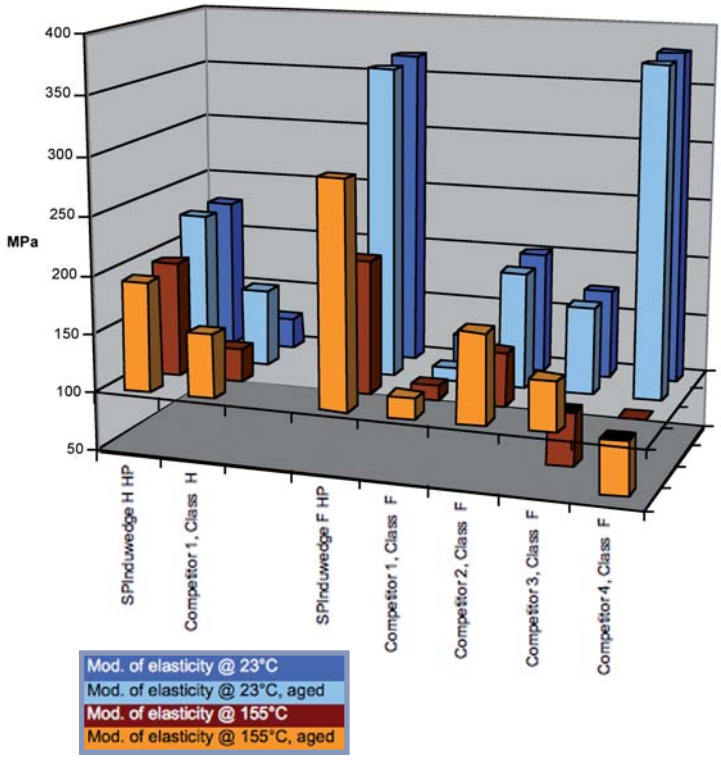


Diagram 2: Flexural Strength

SPInduwedge shows the highest values for flexural strength at elevated temperature. Only competitor 4 shows good flexural strength at room temperature too, but the values decreases to 54 MPa at 155°C, which is not satisfying. Data is obtained by bending test according to ISO 14125.
The advantage of **SPInduwedge** is obvious, especially when you compare figures of non-magnetic material (e.g. EP GC 203/ G-11/ HGW 2372.4 or similar):
SPInduwedge F HP is in the range and even surpasses some non-magnetic materials in mechanical properties.

It can be seen that ageing (heating at 210°C for 14 days) does barely influence the mechanical properties at room temperature, but very well at elevated temperatures. At 155°C all materials shows – as expected – in general lower mechanical properties compared to room temperature, but due to a post curing effect the aged material shows improved properties at this temperature except for materials of competitor 4, where properties decrease extremely for some reason.

Module of Elasticity

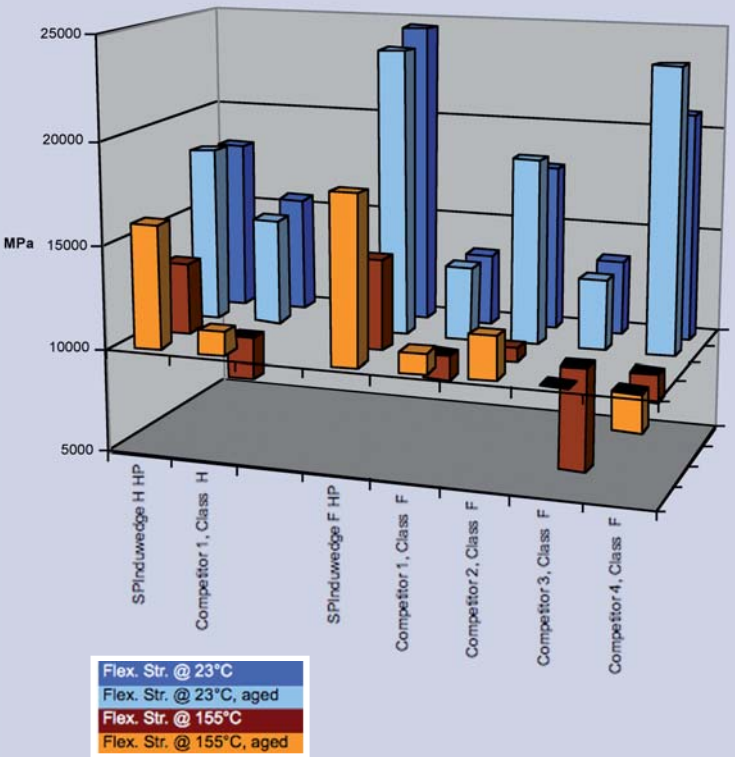


Diagram 3: Module of Elasticity

When looking on the figures of module of elasticity the interpretation is analogical to previous diagram 2: Good values at room temperature are not proving good values at elevated temperature. But in many data sheets values for elevated temperature are not given. **SPInduwege** slot closure keys are they only one showing a module of elasticity above 15.000 MPa at 155°C, some competitors are not reaching this value at room temperature.

Caption of bar-colors
Values of fresh wedge at room temperature
Values of aged wedge at room temperature
Values of fresch wedge at 155°C
Values of aged wedge at 155°C
ageing = heating at 210°C for 14 days

Compared to conventional data sheets, where most data are available at room temperature only, in this investigation the wedges were measured at elevated temperature too, which is the relevant value in operating machines. Furthermore – and completely new – the effect of post curing was taken into account (only known in literature but nowhere attended by extensive measurements).

		Flexural Strength	Flexural Strength	Module of elasticity	Module of elasticity
Material (thickness 4mm)		@ 23°C [Mpa]	@ 155°C [Mpa]	@ 23°C [Mpa]	@ 155°C [Mpa]
SPInduwedge H HP, Class H		230 ± 20	200 ± 10	18200 ± 500	13500 ± 300
	14 d heating @ 210°C	230 ± 10	200 ± 20	18500 ± 900	16000 ± 500
SPInduwedge F HP, Class F		370 ± 50	210 ± 10	24600 ± 1300	14400 ± 400
	14 d heating @ 210°C	370 ± 20	290 ± 20	23900 ± 1400	18200 ± 1500

Table 1: Data of bending test according to ISO 14125, graphically shown in diagram 2 and diagram 3.

		F(max) @ 23°C	F(max) @ 155°C
Material (thickness 5mm)		[N]	[N]
SPInduwedge H HP, Class H		4500 ± 500	2600 ± 300
	14 d heating @ 210°C	4600 ± 200	3200 ± 200
SPInduwedge F HP, Class F		4000 ± 100	1800 ± 300
	14 d heating @ 210°C	4700 ± 500	2500 ± 200

Table 2: Data of cleavage test according to DIN 53464, graphically shown in diagram 1.

HDT (Heat deflection temperature) of all SPInduwedge High Performance wedges, both class H and F, turned out to be at 190°C and above (measured according to ISO 75-3 but with slightly different geometry).

Slot wedges for machines with core ducts

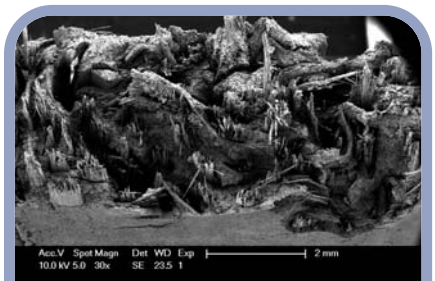
Until now the slots of machines with core duct were filled with a huge number of very short slot wedges to keep the ducts free of material, which would block the air flow.

With SPInduwedge it is possible to use long continuous slot wedges with pressed core duct slots (square-cut or semicircular). There is no damage of the glass fibers and therefore the stability remains unchanged and the edges are not sharp-edged. It is possible to use two wedges per slot and even a single wedge of one meter length is no problem. This leads to an enormous reduction in working hours, lying in the range of 1000 minute and above. But the greatest advantage is the much better stability.

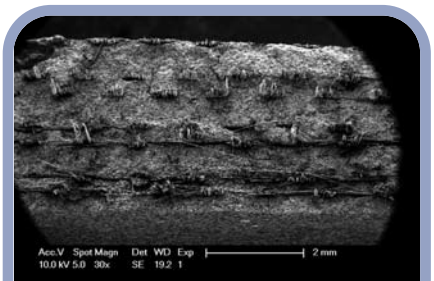
SEM-Pictures

Scanning electron micrograph pictures from the surface of fractures show the difference in the construction. The production process of the SPInduwedge slot wedge is a break through and completely new. A rolled glass cloth is used, which is pressed with a resin iron powder mixture in a specific press. The rolled cloth is responsible that SPInduwedge material has virtually the same mechanical stability in all directions.

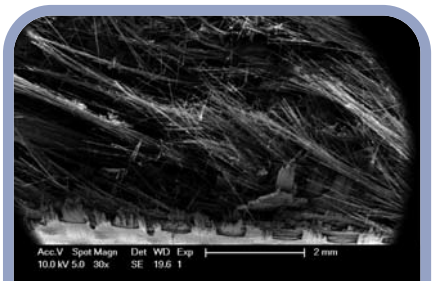
Picture 1: The slot wedge SPInduwedge HP consists of rolled glass fiber cloth and therefore stiffness is equal in all directions and explains the excellent flexural strength.

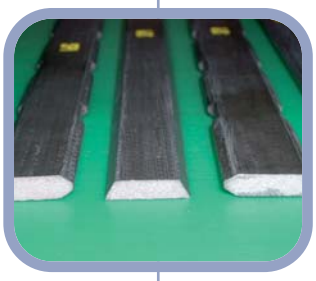


Picture 2: Surface of a fracture from a conventional magnetic slot wedge out of laminated material.



Picture 3: This conventional slot wedge model ("competitor 4") has good properties at room temperature, because of a thick glass cloth layer, but at elevated temperature the properties are poor.





Company History

SPIndustries was established in 1996 in Baden, Austria. At this time its main focus was the trading of insulating material as well as the production of magnetic slot wedges.

Due to the growth of the Company and the market demand, SPIndustries decided in 2000 to build a production site in Hungary close to the Austrian and Slovakian border. As soon as the production site was finished we had the opportunity to produce stators for several well-known companies which were trying to outsource their production to a low labor cost eastern European country.

After successfully establishing the stator production, more companies saw the possibilities as well as the high Quality SPIndustries offered to them and we had to build further production sites: Mosonmagyarovar, Eastern Hungary, De Leon Springs – USA. Currently SPI has more than 180 Employees in 3 different Countries.

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