Grain oriented electrical steel powercore®

Product range
Powercore® is the core material for the future

Grain oriented electrical steel is a highly sophisticated high-tech core material. It is used in transformers to increase or reduce electrical voltages and currents. That is the only way that electricity can be transported over long distances with as little loss as possible.

Premium powercore® electrical steel grades significantly reduce noise emissions in transformers, a distinct advantage in the light of growing urbanization and industrialization. Powercore® electrical steel is so energy-efficient that it is now possible to build considerably smaller transformers with the same power output.

As energy demand grows continuously, powercore® grain oriented electrical steel significantly contribute to protecting the environment around the world and to conserving energy resources.

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**General note:**
All statements as to the properties or utilization of materials and products are for the purposes of description only. Guarantees in respect of the existence of certain properties or utilization of materials are only valid if agreed upon in writing.
Innovation & cooperation

With the high-tech material steel, successful innovations most often occur when the boundaries of individual disciplines are transcended.

Our products emerge both through intensive communication between sales, development and production and the close partnering relationships with our customers. Our proactive network also includes universities, institutes and industry partners.

In this interplay of various types of expertise, we utilize modern laboratory and pilot plants as well as simulation tools to advance the development of high-tech steels, materials, coatings and processes.

A further instrument that helps us stay ahead of the state of the art is our systematic quality management. We also involve our suppliers in this system to enable us, so that we can optimally implement our extremely demanding standards and those of our customers and business partners.

Mindful of our responsibility at all times.

We are committed to environmental compatibility and sustainability in everything we do. From the systematic reuse of water in our production and the use of process gases for our own heating and electrical generation needs to the resource-conserving utilization of all raw materials and the efficient recyclability of our products.
The energy transition is not feasible without powercore®

It is possibly the most underrated material of the future at the moment: electrical steel. Nothing less than our energy supply and the success of the energy transition depend on it, because electrical steel plays a key role wherever electrical energy is efficiently generated, converted or used. The best example are transformers.

Transformers need grain oriented electrical steel to be able to function efficiently. Without transformers, we would have no electricity, neither in the private nor the industrial sector.

Demand for electrical energy is constantly increasing. According to the International Energy Agency (IEA), electricity demand will increase by some two thirds over the next 25 years. The aim is to meet this increasing demand by using renewable energies. On the one hand, because fossil fuels are finite. And on the other hand, because the use of oil, coal and gas accelerates climate change and thus makes a move away from conventional energy generation unavoidable.

However, this also means that energy grids and transformers will have to change in the future to be able to feed this renewable energy into the grid.

For instance, new power lines will be required, some over several thousand kilometres in length, to transport renewable energy generated by wind energy in windy regions or at sea to electricity consumers. Moreover, the volatility of renewable energy generation requires the grids to efficiently and intelligently link generation and consumption with each other. These smart grids denote the communicative integration of energy system stakeholders in generation, transport, storage, distribution and consumption into the energy supply grid.
Grain oriented electrical steel

Our high-tech core material powercore® H has been largely responsible for increasing the efficiency of transformers.

Powercore® H grades have a sharper crystallographic texture than powercore® C grades. This, combined with a performing insulation coating, improves magnetic domain structure for a reduction of core loss and noise, making the powercore® H grades the material of choice for Ecodesign power transformers.

The use of powercore® H can also significantly reduce total manufacturing costs for transformers, a major advantage in the face of rising raw material costs.

Powercore® H is the core material for the future!

Advantages of powercore®

- Energy efficiency thanks to
  - Minimal losses at full load
  - Reduced no-load losses
- Reduced noise emission thanks to
  - Optimized domain structure
  - Improved insulation properties
- Cost benefits thanks to
  - Lower core weights
  - More compact dimensions
The requirements of grain oriented electrical steel as a core material have changed considerably in recent years and will continue to do so in the future. With vast experience and excellent technical expertise, we manufacture grain oriented electrical steels which fulfill the highest standards worldwide.

With our powercore® electrical steel, regulations for energy efficient transformers, for instance the Ecodesign regulation, can be implemented in a targeted manner. This implementation requires an enormous technological push: only with the best grain oriented electrical steels can eco-efficient transformers be built. That is why for many years now we have been making innovative investments to achieve that goal.

Our research and development team in Gelsenkirchen and Isbergues is permanently researching the optimization of our product properties and the production process to make our premium powercore® electrical steel even better for you.

With a technological infrastructure and high material competence, we are and remain your reliable partner for a better world with electricity.

Applications
- Large power transformers
- Distribution transformers
- Small transformers
- Current transformers
- Shunt reactors
- Wound cores
- Power generators

Production sites

- Gelsenkirchen, Germany
- Isbergues, France
- Nashik, India

Premium powercore®
grades for
eco-efficient transformers
### powercore® C: Magnetic properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness (mm)</th>
<th>Thickness (inch)</th>
<th>Typical core loss at 50 Hz W/kg</th>
<th>Typical core loss at 60 Hz W/kg</th>
<th>Typical core loss at 800 A/m W/lb</th>
<th>Guaranteed polarization at 50 Hz Typ. T</th>
<th>Guaranteed polarization at 60 Hz Min. T</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 120-23</td>
<td>0.23</td>
<td>0.009</td>
<td>0.77</td>
<td>1.18</td>
<td>0.46</td>
<td>0.71</td>
<td>1.20</td>
</tr>
<tr>
<td>C 120-27</td>
<td>0.27</td>
<td>0.011</td>
<td>0.80</td>
<td>1.18</td>
<td>0.48</td>
<td>0.71</td>
<td>1.20</td>
</tr>
<tr>
<td>C 130-27</td>
<td>0.27</td>
<td>0.011</td>
<td>0.83</td>
<td>1.23</td>
<td>0.50</td>
<td>0.74</td>
<td>1.30</td>
</tr>
<tr>
<td>C 120-30</td>
<td>0.30</td>
<td>0.012</td>
<td>0.82</td>
<td>1.18</td>
<td>0.49</td>
<td>0.71</td>
<td>1.20</td>
</tr>
<tr>
<td>C 130-30</td>
<td>0.30</td>
<td>0.012</td>
<td>0.84</td>
<td>1.23</td>
<td>0.50</td>
<td>0.74</td>
<td>1.30</td>
</tr>
<tr>
<td>C 150-30</td>
<td>0.35</td>
<td>0.014</td>
<td>1.00</td>
<td>1.48</td>
<td>0.60</td>
<td>0.88</td>
<td>1.65</td>
</tr>
</tbody>
</table>

All grades may be delivered with laser domain refinement if not agreed otherwise. Magnetic properties measured by Epstein frame or by SST. When measured by SST, obtained values are converted to Epstein standard as defined in IEC 60404-8. Typical values represent the average performance level which will be obtained in a transformer for a given grade.

#### powercore® H: Magnetic properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness (mm)</th>
<th>Thickness (inch)</th>
<th>Typical core loss at 50 Hz W/kg</th>
<th>Typical core loss at 60 Hz W/kg</th>
<th>Typical core loss at 800 A/m W/lb</th>
<th>Guaranteed polarization at 50 Hz Typ. T</th>
<th>Guaranteed polarization at 60 Hz Min. T</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 070-20 (L)</td>
<td>0.20</td>
<td>0.008</td>
<td>0.50</td>
<td>0.72</td>
<td>0.30</td>
<td>0.47</td>
<td>0.70</td>
</tr>
<tr>
<td>H 075-20 (L)</td>
<td>0.20</td>
<td>0.008</td>
<td>0.52</td>
<td>0.72</td>
<td>0.31</td>
<td>0.47</td>
<td>0.75</td>
</tr>
<tr>
<td>H 075-23 (L)</td>
<td>0.23</td>
<td>0.009</td>
<td>0.55</td>
<td>0.74</td>
<td>0.33</td>
<td>0.44</td>
<td>0.75</td>
</tr>
<tr>
<td>H 078-23 (L)</td>
<td>0.23</td>
<td>0.009</td>
<td>0.56</td>
<td>0.76</td>
<td>0.34</td>
<td>0.46</td>
<td>0.78</td>
</tr>
<tr>
<td>H 080-23 (L)</td>
<td>0.23</td>
<td>0.009</td>
<td>0.57</td>
<td>0.78</td>
<td>0.34</td>
<td>0.47</td>
<td>0.80</td>
</tr>
<tr>
<td>H 085-23 (L)</td>
<td>0.23</td>
<td>0.009</td>
<td>0.60</td>
<td>0.83</td>
<td>0.36</td>
<td>0.50</td>
<td>0.85</td>
</tr>
<tr>
<td>H 090-23</td>
<td>0.23</td>
<td>0.009</td>
<td>0.62</td>
<td>0.88</td>
<td>0.37</td>
<td>0.53</td>
<td>0.90</td>
</tr>
<tr>
<td>H 100-23</td>
<td>0.23</td>
<td>0.009</td>
<td>0.67</td>
<td>0.98</td>
<td>0.40</td>
<td>0.59</td>
<td>1.00</td>
</tr>
<tr>
<td>H 085-27 (L)</td>
<td>0.27</td>
<td>0.011</td>
<td>0.63</td>
<td>0.83</td>
<td>0.38</td>
<td>0.50</td>
<td>0.85</td>
</tr>
<tr>
<td>H 090-27 (L)</td>
<td>0.27</td>
<td>0.011</td>
<td>0.65</td>
<td>0.88</td>
<td>0.39</td>
<td>0.53</td>
<td>0.90</td>
</tr>
<tr>
<td>H 095-27</td>
<td>0.27</td>
<td>0.011</td>
<td>0.68</td>
<td>0.93</td>
<td>0.41</td>
<td>0.56</td>
<td>0.95</td>
</tr>
<tr>
<td>H 100-27</td>
<td>0.27</td>
<td>0.011</td>
<td>0.71</td>
<td>0.98</td>
<td>0.43</td>
<td>0.59</td>
<td>1.00</td>
</tr>
<tr>
<td>H 105-27</td>
<td>0.27</td>
<td>0.011</td>
<td>0.76</td>
<td>1.08</td>
<td>0.46</td>
<td>0.65</td>
<td>1.10</td>
</tr>
<tr>
<td>H 110-27</td>
<td>0.30</td>
<td>0.012</td>
<td>0.72</td>
<td>0.98</td>
<td>0.44</td>
<td>0.59</td>
<td>1.00</td>
</tr>
<tr>
<td>H 105-30</td>
<td>0.30</td>
<td>0.012</td>
<td>0.75</td>
<td>1.03</td>
<td>0.45</td>
<td>0.62</td>
<td>1.05</td>
</tr>
<tr>
<td>H 110-30</td>
<td>0.30</td>
<td>0.012</td>
<td>0.77</td>
<td>1.08</td>
<td>0.46</td>
<td>0.65</td>
<td>1.10</td>
</tr>
</tbody>
</table>

powercore® H 20 is suitable for distribution and power transformers at industrial frequencies as well as for devices running at medium frequencies. (L) = Magnetic domain refined by laser scribing. Other grades may be delivered with laser domain refinement if not agreed otherwise. Magnetic properties measured by Epstein frame or by SST. When measured by SST, obtained values are converted to Epstein standard as defined in IEC 60404-8. Typical values represent the average performance level which will be obtained in a transformer for a given grade.
The grain oriented electrical steel is supplied with a thin anorganic coating on the glass film layer which forms during annealing. A coating thickness of 2 to 5 μm provides good electrical resistance and a high stacking factor.

The coating, which is annealing resistant up to 840 °C, enables wound cores and punched laminations to be stress relief annealed. The coating is chemically resistant to any fluid it may be exposed to during the production process. It is unaffected by, and likewise does not affect, the different types of transformer oils.

We offer two types of insulation coating: Chrome containing insulation coating and chromium-free coating. From technological point of view both coatings are similar.

### Insulation types

<table>
<thead>
<tr>
<th>Color</th>
<th>Coated sides</th>
<th>Thickness of coating</th>
<th>Surface insulation resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color deviations may occur, but will not affect the properties</td>
<td>both sides</td>
<td>2 μm-5 μm</td>
<td>at room temperature as per DIN/IEC 60404-11</td>
</tr>
<tr>
<td>Phosphate over glass film: grey</td>
<td></td>
<td></td>
<td>&gt;10 G cm²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annealing resistance</th>
<th>Designation according to</th>
<th>Designation according to</th>
</tr>
</thead>
<tbody>
<tr>
<td>under inert gas as per DIN IEC 60404-12</td>
<td>DIN IEC 60404-1-1</td>
<td>ASTM A689</td>
</tr>
<tr>
<td>840 °C/2 h</td>
<td>EC-5-G</td>
<td>C-5 over C-2</td>
</tr>
</tbody>
</table>

Chemical resistance

- to transformer oil: good
**Characteristics**

### Dimensions

<table>
<thead>
<tr>
<th>Standard strips</th>
<th>Slit width</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inside diameter</strong></td>
<td>508 mm</td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>900 - 1,000 mm</td>
</tr>
<tr>
<td><strong>Nominal thickness</strong></td>
<td>0.20 mm</td>
</tr>
<tr>
<td></td>
<td>0.23 mm</td>
</tr>
<tr>
<td></td>
<td>0.27 mm</td>
</tr>
<tr>
<td></td>
<td>0.30 mm</td>
</tr>
<tr>
<td></td>
<td>0.35 mm</td>
</tr>
</tbody>
</table>

### Geometric tolerances

<table>
<thead>
<tr>
<th>Tolerances for widths</th>
<th>Tolerances for widths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max. tolerance on the nominal thickness</strong></td>
<td>±0.020 mm</td>
</tr>
<tr>
<td><strong>Max. difference in thickness parallel to the direction of rolling within a sheet or in a length of strip of 1,000 mm</strong></td>
<td>0.025 mm</td>
</tr>
<tr>
<td><strong>Max. difference in thickness perpendicular to the direction of rolling of a minimum distance of 40 mm from the edges</strong></td>
<td>0.020 mm</td>
</tr>
</tbody>
</table>

### Other characteristics and tolerances

#### Residual curvature
- Max. distance for a sample 500 mm in length applicable for width ≥150 mm: 35 mm
- Max. edge camber for a measuring length of 1,000 mm applicable for width ≥150 mm: 0.5 mm

#### Deviation from the shearing line due to internal stresses
- Max. measured gap within a strip length of 1,000 mm applicable for width ≥200 mm: 1 mm
- Max. wave factor applicable for width ≥150 mm: 1.5%

#### Slit width*
- >150 - 400 mm: 0/-0.3 mm
- >400 - 750 mm: 0/-0.5 mm
- >750 - 1,000 mm: 0/-0.6 mm
  
* Plus tolerances must be stipulated with order.

#### Residual curvature
- The measuring methods for thickness and width are given in the product standards EN 10107 and IEC 60404-8-7. All other measuring methods and definitions are given in EN 10251 and IEC 60404-9. The quoted values are in many cases better than those specified in the EN- or IEC-Norm.

### Typical physical properties

#### Ultimate tensile strength Rm
- Longitudinal in rolling direction: 330-370 MPa
- Transverse to rolling direction: 390-420 MPa

#### Yield point Rp0.2
- Longitudinal in rolling direction: 300-340 MPa
- Transverse to rolling direction: 330-380 MPa

#### Hardness
- HRB: 85-115
- HV: 185-200

#### Saturation polarization Js
- 2.03 T

#### Coercive field strength Hc
- <15 A/m

#### Curie temperature Tc
- 745 °C/1,345 °F

#### Density ρm
- 7.65 kg/dm³

#### Electrical resistivity ρe
- 0.48 μΩm

Other characteristics and tolerances on demand
powercore®: Further processing information

Grain oriented electrical steel is used to build magnetic cores. It should be noted that the best magnetic properties are found only in the rolling direction. If the magnetization is outside the rolling direction, core loss will increase substantially, e.g. at 90° to the rolling direction, the loss increases by a factor of more than three and at 60° it increases by a factor of more than four. It is therefore essential that the steel is magnetized as precisely as possible along the rolling direction in the whole magnetic circuit.

Mechanical stress

Mechanical stress has a highly negative effect on the magnetic properties of grain oriented electrical steel. The strips can become exposed to this type of stress for a variety of reasons:

- external forces (external stresses)
- plastic deformation (internal stresses)

External stress is caused by excessive or uneven compression forcing the magnetic core laminations into a wavy or curved shape.

Internal stress is generated along the cut edges during each slitting operation or as a result of bending the sheet or subjecting it to tension beyond the yield point.

This sometimes unavoidable stress can be almost completely eliminated by stress relief annealing. Material can be annealed in a continuous annealing line under air (short-time annealing) or in a box annealing line under a nitrogen atmosphere (long-time annealing). Whether or not the material is stress relief annealed depends on the conditions at the customers place of installation.

Annealing by the customer

Short-time annealing

Laminations are usually subjected to short-time annealing in a roller furnace. This process takes a few minutes and requires a soaking time of 1 to 2 minutes at a maximum temperature of 850 °C. Since the laminations are annealed under an air atmosphere, the cut edges oxidize, thus creating an insulating coating. Any grease or oil from earlier processing stages is burnt off and is generally harmless in small quantities.

Long-time annealing

Wound cores and stacking transformers undergo long-time annealing in a box-type furnace. Long-time annealing should be carried out under the following conditions:

- Soaking temperature: Min. 820 °C, max. 840 °C to 850 °C
- Soaking time: 2 hours (the coolest part of the material must be at least 800 °C)

- Cooling: Preferably within the furnace to about 200 °C to 350 °C
- Protective atmosphere: Preferably 100 % nitrogen. The addition of hydrogen is not recommended.

The heating, soaking and cooling times are largely determined by the type and size of furnace and the amount of annealing material. The annealing cycle must be adapted to the above parameters. As a general rule, heating the material too quickly may result in local overheating, especially in the outer cores. This risk can be reduced by controlling the temperature with a thermocouple near the heating conductors. The soaking time must be long enough to ensure that the annealing material reaches the soaking temperature (minimum 800 °C) throughout.

If the material cools down too quickly, the cores may warp or distort. It is further recommended that the soaking temperature is controlled by thermocouples positioned at the hottest and the coolest points of the annealing material. The cores should be allowed to cool down in the furnace to a temperature between 200 °C to 350 °C to avoid quenching effects during unloading.

The annealing material must be free from grease, oil and other organic substances to prevent carburization.

Domain refined material

Stress relief annealing of laser-irradiated powercore® H reverses the reduction in core loss produced by the laser treatment. The special design of our laser beam ensures that the excellent adhesive properties and the high resistance value of the insulation are preserved in our laser-irradiated powercore® H grades. As a result, laser-irradiated powercore® H grades show the same favorable noise behavior in the finished transformers as powercore® H grades that have not been laser treated.
For more information, visit us at:
www.thyssenkrupp-steel.com/en/electricalsteel
Steel
Electrical Steel

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