ArcelorMittal

Electrical steels

European product offer

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Because ArcelorMittal operates a policy of continuous development, the product data sheets will naturally be in a constant state of evolution. Therefore, we advise you to regularly consult our online product catalogues at industry.arcelormittal.com > Products & Solutions > Product catalogue & automotive.arcelormittal.com > Product offer > Europe.

Steel advisor

This steel advisor will help you find the properties of the various steels and types of coating that ArcelorMittal can supply to suit your particular application. Having identified your particular market, select your type of application in the table. Alongside each application you will find the catalogue data sheet that contains detailed information about the type of steel and the type of coating we recommend for you.

Domestic appliance

Fields	Applications	Best in Class products	Data sheets substrates	Other recommended products	Data sheets substrates	Data sheets coatings
Small domestic appliance	Microwave transformer	M230-35A M330P-35A	D 20 D 22	M270-35A M330P-50A	D 20 D 22	D 10 D 10
	Small appliance motor	M470-65A M630-65K	D 20 D 30	M800-65A M800-65K Easy Punch	D 20 D 30 D 40	D 10
	Small appliance transformer	M400-50A	D 20	M800-50A	D 20	D 10
Large domestic appliance	Laundry, dishwasher, vacuum cleaner motor	M330-35A M630-65K	D 20 D 30	M600-65A M800-65K	D 20 D 30	D 10
	Refrigerator compressor motor	M230-50A M340-50K	D 20 D 30	M350-50A M450-50K	D 20 D 30	D 10

Building industry

Fields	Applications	Best in Class products	Data sheets substrates	Other recommended products	Data sheets substrates	Data sheets coatings
Partition walls and panels	Magnetic shielded room	M230-50A	D 20	M270-50A	D 20	D 10
Lighting	Lighting ballast	M400-50A M400XP-50A	D 20 D 22	M800-50A M470P-50A	D 20 D 22	D 10 D 10
Cooling and air conditioning	Cold storage compressor motor	M230-50A M340-50K	D 20 D 30	M270-50A M450-50K	D 20 D 30	D 10
	Ventilation fan and air conditioning motor	M600-50A M330P-50A M450-50K	D 20 D 22 D 30	M700-50A M470P-50A	D 20 D 22	D 10 D 10

Transport

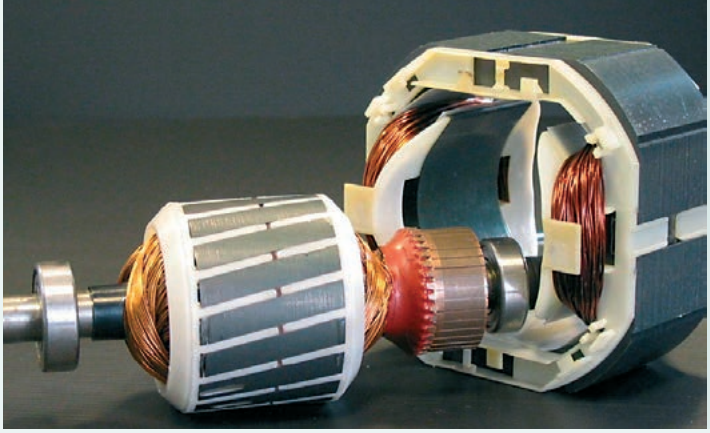
Fields	Applications	Best in Class products	Data sheets substrates	Other recommended products	Data sheets substrates	Data sheets coatings
Railways	Rail traction motor	M400-50A M400XP-50A	D 20 D 22	M400-65A M470P-65A	D 20 D 22	D 10 D 10
	Railway self-induction coil	M230-35A	D 20	M310-50A	D 20	D 10
Marine engineering	Marine propulsion motor	M310-50A M330P-50A	D 20 D 22	M400-50A M470P-50A	D 20 D 22	D 10 D 10
Heavy wheeled vehicles	Mining truck wheel motor	M230-50A M330P-50A	D 20 D 22	M290-65A M470P-65A	D 20 D 22	D 10 D 10

Industry

Fields	Applications	Best in Class products	Data sheets substrates	Other recommended products	Data sheets substrates	Data sheets coatings
Electrical equipment	Low-voltage transformer	M230-35A	D 20	M270-35A	D 20	D 10
	Welding equipment transformer	M270-50A	D 20	M600-50A	D 20	D 10
	Contactor core	M270-50A	D 20	M800-100	D 20	D 10
	Electricity meter core	M350-50A	D 20	M470-50A	D 20	D 10
	Micro-motor	NO20	D 24	M235-35A	D 20	D 10
	Shielding of power lines and transformers	M600-100A M470P-65A	D 20 D 22	M800-100A	D 20	D 10 D 10
	Electromagnet	M470P-65A	D 22			D 10
	Current and voltage transformer	M230-35A M330P-35A	D 20 D 22	M270-35A	D 20	D 10 D 10
	High frequency transformer	NO20	D 24	M235-35A	D 20	D 10
Industrial motor	Medium-power motor	M330-50A M400XP-50A M660-50K M560XP-50K	D 20 D 22 D 30 D 32	M530-65A M470P-65A M600P-65K	D 20 D 22 D 32	D 10 D 10
	High-power motor	M230-50A M330P-50A	D 20 D 22	M270-50A M400P-50A	D 20 D 22	D 10 D 10
	Compressor motor	M470YS-50A	D 26	M530YS-65A	D 26	D 10
Industrial generator	Small and medium-power generator	M270-50A M330P-50A	D 20 D 22	M400-50A M400P-50A	D 20 D 22	D 10 D 10
Wind power	Medium and high-power generator	M330-50A M400XP-50A	D 20 D 22	M400-50A M470P-65A	D 20 D 22	D 10 D 10
Hydro, gas, steam, nuclear turbine power	Medium and high-power generator	M230-35/50A 450-100-TF 180 AM FCE 700-300-TG 178	D 20 D 50 D 52	M270-35/50A 250-100-TF 183 450-500-TG 179	D 20 D 50 D 52	D 10 D 10

Automotive

Fields	Applications	Data sheets substrates	Data sheets coatings
Powertrain machines	High-efficiency alternators	20 10	80
	Belt driven starter-alternators	20 10	80
	High-efficiency starters	20 10	80
	Permanent magnet synchronous machines (PMSM) for centralised traction	10 40 20 30	80
	PMSM for wheel hub motors	10 40	80
	PMSM for current generation	10 40 20 30	80
	Wound rotor synchronous machines (WRSM) for traction	20 10	80
	WRSM for current generation	20 10	80
	Switched reluctance machines (SRM) for traction	10 40	80
	Induction machines (IM) for traction	20 10 40	80
	IM for current generation	20 10 40	80
High-performance auxiliary equipment	Heating, ventilation and air conditioning (HVAC) compressors	10 20	80
	Ignition coils	10	80
	Dashboard metering	10	80
	Hybrid controllers	10 20	80



ArcelorMittal's range of electrical steels for industry

Introduction

This introduction provides an overview of ArcelorMittal's wide range of electrical steels for industry.
As our product range contains a very broad spectrum of steel grades with specific magnetic properties, it is important to carefully select which is best suited for your specific application on the basis of the following criteria:

- Machine group:
  - Rotating machine-type products requiring optimised magnetic performance in all directions of the steel sheet plane (isotropic)
  - Transformer-type products requiring optimised magnetic performance in essentially one direction (anisotropic)
- Required magnetic performance of the steel, particularly specifying the required machine power and efficiency, under given operating conditions such as:
  - Frequency or, where required for certain machine parts, DC current conditions
  - Allowable volume / maximum weight
  - Operating temperature
  - Duty cycle: continuous or stop/start
  - Forced/natural internal/external cooling incorporated into the design
- Required mechanical performance of the steel, which is important for both the machine production process and operating conditions such as:
  - Punchability
  - Ability to withstand large electromechanical forces
- Other specific needs related to the machine's specific use influence the selection of a coating type, for example:
  - Corrosive operating atmosphere
  - Ability to withstand the operations involved in repairing the copper windings
  - Chosen fixation system (welding, automatic stapling, bars)

ArcelorMittal's range

Non-oriented electrical steels are designed for optimum performance in rotating machines; hence they have electromagnetic properties that are very uniform in all directions of the plane of lamination. They exist in essentially two large product groups: **fully processed** and **semi-processed** types. Fully processed means that the product is fully processed when it leaves our production plants. The semi-processed grades still need an additional production process step after the client's punching process, namely an annealing treatment.

D10 Varnish

(Standard: EN 10342:2005)

Varnishes have specific organic/inorganic compositions, depending on the properties required. The dielectric insulation level is of course an important feature, but for motor production and assembly, punchability and weldability are key properties as well. Depending on the machine's application, it may be important to have a varnish with high-temperature resistance, particularly for repairing the copper windings; or enhanced corrosion protection may be desirable, e.g. when the lamination stack is exposed to different atmospheric conditions as a result of forced air cooling.

- The EC-3 varnish is preferable when punchability and insulation are the major concern.
- The EC-5 varnish provides even better insulation, together with thermal resistance and corrosion protection.
- The EC-6 varnish is preferred for large machines, when high insulation levels are essential.

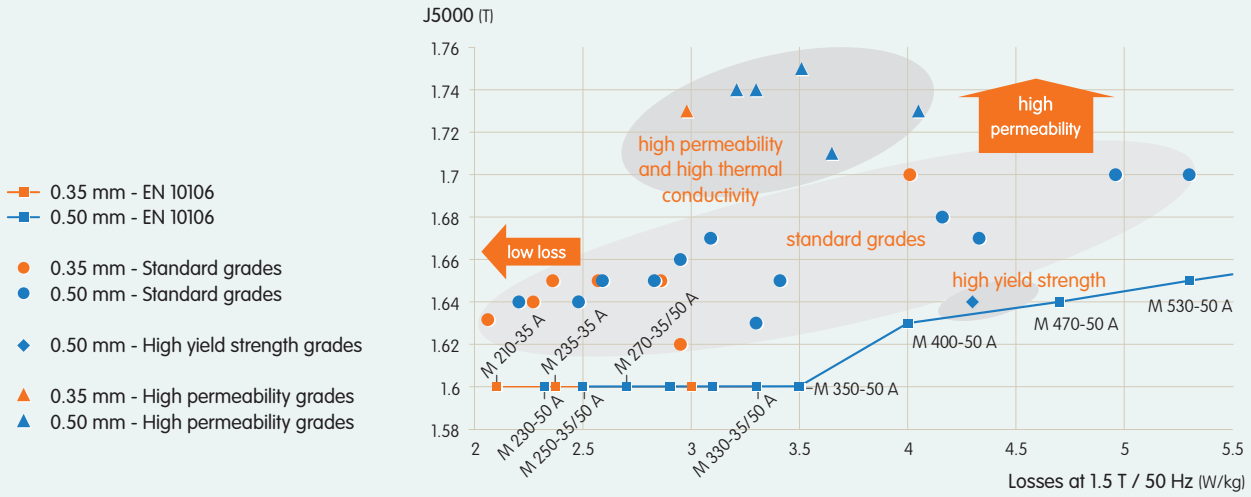
These varnishes are available for the fully processed and cold rolled pole sheet grades. ArcelorMittal's semi-processed electrical steels and the Easy Punch grade have controlled roughness, which eliminates the need for a non-stick varnish during the final annealing process. The hot rolled pole sheet grades have a natural oxide layer for interlaminar insulation.

Fully processed electrical steels

The data sheets from D20 to D26 describe the fully processed electrical steel product range. These steels have guaranteed magnetic properties as supplied. As well as the standardised grades, ArcelorMittal can provide steels with additional features such as enhanced permeability, high thermal conductivity, low losses at high frequencies or high yield strength.

Regarding magnetic performance, it is advisable to select a steel grade on the basis of the desired loss and induction level. For the fully processed 0.5 mm gauge grades, the range of medium and low loss grades is shown in the figure below. It can clearly be seen that ArcelorMittal's product range provides different polarisation levels for given loss requirements, allowing clients to select the most suitable material for their application.

Typical magnetic properties for medium and low loss fully processed grades:



D20 Fully processed standard grades

(Standard: EN 10106:2015)

These grades have magnetic loss levels and magnetic polarisations in compliance with the above EN standard. ArcelorMittal offers a complete product range, including very low loss grades such as M 210-35 A, M 230-50 A and M 290-65 A, which are especially suitable for large power generating machines. For such an application, these low loss grades would be used with the EC-6 varnish coating. They are also suitable for shielding applications at low frequencies (e.g. housings around electrical systems).

These low loss grades are a viable solution for customers wishing to promote their industrial machines to a higher efficiency class (e.g. from IE2 to IE3) in order to comply with new energy efficiency regulations, in line with CO_2 reduction plans. Such machines increasingly use PWM control to regulate speed, which introduces supplementary losses at higher frequencies; our lowest loss grades are particularly well suited to minimising this effect.

Our low loss grades with a thickness of 0.35 mm have also proven to be well suited for the replacement of grain-oriented grades in transformer applications.

The medium range products, such as M 400-50 A or M 530-65 A, are typically used for the production of magnetic ballasts and contactors.

Materials with loss levels of max 7 or 8 W/kg are inherently less alloyed, but are still optimised for punchability in terms of burr height performance.

D22 Fully processed high permeability and high thermal conductivity grades

The permeability and polarisation of these grades are higher than those of standard grades, while still meeting the loss specifications of the above EN 10106:2015 standard. Their high permeability is especially useful for machines where higher efficiency is needed, by reducing no-load losses. This effect is more significant for medium-sized machines with a continuous duty cycle. Permeability is also an interesting feature for small machines, where further weight/volume reduction is an issue. For ballasts, the high permeability makes it possible to reduce the height of the lamination stack and also the quantity of copper windings required for a given ballast class, or even to change the class of the ballast.

The high thermal conductivity of these grades is an important advantage for large machines, such as traction motors, where the ease of heat evacuation from the machine can be the limiting factor affecting its power.

D24 Fully processed high frequency grade

(Standard: EN 10303:2015)

This grade is specifically designed for use at higher frequencies – above 100 Hz – hence also for machines with PWM power supply. This is a result of its thin gauge of 0.2 mm and high silicon level. This grade clearly has a higher cost level than the fully processed standard and high permeability grades and is therefore mainly used when weight and volume reduction is essential, for instance in aeronautic or medical applications.

D26 Fully processed high strength grades

These grades, which are characterised by a much higher yield strength compared with their standard version, were specially developed for generators with a high rotating speed.
For example, M 530YS-65 A AM FCE grade has a typical R_e value of 520 MPa, compared with 315 MPa for the standard version. Consequently, the significant electromagnetic forces occurring while the machine is operating do not plastically deform the teeth of the machine.

Semi-processed electrical steels

The D30 and D32 data sheets describe the semi-processed electrical steel product range. These steels do not have guaranteed magnetic properties as supplied. The client needs to perform an annealing treatment after the punching process to develop the required magnetic properties. ArcelorMittal performs reference annealing tests in its laboratories to ensure that the material as supplied is capable of achieving the guaranteed magnetic properties after annealing. This specific annealing procedure is carried out according to the EN standards referred to below. As well as the standardised grades, ArcelorMittal offers steels with additional features such as enhanced permeability.

D30 Semi-processed standard grades

Standard: EN 10341:2006, which superseded EN 10126:1995 (for non-alloyed versions) and EN 10165:1995 (for alloyed versions).

These grades have loss levels and magnetic polarisation levels in accordance with the EN standards. Non-alloyed semi-processed electrical steels are designed for small industrial motors, fans and domestic appliances such as washing machine motors, microwave oven transformers and refrigerator compressors. Alloyed semi-processed electrical steels are designed for similar higher efficiency versions of these applications, as they have lower losses whilst the permeability remains at a good level.

D32 Semi-processed high permeability grades

The permeability and polarisation of these grades are higher than those of the standard grades, while still meeting the loss specifications of the above EN standard. We offer two categories: isotropic products (indicated by the letter P) and very high permeability grades (indicated by the letters XP). ArcelorMittal's semi-processed very high permeability grades (XP) have a specific texture with a high level of the rotated cube orientation. This means that the easy direction of magnetisation is especially pronounced at 45°. The overall average of polarisation in all directions of the steel sheet plane is therefore much higher than for the standard products. Semi-processed high permeability grades have been proven to enhance the efficiency of industrial motors.

D40 Easy Punch steels with guaranteed punchability

This electrical steel grade has optimised mechanical properties for punching. It is intended for applications where the performance of the motor or transformer is not so critical, e.g. when it has an intermittent duty cycle. ArcelorMittal does not guarantee the magnetic performance of this type of product. Easy Punch can be used as such or with an additional annealing cycle after punching for improved magnetic performance.

Pole sheet electrical steels

(Standard: EN 10265:1995)

The D50 and D52 data sheets describe the pole sheet electrical steel product range. These steels have guaranteed magnetic properties as supplied, but unlike other electrical steel grades, these properties refer to DC magnetising conditions. They are therefore intended for applications such as machines with salient poles. Their mechanical strength is also guaranteed, which is an important feature considering the electromechanical forces to which these machine parts are exposed. Whether the cold rolled or hot rolled versions should be preferred depends on the machine's size and application: the cold rolled versions have a higher polarisation for a given yield strength, but the hot rolled versions are available up to higher yield strength levels.

D50 Cold rolled pole sheet grades

These steels are most commonly used for exciter machines and hydropower applications. ArcelorMittal's cold rolled pole sheet grades have the advantage of being based on fully processed steel technology. This means that, in addition to the guaranteed DC magnetic properties, they also perform well with AC. This can be an advantage should, for example, stray magnetic fields occur.

D52 Hot rolled pole sheet grades

These steels are most commonly used for hydropower applications. ArcelorMittal's hot rolled pole sheets can be supplied pickled, or with an adherent oxide film, which provides interlaminar insulation. The wide product range available, in terms of both gauge and yield strength level, should provide ample choice for any given application. The flatness can be guaranteed before and after laser cutting.

Properties table

In order to help you choose your electrical steel, we have compiled a comparative table (see below) showing the various grades and the relevant data sheets with their magnetic and mechanical properties:

- Easy Punch steels with guaranteed punchability (data sheet D40)
- Semi-processed (data sheets D30 and D32)
- Fully processed (data sheets D20, D22, D24 and D26)
  These grades are divided into the following types:
  - Low grades i.e. with loss levels at 1.5 T above 6 W/kg (data sheets D20 and D22)
  - Medium grades i.e. with loss levels at 1.5 T between 4 and 6 W/kg (data sheets D20, D22 and D26)
  - High grades i.e. with loss levels at 1.5 T below 4 W/kg (data sheets D20, D22 and D24)
- Pole sheets (data sheets D50 and D52)

			Magnetic performance				Mechanical performance	
			Losses	Permeability/ Polarisation	Thermal conductivity	Shielding	Yield strength	Punchability
Easy Punch steels with guaranteed punchability		D40	⊖	□	□	⊖	□	⊞
Semi-processed non-alloyed	Standard	D30	□	+	⊞	⊖	□	+
	High permeability	D32	□	⊞	⊞	⊖	□	+
Semi-processed alloyed		D30	+	+	+	□	+	□
Fully processed low grades	Standard	D20	□	+	+	□	□	+
	High permeability and thermal conductivity	D22	□	⊞	⊞	□	□	+
Fully processed medium grades	Standard	D20	+	□	□	+	+	□
	High permeability and thermal conductivity	D22	+	⊞	⊞	+	+	□
	High yield strength	D26	+	⊖	⊖	□	⊞	⊖
Fully processed high grades	Standard	D20	⊞	⊖	⊖	⊞	⊞	□
	High permeability and thermal conductivity	D22	⊞	+	□	⊞	⊞	+
	High frequency	D24	⊞	⊖	□	⊞	+	⊖
Pole sheets cold rolled		D50	□	+	□	□	+	□
Pole sheets hot rolled		D52	□	+	□	□	⊞	□

⊞ *Excellent performance*
\+ *Good performance*
□ *Neutral performance*
⊖ *Lower performance*

The main purpose of varnish is to provide interlaminar insulation and to improve the punchability of steel.

Varnish for non-oriented grades

Properties

Electrical steel varnishes for non-oriented grades are designed to enhance the behaviour of fully processed electrical steels. Their main purpose is to provide interlaminar insulation and to improve the punchability of these steels. Each type has its own specific properties, such as insulation level, punchability effect, corrosion protection, temperature resistance and weldability; hence it is material use that determines the optimum choice of varnish. All varnishes have been selected and developed to be environmentally friendly: they are hydrosoluble and chromium-free.

Advantages

The **C3**-type varnish is based on synthetic resins, resulting in a product with excellent lubricating properties for the punching process: the coated sheet can be punched without the need for additional lubricant. The resins' chemical composition yields special advantages such as high elasticity and very strong adhesion. It is particularly recommended for automatic stacking processes. Typical gauges range from 1 to 4 µm per side. A coating thickness of less than 1 µm offers the additional advantage of excellent weldability, whereas 3 µm ensures good interlaminar insulation.

The **C5**-type varnish is a pigmented varnish, made with thermostable resins, mineral products and pigments.
For the EC-5-N varnish, the type of mineral products and the amount used have been selected to obtain a coating with excellent temperature resistance during prolonged thermal treatments, which is of particular interest where stress-relief annealing is required after punching. The composition of this varnish was designed to maintain its dielectrical properties during the repair of damaged copper windings. Additionally, the mineral part of the coating provides high thermal conductivity. The combination of resins and mineral products achieves a good compromise between corrosion protection and weldability. Typical gauges range from 1 to 4 µm per side.
The EC-5-P has an increased amount of organic components compared to the EC-5-N, in order to achieve a better punchability, whilst maintaining a good weldability. Typical gauges range from 1 to 2 µm per side.

The **C6**-type varnish is also a pigmented varnish, but is especially suitable for high-power rotating machines, thanks to its high electrical insulation level. The mineral elements have been selected to reduce punching tool wear and favour punching oil retention. They also enhance the rigidity of the varnish, which minimises dimensional changes under high pressure/temperature. This varnish is particularly recommended for use with contactors, to permit a higher flutter frequency whilst reducing noise. Typical gauges range from 4 to 10 µm per side. This varnish can also be provided in a formaldehyde-free version.

Applications

These coatings are used for fully processed grades, as well as for pole sheets in the cold rolled version, in a wide range of electrical applications such as rotating machines, transformers and contactors.

Recommendations for use

The raw materials used have a chemical composition – both in liquid and cured varnish state – which does not require specific protective measures during the processing of the coated steels or during use in a given application.

►

Brand correspondence

	EN 10342:2005	ASTM A976:2008	IEC/CEI 60404-1-1:2004	ArcelorMittal code
C3	EC-3	C-3	EC-3	S
C5	EC-5-P	C-5	EC-5-P	T
C5	EC-5-N	C-5	EC-5-N	G
C6	EC-6	C-6	EC-6	M
C6 formaldehyde-free	EC-6	C-6	EC-6	F

Coating properties

Designation	C3			C5					C6		
Chemical composition	Organic (synthetic resin)			Inorganic (minerals, pigments) Organic (synthetic resin)					Inorganic (minerals, pigments) Organic (synthetic resin)		
Colour	Gold			Grey					Grey blue		
ArcelorMittal code	S01	S12	S24	T01	T12	G01	G12	G24	M47	F47	M6D
Gauge (µm/side)	< 1	1 to 2	2 to 4	< 1	1 to 2	< 1	1 to 2	2 to 4	4 to 7		6 to 10
Typical insulation resistance ($\Omega.cm^2$/side)	2	10	50	5	15	5	15	70	300		> 3000
Temperature resistance (°C) Continuous / Intermittent	180/600 (1)			210/600		250/850			180/540 (1)		
Main properties	Punchability			Punchability		Heat resistance			Insulation		

Insulation measurement: Franklin test according to the standard EN 60404-11:2013.

Continuous temperature resistance according to the standard IEC/CEI 60404-12:1992.

(1) In case of higher intermittent temperatures, please contact us.

To supply the required level of traction for this huge mining truck, four electrical motors are needed: one for each wheel.

Fully processed standard grades

Properties

Non-oriented fully processed electrical steels have guaranteed magnetic properties, in accordance with (or exceeding the levels required by) EN 10106:2015. As well as the maximum loss and minimum polarisation levels cited, full magnetic characterisation curves regarding losses, polarisation, permeability and apparent power at different frequencies are available on request.

Advantages

A full range of these standard grades is available so that a steel grade can be selected according to the specific requirements of each application, from low alloy grades offering the advantage of excellent magnetic permeability, thermal conductivity and punchability to alloyed grades offering the advantage of very low losses, even at higher frequencies.
A wide range of coatings is available, allowing further enhancement of punchability, reduction of interlaminar losses and improvement of corrosion protection.

Applications

Fully processed steels are designed for the manufacture of magnetic circuits for motors, transformers and other electrical equipment. The principal applications are in the electrical engineering, domestic appliance, automotive and building industries. Low loss fully processed steels are also suitable for shielding applications at low frequencies (e.g. housings around electrical systems).

Recommendations for use

The above properties are obtained without heat treatment after stamping.
The material as supplied possesses all the required magnetic properties.

Brand correspondence Thickness 0.35 mm

	EN 10106:2015	Former standard AISI	ASTM A677:2012	JIS C 2552:2014	IEC/CEI 60404-8-4:2013
M 210-35 A	M210-35A			35A210	M210-35A 5
M 230-35 A AM FCE				35A230	
M 235-35 A	M235-35A				M235-35A 5
M 250-35 A	M250-35A	M15	36F145	35A250	M250-35A 5
M 270-35 A	M270-35A	M19	36F155	35A270	M270-35A 5
M 300-35 A	M300-35A	M22	36F165	35A300	M300-35A 5
M 330-35 A	M330-35A	M36	36F185		M330-35A 5

Grades in italics: not included in the EN standard

Brand correspondence Thickness 0.50 mm

	EN 10106:2015	Former standard AISI	ASTM A677:2012	JIS C 2552:2014	IEC/CEI 60404-8-4:2013
M 230-50 A	M230-50A			50A230	M230-50A 5
M 250-50 A	M250-50A			50A250	M250-50A 5
M 270-50 A	M270-50A			50A270	M270-50A 5
M 290-50 A	M290-50A	M19	47F165	50A290	M290-50A 5
M 310-50 A	M310-50A	M22	47F180	50A310	M310-50A 5
M 330-50 A	M330-50A	M27	47F190		M330-50A 5
M 350-50 A	M350-50A	M36	47F200	50A350	M350-50A 5
M 400-50 A	M400-50A	M43	47F210	50A400	M400-50A 5
M 470-50 A	M470-50A	M45	47F240	50A470	M470-50A 5
M 530-50 A	M530-50A	M47	47F280		M530-50A 5
M 600-50 A	M600-50A			50A600	M600-50A 5
M 700-50 A	M700-50A		47F400	50A700	M700-50A 5
M 800-50 A	M800-50A		47F450	50A800	M800-50A 5
M 940-50 A	M940-50A				M940-50A 5

Brand correspondence Thickness 0.65 mm

	EN 10106:2015	Former standard AISI	ASTM A677:2012	JIS C 2552:2014	IEC/CEI 60404-8-4:2013
M 290-65 A AM FCE					
M 310-65 A	M310-65A				M310-65A 5
M 330-65 A	M330-65A	M19	64F200		M330-65A 5
M 350-65 A	M350-65A	M22	64F210		M350-65A 5
M 400-65 A	M400-65A	M36	64F235		M400-65A 5
M 470-65 A	M470-65A	M43	64F250		M470-65A 5
M 530-65 A	M530-65A	M45	64F275		M530-65A 5
M 600-65 A	M600-65A	M47	64F320		M600-65A 5
M 700-65 A	M700-65A				M700-65A 5
M 800-65 A	M800-65A			65A800	M800-65A 5
M 1000-65 A	M1000-65A			65A1000	M1000-65A 5

Grades in italics: not included in the standard

Brand correspondence Thickness 1.00 mm

	EN 10106:2015	Former standard AISI	ASTM A677:2012	JIS C 2552:2014	IEC/CEI 60404-8-4:2013
M 600-100 A	M600-100A				M600-100A 5
M 700-100 A	M700-100A				M700-100A 5
M 800-100 A	M800-100A				M800-100A 5
M 900-100 A AM FCE					
M 1000-100 A	M1000-100A				M1000-100A 5
M 1300-100 A*	M1300-100A				M1300-100A 5

Grades in italics: not included in the standard

** After prior agreement*

Dimensions Thickness 0.35 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 210-35 A	(1) & (3)	-	-	600	1000	20	600	400	1100
M 230-35 A AM FCE	(1) & (3)				1200				
M 235-35 A	(1) & (3)								
M 250-35 A	(1) & (3)	1030	1230		1220				
M 270-35 A	(1) & (3)								
M 300-35 A	(1) & (3)								
M 330-35 A	(1) & (3)								

Grades in italics: not included in the EN standard
(1) After prior agreement regarding sheet lengths between 2000 and 2500 mm
(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Dimensions Thickness 0.50 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 230-50 A	(3)	-	-	600	1000	20	600	400	1100
M 250-50 A	(3)				1200				
M 270-50 A	(2) & (3)	1030	1250		1220				
M 290-50 A	(2) & (3)								
M 310-50 A	(2) & (3)								
M 330-50 A	(2) & (3)								
M 350-50 A	(2) & (3)								
M 400-50 A	(2) & (3)								
M 470-50 A	(2) & (3)								
M 530-50 A	(2) & (3)								
M 600-50 A	(2) & (3)								
M 700-50 A	(2) & (3)								
M 800-50 A	(2) & (3)								
M 940-50 A	(2) & (3)								

(2) Side trimmed: max width 1250 after prior agreement
(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Dimensions Thickness 0.65 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 290-65 A AM FCE	(3)	-	-	600	1000	20	600	400	1100
M 310-65 A	(3)				1200				
M 330-65 A	(3)	1030	1250		1220				
M 350-65 A	(2) & (3)								
M 400-65 A	(2) & (3)								
M 470-65 A	(2) & (3)								
M 530-65 A	(2) & (3)								
M 600-65 A	(2) & (3)								
M 700-65 A	(2) & (3)								
M 800-65 A	(2) & (3)								
M 1000-65 A	(2) & (3)								

(2) Side trimmed: max width 1250 after prior agreement

(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Grades in italics: not included in the standard

Dimensions Thickness 1.00 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 600-100 A	(1), (2) & (3)	1030	1250	600	1220	20	600	400	1100
M 700-100 A	(1), (2) & (3)								
M 800-100 A	(1), (2) & (3)								
M 900-100 A AM FCE	(1), (2) & (3)								
M 1000-100 A	(1), (2) & (3)								
M 1300-100 A	(2) & (3)							-	-

(1) After prior agreement regarding sheet length

(2) Side trimmed: max width 1250 after prior agreement

(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Grades in italics: not included in the standard

Magnetic properties Thickness 0.35 mm

	Conventional density (kg/dm³)	Max loss (W/kg) at 50 Hz at 1 T	Max loss (W/kg) at 50 Hz at 1.5 T	Max loss (W/kg) at 60 Hz at 1.5 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%)	Min number of bends	Min stacking factor
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
M 210-35 A	7.60	0.90	2.10	2.65	1.49	1.60	1.70	17	2	0.95
M 230-35 A AM FCE		0.95	2.30	2.90						
M 235-35 A			2.35	2.97						
M 250-35 A		1.00	2.50	3.14						
M 270-35 A	7.65	1.10	2.70	3.36						
M 300-35 A		1.20	3.00	3.74					3	
M 330-35 A		1.30	3.30	4.12						

Grades in italics: not included in the EN standard
Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.50 mm

	Conventional density (kg/dm³)	Max loss (W/kg) at 50 Hz at 1 T	Max loss (W/kg) at 50 Hz at 1.5 T	Max loss (W/kg) at 60 Hz at 1.5 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%)	Min number of bends	Min stacking factor
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
M 230-50 A	7.60	1.00	2.30	2.95	1.49	1.60	1.70	17	2	0.96
M 250-50 A		1.05	2.50	3.21						
M 270-50 A		1.10	2.70	3.47						
M 290-50 A		1.15	2.90	3.71						
M 310-50 A	7.65	1.25	3.10	3.95				14	3	
M 330-50 A		1.35	3.30	4.20						
M 350-50 A		1.50	3.50	4.45	1.50			12	5	
M 400-50 A	7.70	1.70	4.00	5.10	1.53	1.63	1.73			
M 470-50 A		2.00	4.70	5.90	1.54	1.64	1.74	10	10	
M 530-50 A		2.30	5.30	6.66	1.56	1.65	1.75			
M 600-50 A	7.75	2.60	6.00	7.53	1.57	1.66	1.76			
M 700-50 A	7.80	3.00	7.00	8.79	1.60	1.69	1.77			
M 800-50 A		3.60	8.00	10.06		1.70	1.78			
M 940-50 A	7.85	4.20	9.40	11.84	1.62	1.72	1.81	8		

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.65 mm

	Conventional density (kg/dm³)	Max loss (W/kg) at 50 Hz at 1 T	Max loss (W/kg) at 50 Hz at 1.5 T	Max loss (W/kg) at 60 Hz at 1.5 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%)	Min number of bends	Min stacking factor
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
M 290-65 A AM FCE	7.60	1.25	2.90	3.85	1.49	1.60	1.70	15	2	0.97
M 310-65 A	7.60	1.25	3.10	4.08	1.49	1.60	1.70	15	2	0.97
M 330-65 A		1.35	3.30	4.30						
M 350-65 A		1.50	3.50	4.57				14		
M 400-65 A	7.65	1.70	4.00	5.20	1.52	1.62	1.72			
M 470-65 A		2.00	4.70	6.13	1.53	1.63	1.73	12	5	
M 530-65 A	7.70	2.30	5.30	6.84	1.54	1.64	1.74			
M 600-65 A	7.75	2.60	6.00	7.71	1.56	1.66	1.76	10	10	
M 700-65 A		3.00	7.00	8.98	1.57	1.67				
M 800-65 A	7.80	3.60	8.00	10.26	1.60	1.70	1.78			
M 1000-65 A		4.40	10.00	12.77	1.61	1.71	1.80			

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Grades in italics: not included in the standard

Magnetic properties Thickness 1.00 mm

	Conventional density (kg/dm³)	Max loss (W/kg) at 50 Hz at 1 T	Max loss (W/kg) at 50 Hz at 1.5 T	Max loss (W/kg) at 60 Hz at 1.5 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%)	Min number of bends	Min stacking factor
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
M 600-100 A	7.60	2.60	6.00	8.14	1.53	1.63	1.72	10	2	0.98
M 700-100 A	7.65	3.00	7.00	9.38	1.54	1.64	1.73	8	3	
M 800-100 A	7.70	3.60	8.00	10.70	1.56	1.66	1.75	6	5	
M 900-100 A AM FCE		4.00	9.00	12.05						
M 1000-100 A	7.80	4.40	10.00	13.39	1.58	1.68	1.76		10	
M 1300-100 A		5.80	13.00	17.34	1.60	1.70	1.78			

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Grades in italics: not included in the standard

Mechanical properties

The mechanical properties are for information purposes only.

Mechanical properties Thickness 0.35 mm

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 210-35 A	T	410 - 460	530 - 580	0.76 - 0.81	12 - 22	210 - 240
M 230-35 A AM FCE	T	410 - 460	530 - 580	0.76 - 0.81	12 - 22	210 - 240
M 235-35 A	T	410 - 460	530 - 580	0.76 - 0.81	12 - 22	210 - 240
M 250-35 A	T	410 - 460	530 - 580	0.76 - 0.81	12 - 22	210 - 240
M 270-35 A	T	400 - 450	520 - 570	0.76 - 0.81	15 - 25	195 - 225
M 300-35 A	T	400 - 450	520 - 570	0.76 - 0.81	15 - 25	195 - 225
M 330-35 A	T	370 - 420	510 - 550	0.72 - 0.77	20 - 30	165 - 195

Grades in italics: not included in the EN standard

Mechanical properties Thickness 0.50 mm

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 230-50 A	T	425 - 475	550 - 600	0.75 - 0.80	12 - 22	210 - 240
M 250-50 A	T	425 - 475	550 - 600	0.75 - 0.80	12 - 22	210 - 240
M 270-50 A	T	420 - 470	540 - 590	0.75 - 0.80	15 - 25	200 - 230
M 290-50 A	T	420 - 470	540 - 590	0.73 - 0.78	15 - 25	200 - 230
M 310-50 A	T	400 - 450	530 - 580	0.73 - 0.78	20 - 30	200 - 230
M 330-50 A	T	365 - 415	510 - 560	0.72 - 0.77	20 - 30	180 - 210
M 350-50 A	T	365 - 415	500 - 560	0.72 - 0.77	20 - 30	180 - 210
M 400-50 A	T	340 - 390	480 - 530	0.69 - 0.74	25 - 35	170 - 200
M 470-50 A	T	270 - 320	410 - 460	0.62 - 0.67	28 - 38	140 - 170
M 530-50 A	T	270 - 320	410 - 460	0.62 - 0.67	28 - 38	140 - 170
M 600-50 A	T	260 - 310	390 - 440	0.64 - 0.69	30 - 40	120 - 150
M 700-50 A	T	260 - 310	390 - 440	0.64 - 0.69	30 - 40	120 - 150
M 800-50 A	T	290 - 350	420 - 460	0.69 - 0.74	27 - 37	120 - 150
M 940-50 A	T	290 - 350	420 - 460	0.69 - 0.74	27 - 37	120 - 150

Mechanical properties Thickness 0.65 mm

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 290-65 A AM FCE	T	430 - 480	550 - 600	0.78 - 0.82	12 - 22	210 - 240
M 310-65 A	T	430 - 480	550 - 600	0.78 - 0.82	15 - 25	210 - 240
M 330-65 A	T	430 - 480	550 - 620	0.78 - 0.82	15 - 25	210 - 240
M 350-65 A	T	420 - 470	550 - 600	0.75 - 0.80	15 - 25	200 - 230
M 400-65 A	T	370 - 420	520 - 570	0.71 - 0.76	20 - 30	200 - 230
M 470-65 A	T	370 - 420	520 - 570	0.71 - 0.76	20 - 30	160 - 190
M 530-65 A	T	270 - 320	420 - 470	0.65 - 0.70	30 - 40	140 - 170
M 600-65 A	T	270 - 320	420 - 470	0.65 - 0.70	30 - 40	140 - 170
M 700-65 A	T	280 - 330	420 - 470	0.67 - 0.72	30 - 40	130 - 160
M 800-65 A	T	300 - 350	430 - 480	0.70 - 0.75	27 - 37	130 - 160
M 1000-65 A	T	300 - 350	430 - 480	0.70 - 0.75	27 - 37	120 - 150

Grades in italics: not included in the standard

Mechanical properties Thickness 1.00 mm

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 600-100 A	T	370 - 420	520 - 570	0.71 - 0.76	20 - 30	170 - 200
M 700-100 A	T	290 - 340	450 - 490	0.66 - 0.71	30 - 40	140 - 170
M 800-100 A	T	290 - 340	450 - 490	0.66 - 0.71	30 - 40	140 - 170
M 900-100 A AM FCE	T	290 - 340	450 - 490	0.66 - 0.71	30 - 40	140 - 170
M 1000-100 A	T	260 - 300	390 - 430	0.66 - 0.71	30 - 40	120 - 150
M 1300-100 A	T	260 - 300	390 - 430	0.66 - 0.71	30 - 40	120 - 150

Grades in italics: not included in the standard

Coating properties

These standard grades are available non-insulated or varnished with any of the coating types described in data sheet D10.

Fully processed high permeability and high thermal conductivity grades

These grades generate not only increased efficiency, but also a higher specific power rating, which is an important aspect for traction motors for locomotives, like this ICE-3 high-speed train.

Properties

Non-oriented fully processed high permeability electrical steels have guaranteed magnetic properties significantly superior to the requirements of EN 10106:2015, particularly regarding the polarisation levels obtained. Full magnetic characterisation curves are available on request, as well as thermal conductivity data. The thermal conductivity of these steels is also higher than the conductivity of the fully processed standard grades.

Advantages

The high permeability levels of these grades allow a reduction of the magnetising current required for a given air gap flux. This increases the efficiency of the machine and also makes it possible to increase its specific power rating, thereby reducing the machine's dimensions. High thermal conductivity levels are important, since they facilitate heat evacuation from the machine.

Applications

High permeability is particularly useful for applications such as ballasts and motors, because it makes it possible to build machines that meet the most stringent environmental regulations. High thermal conductivity is a significant advantage for large machines.

Recommendations for use

The above properties are obtained without heat treatment after stamping.
The material as supplied possesses all the required magnetic properties.

Dimensions Thickness 0.35 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 330P-35 A AM FCE	(1) & (3)	1030	1230	600	1200	20	600	400	1100

(1) After prior agreement regarding sheet lengths between 2000 and 2500 mm
(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Dimensions Thickness 0.50 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 330P-50 A AM FCE	(2) & (3)	1030	1230	600	1200	20	600	400	1100
M 350P-50 A AM FCE	(2) & (3)								
M 400P-50 A AM FCE	(2) & (3)								
M 400XP-50 A AM FCE	(2) & (3)								
M 470P-50 A AM FCE	(2) & (3)								

(2) Side trimmed: max width 1250 after prior agreement
(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Dimensions Thickness 0.65 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 470P-65 A AM FCE	(2) & (3)	1030	1230	600	1200	20	600	400	1100

(2) Side trimmed: max width 1250 after prior agreement
(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Magnetic properties Thickness 0.35 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)			Max anisotropy of loss (+/-%)	Min number of bends	Min stacking factor
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m			
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
M 330P-35 A AM FCE	7.75	1.35	3.30	4.12	1.61	1.70	1.82	17	3	0.95

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.50 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)			Max anisotropy of loss (+/-%)	Min number of bends	Min stacking factor
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m			
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
M 330P-50 A AM FCE	7.75	1.45	3.30	4.20	1.62	1.72	1.83	14	3	0.96
M 350P-50 A AM FCE		1.60	3.50	4.45				12	5	
M 400P-50 A AM FCE		1.80	4.00	5.10						
M 400XP-50 A AM FCE					1.65	1.74	1.85			
M 470P-50 A AM FCE		2.00	4.70	5.90	1.62	1.72	1.83	10	10	

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.65 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)			Max anisotropy of loss (+/-%)	Min number of bends	Min stacking factor
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m			
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
M 470P-65 A AM FCE	7.75	2.10	4.70	6.13	1.62	1.72	1.83	12	5	0.97

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Mechanical properties

The mechanical properties are for information purposes only.

Mechanical properties Thickness 0.35 mm

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 330P-35 A AM FCE	T	250 - 300	415 - 455	0.61 - 0.66	25 - 35	130 - 160

Mechanical properties Thickness 0.50 mm

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 330P-50 A AM FCE	T	250 - 300	400 - 450	0.61 - 0.66	27 - 37	135 - 165
M 350P-50 A AM FCE	T	250 - 300	400 - 450	0.61 - 0.66	27 - 37	135 - 165
M 400P-50 A AM FCE	T	260 - 310	420 - 470	0.62 - 0.67	27 - 37	135 - 165
M 400XP-50 A AM FCE	T	260 - 310	420 - 470	0.62 - 0.67	27 - 37	135 - 165
M 470P-50 A AM FCE	T	270 - 320	430 - 480	0.63 - 0.68	27 - 37	140 - 170

Mechanical properties Thickness 0.65 mm

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 470P-65 A AM FCE	T	270 - 320	430 - 480	0.62 - 0.67	30 - 40	140 - 170

Coating properties

These high permeability grades are available non-insulated or varnished.

Fully processed high frequency grade

This type of electrical steel is mainly used when weight and volume reduction is essential, for instance in aeronautic or medical applications. The part shown here is used for a breathing aid.

Properties

This non-oriented fully processed high frequency grade has guaranteed magnetic properties in accordance with EN 10303:2015, which specifically concerns thin electrical steels for use at frequencies above 100 Hz. Full magnetic characterisation curves at various frequencies are available on request.

Advantages

High frequency electrical steels have very low loss levels, especially at high frequencies. These properties are a result of the thin gauge of this material (0.20 mm), its particular chemical composition and specific thermomechanical processing.

Applications

This grade is designed for high speed rotating machines (100 to 5000 Hz). It allows minimisation of losses due to higher harmonics and clearly increases machine efficiency in the case of non-sinusoidal power supply. This thin, fully processed grade is also used when weight and volume reduction are of major importance, such as in medical or aviation applications.

Recommendations for use

The above properties are obtained without heat treatment after stamping.
The material as supplied possesses all the required magnetic properties.

Brand correspondence

	EN 10303:2015	ASTM A1086:2013	IEC/CEI 60404-8-8:2017
NO 20	NO 20-15	20T680 *(15,0)*	NO 20-15

Dimensions

		Before side trimming		Side trimmed		Slit coils	
	Notes	Min width	Max width	Min width	Max width	Min width	Max width
NO 20	(3)	1030	1030	600	1000	20	600

(3) Slit coils: after prior agreement regarding widths between 20 and 44 mm

Magnetic properties

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)			Min number of bends	Min stacking factor
		at 400 Hz at 1 T	at 400 Hz at 1.5 T	at 700 Hz at 1 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m		
		Guaranteed	Indicative	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
NO 20	7.60	15	38	32	1.48	1.59	1.69	2	0.93

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

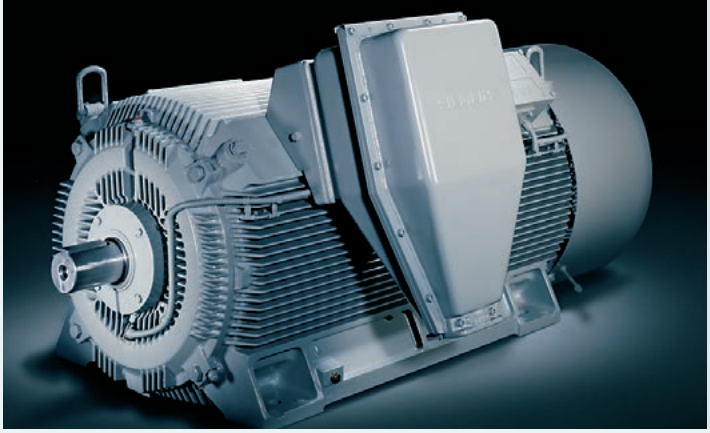
Mechanical properties

The mechanical properties are for information purposes only.

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
NO 20	L	395 - 435	505 - 545	0.78 - 0.83	12 - 22	205 - 235

Coating properties

This high frequency grade is available non-insulated or varnished with a C5-type coating.



Fully processed high strength grades

High strength values, combined with good magnetic properties, make these grades particularly suitable for high-speed rotating machines.

Properties

Non-oriented fully processed high strength grades have not only guaranteed magnetic properties but also guaranteed mechanical properties. Typical for these grades are higher strength values compared with the standard grades, both at room temperature and at higher temperature operating conditions. Full magnetic characterisation curves at different frequencies are available on request.

Advantages

These high strength grades withstand stronger mechanical forces than the standard grades. They are therefore an excellent compromise when a combination of high mechanical strength and low magnetic losses is required.

Applications

High strength values, combined with low losses and good permeability, make these grades particularly suitable for high-speed rotating machines.

Recommendations for use

The above properties are obtained without heat treatment after stamping.
The material as supplied possesses all the required magnetic properties.

Brand correspondence

	Old brand names
M 470YS-50 A AM FCE	HLE50
M 530YS-65 A AM FCE	HLE65

Dimensions

	Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Min width	Max width	Min width	Max width	Min width	Max width	Min width	Max width
M 470YS-50 A AM FCE	1030	1230	600	1200	250	600	400	1100
M 530YS-65 A AM FCE								

Magnetic properties

	Conventional density (kg/dm³)	Max loss (W/kg) at 50 Hz at 1.5 T	Min polarisation (T) at 5000 A/m
		Guaranteed	Guaranteed
M 470YS-50 A AM FCE	7.60	4.7	1.60
M 530YS-65 A AM FCE		5.3	1.62

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Mechanical properties

Guaranteed mechanical properties:

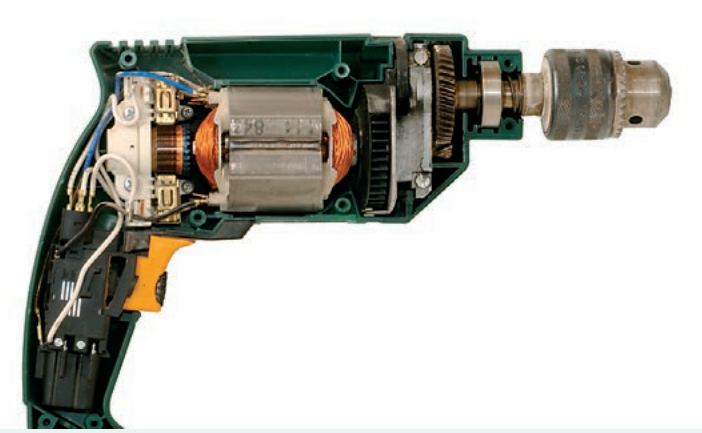
	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)
M 470YS-50 A AM FCE	T	> 470	> 580	> 15
M 530YS-65 A AM FCE	T	> 480	> 590	> 15

The following table specifies the typical mechanical properties:

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
M 470YS-50 A AM FCE	T	485 - 525	605 - 645	0.78 - 0.83	20 - 30	205 - 235
M 530YS-65 A AM FCE	T	495 - 545	610 - 660	0.80 - 0.85	20 - 30	205 - 235

Coating properties

These standard grades are available non-insulated or varnished with any of the coating types described in data sheet D10.



Semi-processed standard grades

These steels are designed for domestic appliances (e.g. washing machine motors), small industrial motors, fans and this electric drill.

Properties

Semi-processed standard grades have guaranteed magnetic properties in accordance with EN 10341:2006 (which superseded EN 10126:1995 for non-alloyed grades and EN 10165:1995 for alloyed grades). The magnetic properties are developed during the final annealing cycle, which is performed by the client after punching the laminations. This annealing treatment reduces losses and improves permeability and polarisation, as a result of recrystallisation, grain growth and also - for certain grades - decarburisation.

Advantages

The punchability of the semi-processed grades has been optimised by the application of an optimised final skin-pass reduction, after the cold rolling and annealing process. Skin-passing produces a controlled surface roughness, ensuring good material behaviour in the punching presses. This roughness also prevents the strips from sticking during the client's final annealing treatment. Regarding magnetic performance, skin-passing also plays an important role by stimulating grain growth during the annealing cycle, which results in further reduction of losses and increased permeability of the steel.

Applications

Non-alloyed semi-processed electrical steels are designed for small industrial motors, fans and domestic appliances such as washing machine motors, microwave oven transformers and refrigerator compressors.

Alloyed semi-processed electrical steels are designed for similar higher efficiency versions of these applications, as they have lower losses whilst the permeability remains at a good level.

Recommendations for use

The punching process needs to be carried out with an appropriate lubricant, which must be selected carefully, especially in the case of the alloyed semi-processed grades.

Brand correspondence Thickness 0.50 mm

	EN 10341:2006	EN 10126:1995	EN 10165:1995	IEC/CEI 60404-8-3:2005
M 340-50 K	M 340-50 K		M 340-50 E	M 340-50 K5
M 390-50 K	M 390-50 K		M 390-50 E	M 390-50 K5
M 450-50 K	M 450-50 K		M 450-50 E	M 450-50 K5
M 560-50 K	M 560-50 K		M 560-50 E	M 560-50 K5
M 660-50 K	M 660-50 K	M 660-50 D		M 660-50 K5
M 890-50 K	M 890-50 K	M 890-50 D		M 890-50 K5
M 1050-50 K	M 1050-50 K	M 1050-50 D		M 1050-50 K5

Brand correspondence Thickness 0.65 mm

	EN 10341:2006	EN 10126:1995	EN 10165:1995	IEC/CEI 60404-8-3:2005
M 390-65 K	M 390-65 K		M 390-65 E	M 390-65 K5
M 450-65 K	M 450-65 K		M 450-65 E	M 450-65 K5
M 520-65 K	M 520-65 K		M 520-65 E	M 520-65 K5
M 630-65 K	M 630-65 K		M 630-50 E	M 630-65 K5
M 800-65 K	M 800-65 K	M 800-65 D		M 800-65 K5
M 1000-65 K	M 1000-65 K	M 1000-65 D		M 1000-65 K5
M 1200-65 K	M 1200-65 K	M 1200-65 D		M 1000-65 K5

Dimensions

Please contact us for thicknesses < 0.50 mm.

Dimensions Thickness 0.50 mm

		Side trimmed		Slit coils	
	Notes	Min width	Max width	Min width	Max width
M 340-50 K	(1)	600	1300	40	600
M 390-50 K					
M 450-50 K			1350		
M 560-50 K					
M 660-50 K			1400		
M 890-50 K					
M 1050-50 K					

(1) After prior agreement

Dimensions Thickness 0.65 mm

		Side trimmed		Slit coils	
	Notes	Min width	Max width	Min width	Max width
M 390-65 K	(1)	600	1300	40	600
M 450-65 K					
M 520-65 K			1350		
M 630-65 K					
M 800-65 K			1400		
M 1000-65 K					
M 1200-65 K					

(1) After prior agreement

Dimensions Thickness 0.70 mm

		Side trimmed		Slit coils	
	Notes	Min width	Max width	Min width	Max width
M 1000-70 K AM FCE		600	1400	40	600

Grades in italics: not included in the standard

Dimensions Thickness 0.80 mm

		Side trimmed		Slit coils	
	Notes	Min width	Max width	Min width	Max width
M 1200-80 K AM FCE		600	1400	40	600

Grades in italics: not included in the standard

Dimensions Thickness 1.00 mm

		Side trimmed		Slit coils	
	Notes	Min width	Max width	Min width	Max width
M 1300-100 K AM FCE		600	1400	40	600
M 1800-100 K AM FCE					

Grades in italics: not included in the standard

Magnetic properties Thickness 0.50 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)		
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
M 340-50 K	7.65	1.42	3.40	4.32	1.54	1.62	1.72
M 390-50 K	7.70	1.62	3.90	4.97	1.56	1.64	1.74
M 450-50 K	7.75	1.92	4.50	5.67	1.57	1.65	1.75
M 560-50 K	7.80	2.42	5.60	7.03	1.58	1.66	1.76
M 660-50 K	7.85	2.80	6.60	8.38	1.62	1.70	1.79
M 890-50 K		3.70	8.90	11.30	1.60	1.68	1.78
M 1050-50 K		4.30	10.50	13.34	1.57	1.65	1.77

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.65 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)		
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
M 390-65 K	7.65	1.62	3.90	5.07	1.54	1.62	1.72
M 450-65 K	7.70	1.92	4.50	5.86	1.56	1.64	1.74
M 520-65 K	7.75	2.22	5.20	6.72	1.57	1.65	1.75
M 630-65 K	7.80	2.72	6.30	8.00	1.58	1.66	1.76
M 800-65 K	7.85	3.30	8.00	10.16	1.62	1.70	1.79
M 1000-65 K		4.20	10.00	12.70	1.60	1.68	1.78
M 1200-65 K		5.00	12.00	15.24	1.57	1.65	1.77

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.70 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)		
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
M 1000-70 K AM FCE	7.85	4.20	10.00		1.60	1.70	1.80

Grades in italics: not included in the standard

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.80 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)		
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
M 1200-80 K AM FCE	7.85	5.00	12.00		1.60	1.70	1.80

Grades in italics: not included in the standard

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 1.00 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)		
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
M 1300-100 K AM FCE	7.85	5.40	13.00		1.60	1.70	1.80
M 1800-100 K AM FCE		6.00	18.00		1.58	1.68	1.77

Grades in italics: not included in the standard

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Mechanical properties

The mechanical properties are for information purposes only.

Mechanical properties Thickness 0.50 mm

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	HV
M 340-50 K	T	400 - 450	450 - 550	7 - 23	150 - 210
M 390-50 K	T	390 - 485	445 - 515	7 - 26	150 - 210
M 450-50 K	T	355 - 435	405 - 475	10 - 29	135 - 190
M 560-50 K	T	380 - 440	435 - 495	10 - 29	130 - 185
M 660-50 K	T	350 - 450	380 - 470	13 - 30	125 - 170
M 890-50 K	T	285 - 450	350 - 470	16 - 35	120 - 170
M 1050-50 K	T	240 - 450	295 - 470	21 - 39	105 - 170

Mechanical properties Thickness 0.65 mm

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	HV
M 390-65 K	T	505 - 565	560 - 610	10 - 21	185 - 235
M 450-65 K	T	435 - 465	470 - 510	18 - 24	180 - 210
M 520-65 K	T	370 - 440	420 - 480	12 - 26	150 - 190
M 630-65 K	T	370 - 440	420 - 480	12 - 31	150 - 190
M 800-65 K	T	360 - 450	380 - 470	12 - 31	130 - 175
M 1000-65 K	T	280 - 450	350 - 470	17 - 37	120 - 170
M 1200-65 K	T	270 - 450	320 - 470	19 - 39	100 - 170

Mechanical properties Thickness 0.70 mm

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	HV
M 1000-70 K AM FCE	T	300 - 340	360 - 400	28 - 35	120 - 140

Grades in italics: not included in the standard

Mechanical properties Thickness 0.80 mm

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	HV
M 1200-80 K AM FCE	T	320 - 375	360 - 400	20 - 30	125 - 155

Grades in italics: not included in the standard

Mechanical properties Thickness 1.00 mm

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	HV
M 1300-100 K AM FCE	T	370 - 400	390 - 430	21 - 27	140 - 170
M 1800-100 K AM FCE	T	255 - 305	290 - 335	29 - 43	105 - 140

Grades in italics: not included in the standard

Coating properties

These semi-processed grades are available non-insulated. The final process step in the decarburising annealing treatment carried out by the client provides a suitable atmosphere and thermal conditions for blueing: the formation of an oxide film, which creates the required surface insulation layer.

These high permeability grades have been proven to enhance the efficiency of industrial motors.

Semi-processed high permeability grades

Properties

Semi-processed high permeability grades have guaranteed superior magnetic properties compared with the standard semi-processed grades (see data sheet D30).
We offer two categories:

- Higher permeability isotropic products (indicated by the letter P)
- Very high permeability grades (indicated by the letters XP). In addition to their overall excellent permeability at higher saturations, these grades have extra high permeability at 45° (diagonal) to the rolling direction.

As for the standard semi-processed grades, the high permeability grades need a final annealing treatment, carried out by the client after punching the laminations.

Advantages

The semi-processed high permeability grades allow core weight reduction and increased efficiency of motors and transformers. The improved efficiency achieved reduces machine operating costs and at the same time makes them more environmentally friendly.

Applications

Semi-processed high permeability grades are designed for motors, generators, transformers, converters and ballasts where higher efficiency is required.

Recommendations for use

M450P-50K AM FCE and M600P-65K AM FCE need no particular machine production process adjustments. The very high polarisation levels of M560XP-50K AM FCE and M700XP-65K AM FCE diagonal to the rolling direction can be exploited advantageously for ballasts and small transformers by adjusting the punching operation, preferably in the 45° direction.

Brand correspondence Thickness 0.50 mm

	Old brand names
M450P-50K AM FCE	
M560XP-50K AM FCE	Ekotex® 50

Brand correspondence Thickness 0.65 mm

	Old brand names
M600P-65K AM FCE	
M700XP-65K AM FCE	Ekotex® 65

Dimensions

Please contact us for thicknesses < 0.50 mm.

Dimensions Thickness 0.50 mm

	Side trimmed		Slit coils	
	Min width	Max width	Min width	Max width
M450P-50K AM FCE	600	1400	40	600
M560XP-50K AM FCE				

Dimensions Thickness 0.65 mm

	Side trimmed		Slit coils	
	Min width	Max width	Min width	Max width
M600P-65K AM FCE	600	1400	40	600
M700XP-65K AM FCE				

Magnetic properties

The very high permeability grades (XP) offer excellent performance at 45°, with J2500 up to 1.79 T. Deviating from the standard Epstein test, we guarantee for these grades the average values measured in all directions of the sheet plane. These values are representative of the real material behaviour in a rotating machine.

The magnetic properties given for the high permeability grades (P) refer to the standard Epstein test (mixture of L and T direction).

Magnetic properties Thickness 0.50 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)		
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
M450P-50K AM FCE	7.85	1.90	4.50	5.70	1.61	1.68	1.79
M560XP-50K AM FCE		2.20	5.60	7.00	1.68	1.76	1.86

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Magnetic properties Thickness 0.65 mm

	Conventional density (kg/dm³)	Max loss (W/kg)			Min polarisation (T)		
		at 50 Hz at 1 T	at 50 Hz at 1.5 T	at 60 Hz at 1.5 T	at 2500 A/m	at 5000 A/m	at 10,000 A/m
		Indicative	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
M600P-65K AM FCE	7.85	2.40	6.00	7.60	1.61	1.68	1.79
M700XP-65K AM FCE		2.50	7.00	8.90	1.68	1.76	1.86

Multiply the values in W/kg by 0.4536 to obtain the values in W/lb.

Mechanical properties

The mechanical properties are for information purposes only.

Mechanical properties Thickness 0.50 mm

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	HV
M450P-50K AM FCE	T	350 - 490	380 - 500	< 30	130 - 180
M560XP-50K AM FCE	T	380 - 450	430 - 470	< 28	130 - 165

Mechanical properties Thickness 0.65 mm

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	HV
M600P-65K AM FCE	T	350 - 490	380 - 500	< 30	130 - 180
M700XP-65K AM FCE	T	380 - 450	430 - 470	< 28	130 - 165

Coating properties

As with the standard grades, the high permeability grades are available non-insulated. However, these high permeability grades can be supplied with an organic or inorganic-organic coating to meet higher insulating requirements.

The Easy Punch grade is designed for excellent punchability and stackability, ideal for this alternator.

Easy Punch steels with guaranteed punchability

Properties

The Easy Punch grade has guaranteed mechanical properties and roughness.
Magnetic properties are not guaranteed, as they are not optimised in this product.
Should the application require enhanced magnetic performance, other electrical steel grades in our product range are recommended.

Advantages

This Easy Punch grade has excellent punchability and stackability, thanks to appropriate mechanical properties and roughness. It is therefore eminently suitable for automatic stacking and assembling techniques. The excellent punchability is achieved by means of a final skin-pass treatment, which produces high R_e/R_m values (over 0.9). Easy Punch also has excellent weldability.

Applications

The Easy Punch grade is designed for small machines for intermittent use:

- Automotive equipment such as alternators, windscreen wipers, window-opening motors
- Small domestic appliances such as coffee grinders, mixers
- Small hand tools such as drills

Recommendations for use

Usually, the client does not perform heat treatment after punching. Heat treatment is an option to increase the magnetic performance of Easy Punch.

Brand correspondence

	Old brand names
Easy Punch	Usidécoupe

Dimensions

The Easy Punch grade is available in thicknesses ranging from 0.5 to 1.2 mm. For thicknesses less than 0.7 mm, the width may not exceed 1400 mm.

	Side trimmed	
	Min width	Max width
Easy Punch	600	1500

Mechanical properties

Guaranteed mechanical properties:

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m
Easy Punch	T	270 - 370	310 - 380	> 0.85

The following table specifies the typical mechanical properties:

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
Easy Punch	T	290 - 370	310 - 380	≥ 0.90	23 - 35	115 - 125

Coating properties

This Easy Punch grade is available non-insulated. Corrosion protection can be enhanced by applying a light oiling treatment.

Cold rolled pole sheet grades

The cold rolled pole sheet grades are designed for large high-speed machines because of their excellent combination of mechanical strength and magnetic performance, which makes them ideal for industrial applications.

Properties

Cold rolled pole sheet grades are classified according to their yield strength (EN 10265:1995). As well as guaranteed mechanical properties, they have guaranteed magnetic properties, but unlike other electrical steel grades, their magnetic properties are determined under direct current (DC) conditions. Full magnetic characterisation curves in DC and also at various frequencies are available on request.

This data sheet deals with the cold rolled grades that conform to the standard.

Advantages

High yield strength values allow these grades to withstand strong electromechanical forces. As well as excellent DC magnetic properties significantly superior to the requirements of the standard, these grades perform well on loss and induction levels at 50 Hz, thanks to a special chemical composition.

Applications

Cold rolled pole sheet grades are designed for large high-speed machines because of their excellent combination of mechanical strength and magnetic performance.

Recommendations for use

These properties are obtained without heat treatment after stamping.
The material as supplied possesses all the required magnetic properties.

Brand correspondence Thickness 0.65 mm

	EN 10265:1995	IEC/CEI 60404-8-5:1989
250-65-TF 183	250-65-TF 183	250-65-TF 183
300-65-TF 182	300-65-TF 182	300-65-TF 182
350-65-TF 181	350-65-TF 181	350-65-TF 181
400-65-TF 180	400-65-TF 180	400-65-TF 180

Brand correspondence Thickness 1.00 mm

	EN 10265:1995	IEC/CEI 60404-8-5:1989
250-100-TF 183	250-100-TF 183	250-100-TF 183
300-100-TF 182	300-100-TF 182	300-100-TF 182
350-100-TF 181	350-100-TF 181	350-100-TF 181
400-100-TF 180	400-100-TF 180	400-100-TF 180
450-100-TF 180 AM FCE		

Grades in italics: not included in the standard

Dimensions Thickness 0.65 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)
250-65-TF 183	(2)	1030	1230	600	1200	250	600	400	1130
300-65-TF 182	(2)								
350-65-TF 181	(2)								
400-65-TF 180	(2)								

(2) Side trimmed: max width 1250 mm after prior agreement

Dimensions Thickness 1.00 mm

		Before side trimming		Side trimmed		Slit coils		Sheet length 400 to 2500 mm	
	Notes	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)
250-100-TF 183	(1) & (2)	1030	1230	600	1200	250	600	400	1130
300-100-TF 182	(1) & (2)								
350-100-TF 181	(1) & (2)								
400-100-TF 180	(1) & (2)								
450-100-TF 180 AM FCE	(1) & (2)								

(1) After prior agreement regarding sheet lengths between 2000 and 2500 mm
(2) Side trimmed: max width 1250 mm after prior agreement
Grades in italics: not included in the standard

Magnetic properties Thickness 0.65 mm

	Min polarisation (T) in DC at 5000 A/m		Min polarisation (T) in DC at 15,000 A/m	
	Guaranteed	Typical	Guaranteed	Typical
250-65-TF 183	1.60	1.72	1.83	1.91
300-65-TF 182	1.55	1.69	1.82	1.88
350-65-TF 181	1.52	1.67	1.81	1.86
400-65-TF 180	1.50	1.64	1.80	1.84

Magnetic properties Thickness 1.00 mm

	Min polarisation (T) in DC at 5000 A/m		Min polarisation (T) in DC at 15,000 A/m	
	Guaranteed	Typical	Guaranteed	Typical
250-100-TF 183	1.60	1.71	1.83	1.90
300-100-TF 182	1.55	1.69	1.82	1.88
350-100-TF 181	1.52	1.67	1.81	1.86
400-100-TF 180	1.50		1.80	
450-100-TF 180 AM FCE				

Grades in italics: not included in the standard

Mechanical properties

Guaranteed mechanical properties:

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)
250-65-TF 183	T	> 250	> 325	> 16
300-65-TF 182		> 300	> 375	> 15
350-65-TF 181		> 350	> 425	> 13
400-65-TF 180		> 400	> 450	> 10
250-100-TF 183		> 250	> 325	> 16
300-100-TF 182		> 300	> 375	> 15
350-100-TF 181		> 350	> 425	> 13
400-100-TF 180		> 400	> 450	> 10
450-100-TF 180 AM FCE		> 450	> 500	

Grades in italics: not included in the standard

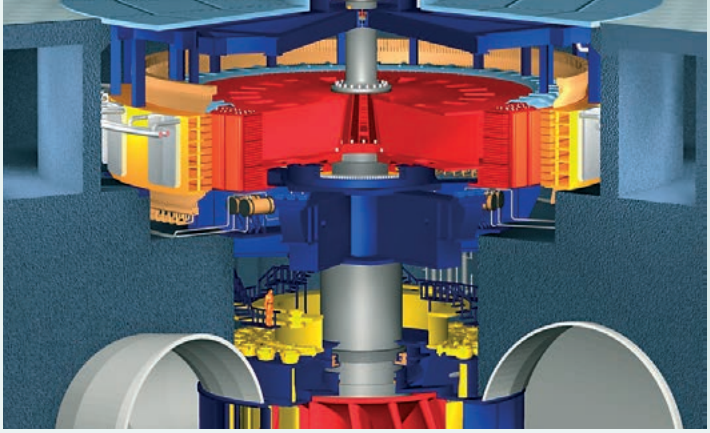
The following table specifies the typical mechanical properties:

	Direction	R_e (MPa)	R_m (MPa)	A_{80} (%)	R_e/R_m	HV
250-65-TF 183	T	270 - 320	400 - 440	30 - 40	0.68 - 0.73	120 - 150
300-65-TF 182		320 - 360	450 - 490		0.70 - 0.75	140 - 170
350-65-TF 181		400 - 440	530 - 570	25 - 35	0.74 - 0.79	180 - 210
400-65-TF 180		470 - 510	590 - 630		0.77 - 0.82	200 - 230
250-100-TF 183		290 - 340	420 - 470	30 - 40	0.68 - 0.73	130 - 160
300-100-TF 182		320 - 360	450 - 490	28 - 38	0.70 - 0.75	140 - 170
350-100-TF 181		400 - 440	530 - 570	25 - 35	0.74 - 0.79	180 - 210
400-100-TF 180		420 - 460	540 - 580		0.75 - 0.80	190 - 220
450-100-TF 180 AM FCE		480 - 520	580 - 620	20 - 30	0.78 - 0.82	200 - 230

Grades in italics: not included in the standard

Coating properties

These cold rolled pole sheet grades are available non-insulated or varnished with any of the coatings described in data sheet D10.



Hot rolled pole sheet grades

High yield strength values allow these grades to withstand strong centrifugal and electromechanical forces, both in static and dynamic conditions, which is indispensable for hydroelectric power stations, as illustrated here.

Properties

Hot rolled pole sheet grades are classified according to their yield strength (EN 10265:1995). As well as guaranteed mechanical properties, they have guaranteed magnetic properties, but unlike other electrical steel grades, their magnetic characterisation is determined under direct current (DC) conditions.

Advantages

High yield strength values allow these grades to withstand strong centrifugal and electromechanical forces, both in static and dynamic conditions. The DC magnetic properties are excellent and significantly superior to the requirements of the standard.
For the hot rolled pole sheets with yield strength guarantee up to 400 MPa the flatness guarantee is maintained after laser cutting of the laminations.
For the hot rolled pole sheets with yield strength guarantee beyond 400 MPa the flatness remains excellent, even after laser cutting of the laminations.

Applications

Hot rolled pole sheet grades can be supplied in the form of coils or sheets.
Hot rolled pole sheet grades are designed for large high-speed machines because of their excellent combination of mechanical strength and good magnetic performance.
Good magnetic properties are of major importance for the performance of the poles, whereas excellent mechanical properties are needed for the rims.

Recommendations for use

The above properties are obtained without heat treatment, whatever be the mechanical or thermal cutting process used to obtain the desired lamination diameter. The material as supplied possesses all the required magnetic properties.

Brand correspondence

	EN 10265:1995	IEC/CEI 60404-8-5:1989	Old brand names
250-150-TG 180	250-150-TG 180	250-150-TG 180	Usinalter 250
250-200-TG 180	250-200-TG 180	250-200-TG 180	Usinalter 250
250-300-TG 180	250-300-TG 180	250-300-TG 180	Usinalter 250
250-400-TG 180	250-400-TG 180	250-400-TG 180	Usinalter 250
250-500-TG 180	250-500-TG 180	250-500-TG 180	Usinalter 250
300-150-TG 180	300-150-TG 180	300-150-TG 180	Usinalter 300
300-200-TG 180	300-200-TG 180	300-200-TG 180	Usinalter 300
300-300-TG 180	300-300-TG 180	300-300-TG 180	Usinalter 300
300-400-TG 180	300-400-TG 180	300-400-TG 180	Usinalter 300
300-500-TG 180	300-500-TG 180	300-500-TG 180	Usinalter 300
350-150-TG 179	350-150-TG 179	350-150-TG 179	Usinalter 350
350-200-TG 179	350-200-TG 179	350-200-TG 179	Usinalter 350
350-250-TG 179	350-250-TG 179	350-250-TG 179	Usinalter 350
350-300-TG 179	350-300-TG 179	350-300-TG 179	Usinalter 350
350-400-TG 179	350-400-TG 179	350-400-TG 179	Usinalter 350
350-500-TG 179	350-500-TG 179	350-500-TG 179	Usinalter 350

Brand correspondence (continued)

	EN 10265:1995	IEC/CEI 60404-8-5:1989	Old brand names
400-180-TG 179	400-180-TG 179	400-180-TG 179	Usinalter 400
400-200-TG 179	400-200-TG 179	400-200-TG 179	Usinalter 400
400-240-TG 179	400-240-TG 179	400-240-TG 179	Usinalter 400
400-300-TG 179	400-300-TG 179	400-300-TG 179	Usinalter 400
400-400-TG 179	400-400-TG 179	400-400-TG 179	Usinalter 400
400-500-TG 179	400-500-TG 179	400-500-TG 179	Usinalter 400
450-180-TG 179*	450-180-TG 179	450-180-TG 179	Usinalter 450
450-200-TG 179*	450-200-TG 179	450-200-TG 179	Usinalter 450
450-300-TG 179*	450-300-TG 179	450-300-TG 179	Usinalter 450
450-400-TG 179*	450-400-TG 179	450-400-TG 179	Usinalter 450
450-500-TG 179*	450-500-TG 179	450-500-TG 179	Usinalter 450
500-200-TG 179*	500-200-TG 179	500-200-TG 179	Usinalter 500
500-300-TG 179*	500-300-TG 179	500-300-TG 179	Usinalter 500
500-400-TG 179*	500-400-TG 179	500-400-TG 179	Usinalter 500
500-500-TG 179*	500-500-TG 179	500-500-TG 179	Usinalter 500
550-200-TG 178*	550-200-TG 178	550-200-TG 178	Usinalter 550
550-220-TG 178*	550-220-TG 178	550-220-TG 178	Usinalter 550
550-250-TG 178*	550-250-TG 178	550-250-TG 178	Usinalter 550
550-300-TG 178*	550-300-TG 178	550-300-TG 178	Usinalter 550
550-400-TG 178*	550-400-TG 178	550-400-TG 178	Usinalter 550
550-500-TG 178*	550-500-TG 178	550-500-TG 178	Usinalter 550
600-200-TG 178*	600-200-TG 178	600-200-TG 178	Usinalter 600
600-250-TG 178*	600-250-TG 178	600-250-TG 178	Usinalter 600
600-300-TG 178*	600-300-TG 178	600-300-TG 178	Usinalter 600
600-400-TG 178*	600-400-TG 178	600-400-TG 178	Usinalter 600
600-500-TG 178*	600-500-TG 178	600-500-TG 178	Usinalter 600
650-200-TG 178*	650-200-TG 178	650-200-TG 178	Usinalter 650
650-250-TG 178*	650-250-TG 178	650-250-TG 178	Usinalter 650
650-300-TG 178*	650-300-TG 178	650-300-TG 178	Usinalter 650
650-400-TG 178*	650-400-TG 178	650-400-TG 178	Usinalter 650
650-500-TG 178*	650-500-TG 178	650-500-TG 178	Usinalter 650
700-200-TG 178*	700-200-TG 178	700-200-TG 178	Usinalter 700
700-250-TG 178*	700-250-TG 178	700-250-TG 178	Usinalter 700
700-300-TG 178*	700-300-TG 178	700-300-TG 178	Usinalter 700
700-400-TG 178*	700-400-TG 178	700-400-TG 178	Usinalter 700
700-500-TG 178*	700-500-TG 178	700-500-TG 178	Usinalter 700

** Please contact us for the flatness.*

Dimensions

	Mill finish		Side trimmed**	
	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)
250-150-TG 180	675	1350	595	1270
250-200-TG 180		1550		1470
250-300-TG 180		2037		1957
250-400-TG 180		2137		2057
250-500-TG 180				
300-150-TG 180		1055		975
300-200-TG 180		1550		1470
300-300-TG 180		1610		1530
300-400-TG 180		1887		1807
300-500-TG 180		2137		2057
350-150-TG 179		1055		975
350-200-TG 179		1550		1470
350-250-TG 179		1400		1320
350-300-TG 179		1610		1530
350-400-TG 179		1887		1807
350-500-TG 179		2137		2057
400-180-TG 179		1055		975
400-200-TG 179		1255		1175
400-240-TG 179		1330		1250
400-300-TG 179		1550		1470
400-400-TG 179		1840		1760
400-500-TG 179		2137		2057
450-180-TG 179		1055		975
450-200-TG 179		1255		1175
450-300-TG 179		1550		1470
450-400-TG 179		1840		1760
450-500-TG 179		2137		2057
500-200-TG 179		1255		1175
500-300-TG 179		1550		1470
500-400-TG 179				
500-500-TG 179		1640		1560
550-200-TG 178		1105		1025
550-220-TG 178		1180		1100
550-250-TG 178		1255		1175
550-300-TG 178		1350		1270
550-400-TG 178		1550		1470
550-500-TG 178		1640		1560

Please contact us for other dimensions.

*** Smaller widths are available after slitting.*

Dimensions (continued)

	Mill finish		Side trimmed**	
	Min width (mm)	Max width (mm)	Min width (mm)	Max width (mm)
600-200-TG 178	675	1225	595	1145
600-250-TG 178				
600-300-TG 178		1520		1440
600-400-TG 178		1620		1540
600-500-TG 178		1720		1640
650-200-TG 178		1225		1145
650-250-TG 178				
650-300-TG 178		1520		1440
650-400-TG 178		1620		1540
650-500-TG 178		1720		1640
700-200-TG 178		1225		1145
700-250-TG 178				
700-300-TG 178		1520		1440
700-400-TG 178		1620		1540
700-500-TG 178		1720		1640

Please contact us for other dimensions.

*** Smaller widths are available after slitting.*

Magnetic properties

	Min polarisation (T) in DC at 5000 A/m	Min polarisation (T) in DC at 15,000 A/m
	Guaranteed	Guaranteed
250-150-TG 180	1.60	1.80
250-200-TG 180		
250-300-TG 180		
250-400-TG 180		
250-500-TG 180		
300-150-TG 180		
300-200-TG 180		
300-300-TG 180		
300-400-TG 180		
300-500-TG 180		

Magnetic properties (continued)

	Min polarisation (T) in DC at 5000 A/m	Min polarisation (T) in DC at 15,000 A/m
	Guaranteed	Guaranteed
350-150-TG 179	1.55	1.79
350-200-TG 179		
350-250-TG 179		
350-300-TG 179		
350-400-TG 179		
350-500-TG 179		
400-180-TG 179		
400-200-TG 179		
400-240-TG 179		
400-300-TG 179		
400-400-TG 179		
400-500-TG 179		
450-180-TG 179	1.54	
450-200-TG 179		
450-300-TG 179		
450-400-TG 179		
450-500-TG 179		
500-200-TG 179	1.53	
500-300-TG 179		
500-400-TG 179		
500-500-TG 179		
550-200-TG 178	1.52	1.78
550-220-TG 178		
550-250-TG 178		
550-300-TG 178		
550-400-TG 178		
550-500-TG 178		
600-200-TG 178	1.50	
600-250-TG 178		
600-300-TG 178		
600-400-TG 178		
600-500-TG 178		
650-200-TG 178	1.48	
650-250-TG 178		
650-300-TG 178		
650-400-TG 178		
650-500-TG 178		
700-200-TG 178	1.46	
700-250-TG 178		
700-300-TG 178		
700-400-TG 178		
700-500-TG 178		

Mechanical properties

Guaranteed mechanical properties:

	Direction	Thickness (mm)	R_e (MPa)	R_m (MPa)	A_{80} (%)	A $5.65\sqrt{S_o}$ (%)
250-150-TG 180	T	1.5 - 1.5	≥ 250	350 - 480	≥ 20	-
250-200-TG 180	T	2 - 2	≥ 250	350 - 480	≥ 20	-
250-300-TG 180	T	3 - 3	≥ 250	350 - 480	-	≥ 26
250-400-TG 180	T	4 - 4	≥ 250	350 - 480	-	≥ 26
250-500-TG 180	T	5 - 5	≥ 250	350 - 480	-	≥ 26
300-150-TG 180	T	1.5 - 1.5	≥ 300	400 - 520	≥ 20	-
300-200-TG 180	T	2 - 2	≥ 300	400 - 520	≥ 20	-
300-300-TG 180	T	3 - 3	≥ 300	400 - 520	-	≥ 24
300-400-TG 180	T	4 - 4	≥ 300	400 - 520	-	≥ 24
300-500-TG 180	T	5 - 5	≥ 300	400 - 520	-	≥ 24
350-150-TG 179	L	1.5 - 1.5	≥ 350	450 - 600	≥ 18	-
	T	1.5 - 1.5	≥ 350	450 - 600	≥ 18	-
350-200-TG 179	L	2 - 2	≥ 350	450 - 600	≥ 18	-
	T	2 - 2	≥ 350	450 - 600	≥ 18	-
350-250-TG 179	L	2.5 - 2.5	≥ 350	450 - 600	≥ 18	-
	T	2.5 - 2.5	≥ 350	450 - 600	≥ 18	-
350-300-TG 179	L	3 - 3	≥ 350	450 - 600	-	≥ 22
	T	3 - 3	≥ 350	450 - 600	-	≥ 22
350-400-TG 179	L	4 - 4	≥ 350	450 - 600	-	≥ 22
	T	4 - 4	≥ 350	450 - 600	-	≥ 22
350-500-TG 179	L	5 - 5	≥ 350	450 - 600	-	≥ 22
	T	5 - 5	≥ 350	450 - 600	-	≥ 22
400-180-TG 179	L	1.8 - 1.8	≥ 400	500 - 680	≥ 16	-
	T	1.8 - 1.8	≥ 400	500 - 680	≥ 16	-
400-200-TG 179	L	2 - 2	≥ 400	500 - 680	≥ 16	-
	T	2 - 2	≥ 400	500 - 680	≥ 16	-
400-240-TG 179	L	2.4 - 2.4	≥ 400	500 - 680	≥ 16	-
	T	2.4 - 2.4	≥ 400	500 - 680	≥ 16	-
400-300-TG 179	L	3 - 3	≥ 400	500 - 680	-	≥ 19
	T	3 - 3	≥ 400	500 - 680	-	≥ 19
400-400-TG 179	L	4 - 4	≥ 400	500 - 680	-	≥ 19
	T	4 - 4	≥ 400	500 - 680	-	≥ 19
400-500-TG 179	L	5 - 5	≥ 400	500 - 680	-	≥ 19
	T	5 - 5	≥ 400	500 - 680	-	≥ 19

Mechanical properties (continued)

	Direction	Thickness (mm)	R_e (MPa)	R_m (MPa)	A_{80} (%)	A $5.65\sqrt{S_o}$ (%)
450-180-TG 179	L	1.8 - 1.8	≥ 450	550 - 750	≥ 16	-
	T	1.8 - 1.8	≥ 450	550 - 750	≥ 16	-
450-200-TG 179	L	2 - 2	≥ 450	550 - 750	≥ 16	-
	T	2 - 2	≥ 450	550 - 750	≥ 16	-
450-300-TG 179	L	3 - 3	≥ 450	550 - 750	-	≥ 17
	T	3 - 3	≥ 450	550 - 750	-	≥ 17
450-400-TG 179	L	4 - 4	≥ 450	550 - 750	-	≥ 17
	T	4 - 4	≥ 450	550 - 750	-	≥ 17
450-500-TG 179	L	5 - 5	≥ 450	550 - 750	-	≥ 17
	T	5 - 5	≥ 450	550 - 750	-	≥ 17
500-200-TG 179	L	2 - 2	≥ 500	600 - 800	≥ 14	-
	T	2 - 2	≥ 500	600 - 800	≥ 14	-
500-300-TG 179	L	3 - 3	≥ 500	600 - 800	-	≥ 14
	T	3 - 3	≥ 500	600 - 800	-	≥ 14
500-400-TG 179	L	4 - 4	≥ 500	600 - 800	-	≥ 14
	T	4 - 4	≥ 500	600 - 800	-	≥ 14
500-500-TG 179	L	5 - 5	≥ 500	600 - 800	-	≥ 14
	T	5 - 5	≥ 500	600 - 800	-	≥ 14
550-200-TG 178	L	2 - 2	≥ 550	650 - 850	≥ 12	-
	T	2 - 2	≥ 550	650 - 850	≥ 12	-
550-220-TG 178	L	2.2 - 2.2	≥ 550	650 - 850	≥ 12	-
	T	2.2 - 2.2	≥ 550	650 - 850	≥ 12	-
550-250-TG 178	L	2.5 - 2.5	≥ 550	650 - 850	≥ 12	-
	T	2.5 - 2.5	≥ 550	650 - 850	≥ 12	-
550-300-TG 178	L	3 - 3	≥ 550	650 - 850	-	≥ 14
	T	3 - 3	≥ 550	650 - 850	-	≥ 14
550-400-TG 178	L	4 - 4	≥ 550	650 - 850	-	≥ 14
	T	4 - 4	≥ 550	650 - 850	-	≥ 14
550-500-TG 178	L	5 - 5	≥ 550	650 - 850	-	≥ 14
	T	5 - 5	≥ 550	650 - 850	-	≥ 14
600-200-TG 178	L	2 - 2	≥ 600	700 - 900	≥ 10	-
	T	2 - 2	≥ 600	700 - 900	≥ 10	-
600-250-TG 178	L	2.5 - 2.5	≥ 600	700 - 900	≥ 10	-
	T	2.5 - 2.5	≥ 600	700 - 900	≥ 10	-
600-300-TG 178	L	3 - 3	≥ 600	700 - 900	-	≥ 12
	T	3 - 3	≥ 600	700 - 900	-	≥ 12

Mechanical properties (continued)

	Direction	Thickness (mm)	R_e (MPa)	R_m (MPa)	A_{80} (%)	$A\ 5.65\sqrt{S_o}$ (%)
600-400-TG 178	L	4 - 4	≥ 600	700 - 900	-	≥ 12
	T	4 - 4	≥ 600	700 - 900	-	≥ 12
600-500-TG 178	L	5 - 5	≥ 600	700 - 900	-	≥ 12
	T	5 - 5	≥ 600	700 - 900	-	≥ 12
650-200-TG 178	L	2 - 2	≥ 650	750 - 900	≥ 10	-
	T	2 - 2	≥ 650	750 - 900	≥ 10	-
650-250-TG 178	L	2.5 - 2.5	≥ 650	750 - 900	≥ 10	-
	T	2.5 - 2.5	≥ 650	750 - 900	≥ 10	-
650-300-TG 178	L	3 - 3	≥ 650	750 - 900	-	≥ 12
	T	3 - 3	≥ 650	750 - 900	-	≥ 12
650-400-TG 178	L	4 - 4	≥ 650	750 - 900	-	≥ 12
	T	4 - 4	≥ 650	750 - 900	-	≥ 12
650-500-TG 178	L	5 - 5	≥ 650	750 - 900	-	≥ 12
	T	5 - 5	≥ 650	750 - 900	-	≥ 12
700-200-TG 178***	L	2 - 2	≥ 700	750 - 900	≥ 10	-
	T	2 - 2	≥ 700	750 - 900	≥ 10	-
700-250-TG 178***	L	2.5 - 2.5	≥ 700	750 - 900	≥ 10	-
	T	2.5 - 2.5	≥ 700	750 - 900	≥ 10	-
700-300-TG 178***	L	3 - 3	≥ 700	750 - 900	-	≥ 12
	T	3 - 3	≥ 700	750 - 900	-	≥ 12
700-400-TG 178***	L	4 - 4	≥ 700	750 - 900	-	≥ 12
	T	4 - 4	≥ 700	750 - 900	-	≥ 12
700-500-TG 178***	L	5 - 5	≥ 700	750 - 900	-	≥ 12
	T	5 - 5	≥ 700	750 - 900	-	≥ 12

**** Guaranteed tensile strength R_m ≥ 750 MPa*

Coating properties

Hot rolled pole sheet grades are available non-insulated. They can be supplied with the hot rolled oxide layer or pickled.
When pickled, they are protected with Easyfilm® dry coating, which offers protection against atmospheric corrosion for a period of three months.

iCARe®: ArcelorMittal's range of electrical steels for automotive

About iCARe®

iCARe® is ArcelorMittal's range of innovative electrical steels for the automotive market. Our iCARe® steels help automakers create environmentally friendly mobility solutions for a greener world.

These values are at the core of the name iCARe®. Finding innovative (i) and environmentally friendly (e) solutions is essential for the CAR of tomorrow.

Introduction

ArcelorMittal's iCARe® steels are a combination of standard and high performance electrical steel grades which have been specifically designed to meet the particular needs of electric and hybrid vehicle makers. Our iCARe® steels exhibit high permeability, low loss levels and have excellent yield strength.

The large number of products in the iCARe® range provides technical solutions for automakers which achieve:

- Lower CO_2 emissions and better fuel consumption for hybrid vehicles
- Longer drive range with existing battery technology
- Lower total cost of electrification
- Better power density of electric machines, to reduce the size and weight of electrical drive trains

The iCARe® offer

There are three steel types included in ArcelorMittal's iCARe® offering: Save, Torque and Speed. Each has been specifically designed for a typical electric automotive application. ArcelorMittal also offers advanced technical support to manufacturers, enabling them to realise the full potential of our iCARe® offer.

Save

A steel with very low losses, Save is ideal for the efficiency of the electrical machine. Its key role is to optimise the use of current coming from the battery. See our iCARe® Save data sheet to discover more about the range.

420 Save

These enhanced Save grades combine low losses with higher yield strength, compared to the standard Save grades. 420 MPa is the minimum guaranteed yield strength for the 420 Save grades. Such improved and guaranteed yield strength of the 420 Save products allows rotor design improvements, which increase the overall performance of the electrical machine.

Torque

Torque is a range of steels with high permeability which can achieve the highest levels of mechanical power output for a motor or current supply for a generator. Guaranteed polarisation levels are higher than those from Save. See our iCARe® Torque data sheet to find more about the full offering.

Speed

A group of specific high strength electrical steels for high speed rotors which maintain high levels of magnetic performance. These grades allow the machine to be more compact and have a higher power density. The grades come with guaranteed yield strengths, and guaranteed magnetic properties. The iCARe® Speed data sheet contains full details of the offering.

Coatings for iCARe®

Electrical steel varnishes for non-oriented grades are designed to enhance the behaviour of fully processed electrical steels. Their main purpose is to provide interlaminar insulation and to improve the punchability of these steels. ArcelorMittal recommends to use C5 coatings for its iCARe® electrical steels. The coatings are suitable for fully processed grades for hybrid and electric traction machines and compressors. For alternators, uncoated solutions can be used. More information about the use of these coatings can be found in the Coatings for iCARe® data sheet.

Advanced technical support

For automakers who wish to exploit the full potential of ArcelorMittal's iCARe® steels, we can offer advanced technical support in many areas including modelling, prototyping and material handling.

ArcelorMittal's machine modelling services

As a steel provider, ArcelorMittal also offers our customers all the help they need to choose the most suitable steels. We can also help to design the electrical machine. This level of assistance is possible thanks to our advanced R&D know-how and the high-tech equipment available in our research centres. For more information see our iCARe® Advanced technical support data sheet.

Prototyping services

Our modelling services enable design engineers to make precise machine calculations. This allows them to reduce the number of prototypes needed before pre-series begin. A minimal amount of prototyping is still needed to prove the machine's performance. ArcelorMittal can offer small quantities of sheets for first stage Epstein and tensile testing, and for the next stage of laser cutting. In the industrial validation phase, ArcelorMittal can provide small slit coils for punching and machine assembly development.

Material handling issues

The production of prototype or series machines can involve production processes that have the potential to degrade the properties of the fully processed steels we have supplied. Advanced R&D support is available to help customers quantify the impact of material handling processes on the magnetic performance of the machine's lamination stack. Our iCARe® Advanced technical support data sheet contains more information.

ArcelorMittal's electrical steel offering

In order to stretch the amount of power extracted from the battery, every other element in the electric vehicle must be optimised for low weight and high efficiency. This is particularly important for the electric motor and generator which form the heart of the powertrain.

ArcelorMittal's iCARe® electrical steel solutions can bring significant performance improvements to the core of the electric machine, and improve battery performance. The combination of efficiency and light weight means electric vehicles can go longer between charges, extending the drive range of the vehicle.

ArcelorMittal's iCARe® range includes specific electrical steels for applications where high power density or high torque are required. iCARe® steels enable the electrical systems in the vehicle to operate more efficiently, maximising power and delivering increased cranking torque. When the machine design is optimised using iCARe® steels, further weight savings can be achieved as fewer magnets and less copper windings are required. This also has the potential to reduce costs.

Importance of polarisation

The level of induction reached in the air gap between the rotor and the stator determines the torque a motor can develop. In the starter motor of a car, this break-away torque is very important. At low car speeds, the quality of the electrical steel used can create large differences in the dynamic behaviour of electric vehicles.

Importance of losses

An electric machine is no more than a system to convert electrical energy to mechanical energy (or vice-versa). The torque generated in the starter motor, is created by a polarisation level created in the steel, due to a magnetic field. The magnetic field can be provided by injecting current in a copper winding around the steel.

The key point is that the magnetic field creates a change in the magnetic structure inside the steel, in equilibrium with the applied field, which leads to a certain level of polarisation.

In an alternating current cycle, the magnetic field is reversed in some point later in time, but the internal magnetic structure of the steel cannot adapt immediately. There is a delayed

response, known as hysteresis, which is linked to irreversible processes taking place inside the steel.

Hysteresis is responsible for some energy loss, known as iron loss. As the steel warms up, the motor gets warm as part of the electricity provided to the motor is changed into wasted heat rather than useful mechanical output. With higher cycling speeds, hence higher electric frequencies, these losses become more important. Lowering the iron losses from the machine's steel laminations increases the amount of battery energy available in an electric or hybrid vehicle.

Thermal conductivity

The heat generated in an electrical machine needs to be extracted to ensure the safe operation of the machine. Failure to adequately remove the heat can lead to lower performance in terms of power or current output.

The heat is generated by the iron losses described above, along with losses from permanent magnets or copper windings. In fact, the insulation of copper windings is critical in the thermal equilibrium of a machine.

The heat can be evacuated via the:

- Rotor laminations towards the rotor shaft
- Air gap
- Stator lamination towards the housing. In this case it is important to choose steels with good thermal conductivity for the lamination

Mechanical properties

The mechanical properties of steels used in electrical applications must be adapted to allow good punchability. The punch should be able to form a sharp edge shape. If the edge is not sharp, shortcuts in the magnetic field may occur between assembled laminations and the edge of the steel may be deformed, reducing its magnetic properties. However, these factors must be balanced against the desired useful life of the punching tool.

ArcelorMittal's fully processed electrical steels are optimised for punchability. Further reductions in tool wear can be achieved by applying a suitable coating.

For hybrid and electric traction machines, the mechanical needs of the steel go beyond punchability. One method used to obtain higher power density machines is to work with higher speed rotors. This requires the rotor laminations to withstand higher centrifugal, electromagnetic and dynamic forces as the rotors speed up and slow down. The laminations often have very intricate, lace-like designs. It is a real challenge for mechanical machine designers to meet these strength needs in both standard and exceptional situations.

Finding the balance

The limitations of batteries can be mitigated if the available battery energy is optimally utilised. This requires light and highly efficient electrical steels which have low losses as their key property. Finding the balance between losses, permeability, saturation polarisation, thermal conductivity, tensile strength and yield strength, is vital for automotive electrical steels.

ArcelorMittal's experience as a provider of electrical steels for automotive applications has enabled us to develop steels which meet these challenges. We understand that optimal electrical motor solutions utilise different electrical steels for the stator and the rotor. Electrical steel grades with very low losses and high permeability are required for the stator, while high strength grades are required for the rotor.

Optimising all the electric components of a vehicle

In a process of continuous improvement, different efforts to optimise the electrical applications in vehicles are ongoing. The process started with the re-engineering of auxiliary electrical equipment such as alternators and starter motors. That led to the introduction of electric traction machines, first in hybrid drives and now moving towards vehicles powered fully by electric traction.

These changes have led to significant improvements in individual electrical components in vehicles.

Increased demand on alternators

Alternators have always provided the electricity necessary to power the engine pump, the engine cooling system, seat and window motors, and other essential applications. Since the 1970s, there has been an ever-increasing demand for onboard electricity from vehicle safety and comfort features. Meeting this demand has a corresponding impact on the amount of electricity that must be generated by the vehicle.

Thanks to the development of high-efficiency alternators, more current can be generated without increasing the amount of mechanical energy drawn from the ICE. Fuel consumption is therefore not affected.

Changes for starter motors

Until recently, starter motors have only been needed once in every drive cycle to crank the ICE into life. This changed with the introduction of stop-start systems which cut the ICE at a red light and restart it immediately when the gas pedal is depressed by the driver. Stop-start systems can lead to a 5% drop in both fuel consumption and CO_2-equivalent (CO_2-eq.) emissions.

To accommodate this change in function, starter motors have been completely redesigned to enable them to provide both a cold starting function at the beginning of the drive cycle as well as repetitive hot starts. The starter motors in stop-start systems are extremely efficient.

The challenge of creating electrical traction motors for automotive

The level of electrification of the powertrain has now evolved to the point where the ICE can be replaced with one or more electric machines. These machines provide pure electric traction.

Even when a designer elects to create an electrically powered vehicle, there are further considerations to be made. For example, if the vehicle has a higher power electric machine, more energy can be recuperated during braking. However, the battery must be capable of accepting the transfer of such energy.

In the gap between pure ICE and pure electric vehicles, there are many intermediate powertrain solutions where both the ICE and electric machines are present. In these hybrid configurations, many lay-outs exist and each represents a different set of compromises between the use of fossil fuels and electric energy. These compromises come about because vehicle designers must make choices between the cost of the ICE versus an electric machine. The battery cost and the environmental objectives of the car are the major decision criteria for this choice.

If a hybrid design is selected, the savings in fuel consumption depend on the level of hybridisation. There are generally two options:

- A mild hybrid which reduces fuel consumption by around 15% using a moderately powered electric motor and smaller battery
- A full hybrid which can reduce fuel consumption by up to 30% using a higher powered electric engine and larger battery capacity

Vehicles powered by electric traction machines are gaining increasing prominence. Unlike vehicles which utilise fossil fuels, pure electric cars produce very few harmful emissions during use. This makes them an attractive option for car makers who are seeking new strategies to meet ever-stricter regulations on vehicle emissions.

However, there are still significant challenges to overcome before electrical vehicles gain widespread acceptance with the general public. There are concerns about infrastructure, particularly the availability of recharging stations; and about the cost, range and longevity of the vehicles themselves.

Many of these concerns can be traced back to the battery in an electric vehicle. Classic batteries utilise a lead-acid technology which is extremely heavy, expensive, slow to recharge and limited in capacity.

New battery technologies have a higher capacity, but the cost and weight of the battery limits the drive range of pure electric vehicles. This is a key focus of electric vehicle development today.

Further information

For more information about ArcelorMittal's iCARe® range of electrical steels and the support we can provide, please visit: automotive.arcelormittal.com/icare

iCARe® Save

Properties

The iCARe® Save product family comes with guaranteed losses at 400 Hz and indicative maximum values at 700 Hz. These values are representative of the steel's behaviour at high frequencies.

Advantages

Save grades enable you to reduce the iron losses from the stators of synchronous machines. They are particularly useful for reducing iron losses in high-speed hybrid and electric traction machines, and generators which extend the range of electric vehicles. The iCARe® grades offer better losses than those of the materials described in the standards (see the brand correspondence table below).

Applications

Save grades are most effective at reducing iron losses from machine parts which are subject to high base frequencies and additional harmonics. Save thus helps to improve machine efficiency, which leads to an increase in power density. Power density can be tuned to create a lighter, smaller machine, or a more powerful machine for a given weight. Driving range is extended as Save reduces machine weight and costs and saves battery energy.

Recommendations for use

Save grades can be used immediately after lamination punching. The punching effect can be eliminated by performing a stress-relief annealing. This optimises their performance in applications with fine teeth, and enables a substantial part of the lower frequency area to be exploited. A C5-type coating is recommended.

Save stacks can be produced using existing assembly techniques such as interlocking or welding.

Brand correspondence

	EN 10303:2015	ASTM A1086:2013	IEC/CEI 60404-8-8:2017
Save 20-13	NO 20-13		NO 20-13
Save 20-15	NO 20-15	20T680 *(15,0)*	NO 20-15
Save 25-14	NO 25-14		NO 25-14
Save 25-16	NO 25-17*	25T730 *(16,0)*	NO 25-17*
Save 27-15	NO 27-15		
Save 27-17	NO 27-18*	27T770 *(17,0)*	
Save 30-14.5			
Save 30-15	NO 30-16*		NO 30-16*
Save 30-17	NO 30-19*	30T820 *(18,0)**	NO 30-19*
Save 35-18			
Save 35-19	NO 35-19		NO 35-19
Save 35-20	NO 35-22*		NO 35-22*

** Closest equivalent. The iCARe® grades offer better losses than those of the materials described in the standards.*

This brand correspondence above is based on loss level at 1 T/400 Hz. Regarding magnetic polarisation, Save grades are at the same level or better than the standard requirements.

Magnetic properties

	Conventional density (kg/dm³)	Max loss (W/kg) at 400 Hz at 1 T	Max loss (W/kg) at 700 Hz at 1 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%) at 400 Hz at 1 T	Min number of bends	Min stacking factor
		Guaranteed	Indicative	Guaranteed	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
Save 20-13	7.60	13	29	1.49	1.60	1.70	15	5	0.93
Save 20-15	7.60	15	32	1.49	1.60	1.70	15	5	0.93
Save 25-14	7.60	14	34	1.49	1.60	1.70	15	5	0.94
Save 25-16	7.60	16	37	1.49	1.60	1.70	15	5	0.94
Save 27-15	7.60	15	37	1.49	1.60	1.70	15	5	0.94
Save 27-17	7.60	17	40	1.49	1.60	1.70	15	5	0.94
Save 30-14.5	7.60	14.5	37	1.49	1.60	1.70	15	5	0.95
Save 30-15	7.60	15	38	1.49	1.60	1.70	15	5	0.95
Save 30-17	7.60	17	41	1.49	1.60	1.70	15	5	0.95
Save 35-18	7.60	18	44	1.49	1.60	1.70	15	5	0.95
Save 35-20	7.60	20	48	1.49	1.60	1.70	15	5	0.95

Mechanical properties

The data in the following table is provided for information purposes only.

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
Save 20-13	L	410 - 450	520 - 560	0.78 - 0.83	10 - 20	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	10 - 20	200 - 230
Save 20-15	L	390 - 430	510 - 550	0.76 - 0.81	15 - 30	195 - 225
	T	410 - 450	540 - 580	0.76 - 0.81	15 - 30	195 - 225
Save 25-14	L	410 - 450	520 - 560	0.78 - 0.83	12 - 25	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	12 - 25	200 - 230
Save 25-16	L	390 - 430	510 - 550	0.76 - 0.81	15 - 30	195 - 225
	T	410 - 450	540 - 580	0.76 - 0.81	15 - 30	195 - 225
Save 27-15	L	410 - 450	520 - 560	0.78 - 0.83	12 - 25	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	12 - 25	200 - 230
Save 27-17	L	390 - 430	510 - 550	0.76 - 0.81	15 - 30	195 - 225
	T	410 - 450	540 - 580	0.76 - 0.81	15 - 30	195 - 225
Save 30-14.5	L	410 - 450	520 - 560	0.78 - 0.83	12 - 25	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	12 - 25	200 - 230
Save 30-15	L	410 - 450	520 - 560	0.78 - 0.83	12 - 25	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	12 - 25	200 - 230
Save 30-17	L	390 - 430	510 - 550	0.76 - 0.81	15 - 30	195 - 225
	T	410 - 450	540 - 580	0.76 - 0.81	15 - 30	195 - 225
Save 35-18	L	410 - 450	520 - 560	0.78 - 0.83	10 - 20	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	10 - 20	200 - 230
Save 35-20	L	390 - 430	510 - 550	0.76 - 0.81	15 - 30	195 - 225
	T	410 - 450	540 - 580	0.76 - 0.81	15 - 30	195 - 225

Further information

For more information about ArcelorMittal's iCARe® range of electrical steels and the support we can provide, please visit: automotive.arcelormittal.com/icare

iCARe® 420 Save

Properties

The iCARe® 420 Save products are low loss electrical steel grades with a guaranteed yield strength of 420 MPa. Compared to the standard iCARe® Save grades, these iCARe® 420 Save grades have a higher yield strength. The iCARe® 420 Save product family combines improved mechanical properties with low core losses, which are specified as guaranteed losses at 400 Hz and indicative maximum values at 700 Hz, both at 1 T. These values are representative of the steel's core loss behaviour at high frequencies.

Advantages

The improved and guaranteed yield strength (420 MPa) of the iCARe® 420 Save products allows for rotor design improvements of for instance interior permanent magnet synchronous machines. Combined with the low core losses which are particularly useful in the stator, such mechanical rotor design improvements increase the overall performance of the electrical machine.

Applications

iCARe® 420 Save grades have an improved combination of mechanical properties, core losses and magnetic polarisation, and are most effective at reducing iron losses from machine parts which are subject to high base frequencies, additional space and time harmonics. The valorisation of the improved mechanical properties of the iCARe® 420 Save grades can be found in those electrical machine topologies where its higher yield strength can be exploited by optimising the mechanical design and/or increasing the machine's rotating speed, thus enhancing the power density.

In general, Save grades help to improve machine efficiency, especially in the high speed region of the operational torque-versus-speed map. Save grades are particularly useful for reducing iron losses in high-speed hybrid and electric traction machines: the driving range is extended as Save grades save battery energy. Also, having lower core losses implies leaner cooling strategies and thermal management of the electrical machines.

Recommendations for use

Save grades can be used immediately after lamination punching. The punching effect can be eliminated by performing a stress-relief annealing. This optimises their performance in applications with fine teeth, and enables a substantial part of the lower frequency area to be exploited. A C5-type coating is recommended.
Save stacks can be produced using existing assembly techniques such as interlocking or welding.

Magnetic properties

	Conventional density (kg/dm³)	Max loss (W/kg) at 400 Hz at 1 T	Max loss (W/kg) at 700 Hz at 1 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%) at 400 Hz at 1 T	Min number of bends	Min stacking factor
		Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed	Guaranteed
420 Save 20-13	7.60	13	29	1.49	1.60	1.70	15	5	0.93
420 Save 25-14*	7.60	14	34	1.49	1.60	1.70	15	5	0.94
420 Save 27-15	7.60	15	37	1.49	1.60	1.70	15	5	0.94
420 Save 30-16	7.60	16	41	1.49	1.60	1.70	15	5	0.95

** On request*

Remark: better guaranteed magnetic properties are available on request.

Mechanical properties

The typical data in the following table is provided for information purposes only.

	Direction	R_e (MPa) Guaranteed	R_e (MPa) Typical	R_m (MPa) Typical	R_e/R_m Typical	A_{80} (%) Typical	HV Typical
420 Save 20-13	L	> 420	430 - 470	550 - 600	0.77 - 0.81	10 - 20	200 - 230
	T	> 420	445 - 485	565 - 615	0.77 - 0.81	10 - 20	200 - 230
420 Save 25-14*	L	> 420	430 - 470	550 - 600	0.77 - 0.81	10 - 20	200 - 230
	T	> 420	445 - 485	565 - 615	0.77 - 0.81	10 - 20	200 - 230
420 Save 27-15	L	> 420	430 - 470	550 - 600	0.77 - 0.81	12 - 25	200 - 230
	T	> 420	445 - 485	565 - 615	0.77 - 0.81	12 - 25	200 - 230
420 Save 30-16	L	> 420	430 - 470	550 - 600	0.77 - 0.81	12 - 25	200 - 230
	T	> 420	445 - 485	565 - 615	0.77 - 0.81	12 - 25	200 - 230

** On request*

Further information

For more information about ArcelorMittal's iCARe® range of electrical steels and the support we can provide, please visit: automotive.arcelormittal.com/icare

iCARe® Torque

Properties

The iCARe® Torque product family comes with guaranteed losses at 400 Hz and indicative maximum values at 700 Hz. These values are representative of the steel's behaviour at high frequencies.

Advantages

Torque grades assist flux generation, allowing the motor to develop more mechanical output. If mechanical output is not an issue, permanent magnet or copper winding can be reduced to save on costs.

Applications

Torque grades are suitable for machines which need high torque at low speeds. They provide the fast acceleration required by hybrid and electric vehicles.

Recommendations for use

Torque grades can be used immediately after lamination punching. The effect of punching can be eliminated if a stress-relief annealing is applied. This optimises the performance of the Torque grades in applications with fine teeth. It can also provide substantial performance improvements in the lower frequency range. To achieve these effects, a C5 type coating is advised.

Torque stacks can be produced using existing assembly techniques such as interlocking or welding.

Magnetic properties

	Conventional density (kg/dm³)	Max loss (W/kg) at 400 Hz at 1 T	Max loss (W/kg) at 700 Hz at 1 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%) at 400 Hz at 1 T	Min number of bends	Min stacking factor
		Guaranteed	Indicative	Guaranteed	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
Torque 20-15 *	7.65	15	34	1.55	1.65	1.76	15	5	0.93
Torque 25-12.5	7.60	12.5	32	1.54	1.64	1.75	15	5	0.94
Torque 25-16	7.65	16	37	1.55	1.65	1.76	15	5	0.94
Torque 27-13.5	7.60	13.5	34	1.54	1.64	1.75	15	5	0.94
Torque 27-16	7.65	16	38	1.55	1.65	1.76	15	5	0.94
Torque 30-14.5	7.60	14.5	37	1.54	1.64	1.75	15	5	0.95
Torque 30-15	7.60	15	39	1.55	1.65	1.76	15	5	0.95
Torque 30-17	7.65	17	40	1.55	1.65	1.76	15	5	0.95
Torque 30-18	7.65	18	41	1.55	1.65	1.76	15	5	0.95
Torque 35-20	7.65	20	50	1.55	1.65	1.76	15	5	0.95

** On request*

Mechanical properties

The data in the following table is provided for information purposes only.

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
Torque 20-15 *	L	340 - 380	470 - 510	0.71 - 0.76	13 - 28	170 - 200
	T	360 - 400	490 - 530	0.71 - 0.76	13 - 28	170 - 200
Torque 25-12.5	L	410 - 450	520 - 560	0.78 - 0.83	12 - 25	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	12 - 25	200 - 230
Torque 25-16	L	340 - 380	470 - 510	0.71 - 0.76	13 - 28	170 - 200
	T	360 - 400	490 - 530	0.71 - 0.76	13 - 28	170 - 200
Torque 27-13.5	L	410 - 450	520 - 560	0.78 - 0.83	12 - 25	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	12 - 25	200 - 230
Torque 27-16	L	340 - 380	470 - 510	0.71 - 0.76	13 - 28	170 - 200
	T	360 - 400	490 - 530	0.71 - 0.76	13 - 28	170 - 200
Torque 30-14.5	L	410 - 450	520 - 560	0.78 - 0.83	12 - 25	200 - 230
	T	425 - 465	535 - 575	0.78 - 0.83	12 - 25	200 - 230
Torque 30-15	L	390 - 430	510 - 550	0.76 - 0.81	15 - 30	195 - 225
	T	410 - 450	540 - 580	0.76 - 0.81	15 - 30	195 - 225
Torque 30-17	L	340 - 380	470 - 510	0.71 - 0.76	13 - 28	170 - 200
	T	360 - 400	490 - 530	0.71 - 0.76	13 - 28	170 - 200
Torque 30-18	L	340 - 380	470 - 510	0.71 - 0.76	13 - 28	170 - 200
	T	360 - 400	490 - 530	0.71 - 0.76	13 - 28	170 - 200
Torque 35-20	L	340 - 380	470 - 510	0.71 - 0.76	13 - 28	170 - 200
	T	360 - 400	490 - 530	0.71 - 0.76	13 - 28	170 - 200

** On request*

Further information

For more information about ArcelorMittal's iCARe® range of electrical steels and the support we can provide, please visit: automotive.arcelormittal.com/icare

iCARe® Speed

Properties

The iCARe® Speed product family comes with guaranteed losses at 400 Hz and indicative maximum values at 700 Hz. These values are representative of the steel's behaviour at high frequencies.

Advantages

The Speed grades provide an excellent compromise between mechanical properties and losses.

Applications

Speed has been developed for very high speed rotors. This enables manufacturers to make more compact machines for a given mechanical output.

Recommendations for use

Speed grades can be used immediately after lamination punching. The effect of punching can be eliminated if a stress-relief annealing is applied. This optimises the performance of the Speed grades in applications with fine teeth. It can also provide substantial performance improvements in the lower frequency range. To achieve these effects, a C5 type coating is advised.

Speed stacks can be produced using any existing assembly technique such as interlocking or welding.

Magnetic properties

	Conventional density (kg/dm³)	Max loss (W/kg) at 400 Hz at 1 T	Max loss (W/kg) at 700 Hz at 1 T	Min polarisation (T) at 2500 A/m	Min polarisation (T) at 5000 A/m	Min polarisation (T) at 10,000 A/m	Max anisotropy of loss (+/-%) at 400 Hz at 1 T	Min number of bends	Min stacking factor
		Guaranteed	Indicative	Guaranteed	Guaranteed	Indicative	Guaranteed	Guaranteed	Guaranteed
Speed 35-440	7.60	23	60	1.51	1.62	1.72	15	5	0.95
Speed 35-510	7.60	28	65	1.51	1.62	1.72	15	5	0.95

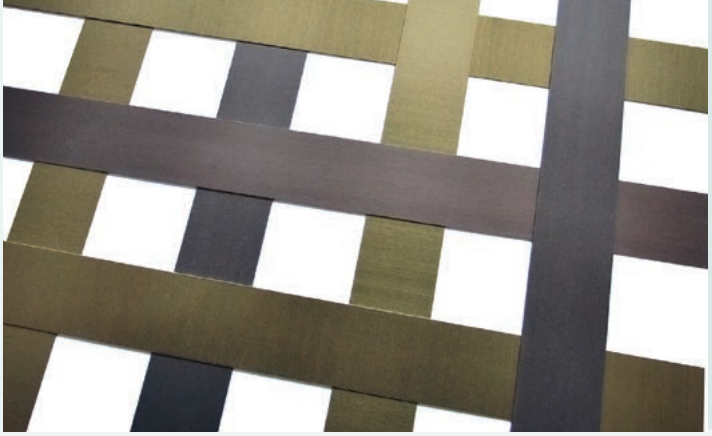
Mechanical properties

The minimal values for R_e and R_m data are guaranteed in the rolling direction. The other values in the following table are provided for information purposes only.

	Direction	R_e (MPa)	R_m (MPa)	R_e/R_m	A_{80} (%)	HV
Speed 35-440	L	440 - 490	570 - 620	0.76 - 0.88	20 - 30	210 - 240
	T	465 - 515	590 - 640	0.76 - 0.88	20 - 30	210 - 240
Speed 35-510	L	510 - 560	605 - 655	0.80 - 0.92	20 - 30	210 - 240
	T	540 - 590	625 - 675	0.80 - 0.92	20 - 30	210 - 240

Further information

For more information about ArcelorMittal's iCARe® range of electrical steels and the support we can provide, please visit: automotive.arcelormittal.com/icare



Coatings for iCARe®

Properties

Electrical steel varnishes for non-oriented grades are designed to enhance the behaviour of fully processed electrical steels. Their main purpose is to provide interlaminar insulation and to improve the punchability of these steels. Each type has its own specific properties, such as insulation level, punchability effect, corrosion protection, temperature resistance and weldability; hence it is material use that determines the optimum choice of varnish. All varnishes have been selected and developed to be environmentally friendly: they are hydrosoluble and chromium-free.

Advantages

The C5-type varnish is the preferred varnish for automotive applications: it is a pigmented varnish, made with thermostable resins, mineral products and pigments.
For the EC-5-N varnish, the type of mineral products and the amount used have been selected to obtain a coating with excellent temperature resistance during prolonged thermal treatments. This is of particular interest where stress-relief annealing is required after punching. Additionally, the mineral part of the coating provides high thermal conductivity. The combination of resins and mineral products achieves a good compromise between corrosion protection and weldability.
The EC-5-P has an increased amount of organic components compared to the EC-5-N, in order to achieve a better punchability, whilst maintaining a good weldability.
The standard gauge range is from 0.5 to 1.5 µm per side.

Applications

These coatings are used for fully processed grades for hybrid and electric traction machines and compressors. For alternators, uncoated solutions can be used.

Recommendations for use

The raw materials used in these coatings have a chemical composition – both in the liquid and cured varnish state – which does not require specific protective measures during the processing of the coated steels or during use in a given application.

Brand correspondence

	EN 10342:2005	ASTM A976:2003	IEC/CEI 60404-1-1:2004	ArcelorMittal code
C5	EC-5-P	C-5	EC-5-P	T
C5	EC-5-N	C-5	EC-5-N	G

Coating properties

Designation	C5	
Chemical composition	Inorganic (minerals, pigments) Organic (synthetic resin)	
Colour	Grey	
ArcelorMittal code	T11	G11
Gauge (µm/side)	0.5 to 1.5	
Typical insulation resistance ($\Omega.cm^2$/side)	10	
Temperature resistance (°C) Continuous / Intermittent	210/600	250/850
Main properties	Punchability	Heat resistance

Insulation measurement: Franklin test according to the standard EN 60404-11:2013.

Continuous temperature resistance according to the standard IEC/CEI 60404-12:1992.

Packaging

All packaging materials are in accordance with the European directive on the disposal of packaging material (1994/62/EC), which bans material containing heavy metals. We are working in close collaboration with our clients to avoid unnecessary packaging so as to reduce waste to an absolute minimum.

Coatings for electrical steels are designed for their insulating, thermal and mechanical properties during assembly of a lamination stack. Although certain types of coating offer some corrosion resistance, they cannot guarantee sufficient protection against oxidation. Moreover, the roll edges are not varnished.

It goes without saying that packaging reduces the risk of oxidation. Nevertheless, it should be noted that our packaging is not completely watertight or airtight, with the result that it does not offer a 100% guarantee against oxidation. It does provide sufficient protection against oxidation under appropriate handling, transport and storage conditions and when used within a reasonable period of time.

Appropriate storage of electrical steels is therefore the key factor in ensuring that the steel surface is kept in good condition. We recommend taking the following precautions:

- Reseal any damaged packaging
- Protect against bad weather
- Store preferably in temperature-controlled warehouses (so as to avoid temperature fluctuations and hence condensation)
- Repackage after partial use

Electrical steels can be supplied as follows:

	Packaging code[1]		
	Road, rail or inland waterways	Maritime Continental	Maritime Intercontinental
With horizontal axis:			
- Without cradle	C14	C24	C28
- With cradle	CL4	CM4	CM4
With vertical axis:			
- With pallet	CB4, EDE	CC4, EDF	CC4, EDF

(1) For packaging code definitions, see industry.arcelormittal.com > Products & Solutions > Product catalogue > Packaging of coils.

Other packaging types available after prior agreement.

Important warning: the client's attention is drawn to the fact that unpacking the products is a potentially dangerous operation. Appropriate action must be taken to ensure the personal safety of personnel engaged in these operations.

These unpacking operations are performed by the client, under his sole responsibility, and must be executed in accordance with all rules and regulations in force, such as standards, technical notices, professional rules and best practices, and in accordance with the recommendations in the documentation provided by the seller, in whatever form this may be, and under appropriate conditions to ensure that no personal injury or damage to property is sustained.

In all cases, any recommendations and/or any technical advice provided by the seller, before and/or during the unpacking of the products, whether provided verbally, in writing or online, are given in good faith but shall not relieve the client of his obligation to take all appropriate measures to prevent any injury to persons and/or damage to property arising during or as a result of such unpacking operations.

Please visit our website (industry.arcelormittal.com > Sustainability > Product safety > Safety first! Best practices to unpack the products) for further information on safety measures when unpacking coils.

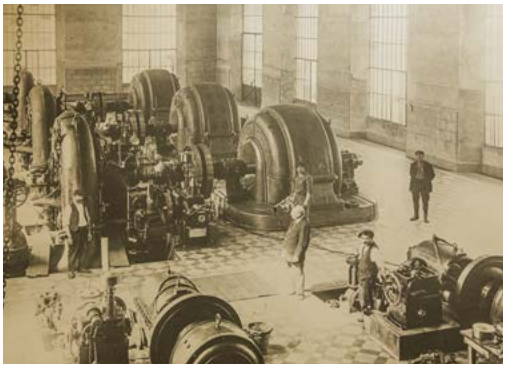
When ordering sheets, please contact us for further information on packaging definition.

St.-Chély d'Apcher: ArcelorMittal's green mill energises mobility

ArcelorMittal St.-Chély d'Apcher (France) specialises in producing electrical steels which are utilised in many different industries including:

- Energy generation and transportation for hydro, wind, nuclear, and conventional power plants
- Industrial motors
- Consumer goods such as household appliances and tools
- Automotive including high-grade products for electric and hybrid engines and motors

St.-Chély d'Apcher is part of ArcelorMittal Méditerranée, and supplies more than 150 customers across the world. Around 75 percent of the electrical steels produced at the mill are exported outside France, with a quarter going outside Europe.



Writing the history of steel in France

The St.-Chély d'Apcher steel plant is located in France's Lozère department. Founded as the Aciéries et Forges de Firminy (Steelworks and Forges of Firminy), the mill started operations in 1917.

The choice of location was deliberate. The site was selected for its proximity to a railway line and sources of hydroelectricity.

With regular updates to its production facilities, St.-Chély d'Apcher has been a constant presence in France's steel industry throughout the 20th Century. In the 1990s, the mill started to focus exclusively on the production of electrical steels. Today, it is one of the world's leading mills for the production of high-end electrical steels. It is also the largest private employer in Lozère.

Green energy for green mobility

Since 1917, the steel mill at St.-Chély d'Apcher operates two hydropower plants. The Vergne hydropower plant uses water from the Bès river, while the Ranc plant is located on the Truyère river. Both are around 25 kilometres from the steel mill.

Despite being over 100 years old, the two hydroelectric plants still meet the energy needs of the mill. Many of their major parts are original.

It's fitting that one of the greenest mills in ArcelorMittal's portfolio produces electrical steels which are enhancing the energy efficiency of many different industries.

Hydroelectric plant	Fall	Total power	Flow/second
Ranc	19 metres	2,600 KVA	12 m^3
Vergne	144 metres	13,350 KVA	12 m^3

Investing in the future of the plant and the community

In 2013, St.-Chély d'Apcher commissioned a new continuous annealing production line, an investment worth €90 million. The first of its type in Europe, the new line has enabled the mill to develop new electrical steels for automotive, energy, and industrial electric motor applications.

The steel produced at the mill is heated to over 1,000°C to give it the magnetic properties it needs. In 2017, ArcelorMittal announced a new project to recover this 'waste' heat using new installations designed and built by Schneider Electric. The facility can generate 4.8 MW of energy which is reused within the mill to reduce fuel consumption.

By recovering and reusing the heat, the mill reduces its energy consumption by 17 GWh annually. CO_2 emissions are reduced by over 4,000 tonnes a year, roughly equivalent to taking 2,000 new cars off the road.

Any excess heat is transferred to the town's district network through a 1.2 km network between the mill and local energy firm's boiler building. The heat is used to warm schools, hospitals, homes, and the local swimming pool. Redistributing energy in this way offsets the equivalent energy consumption of 1,150 homes.

"While this collaborative project reduces the mill's carbon footprint, it also cuts our energy consumption by 10 percent," says Philippe Chapus, director of ArcelorMittal in St.-Chély d'Apcher. "The project also demonstrates ArcelorMittal's commitment to making a positive contribution to our local communities."

The investment project was led by Kyotherm Group and ArcelorMittal, and supported by the French environment and energy management agency, ADEME, and the Occitanie region.

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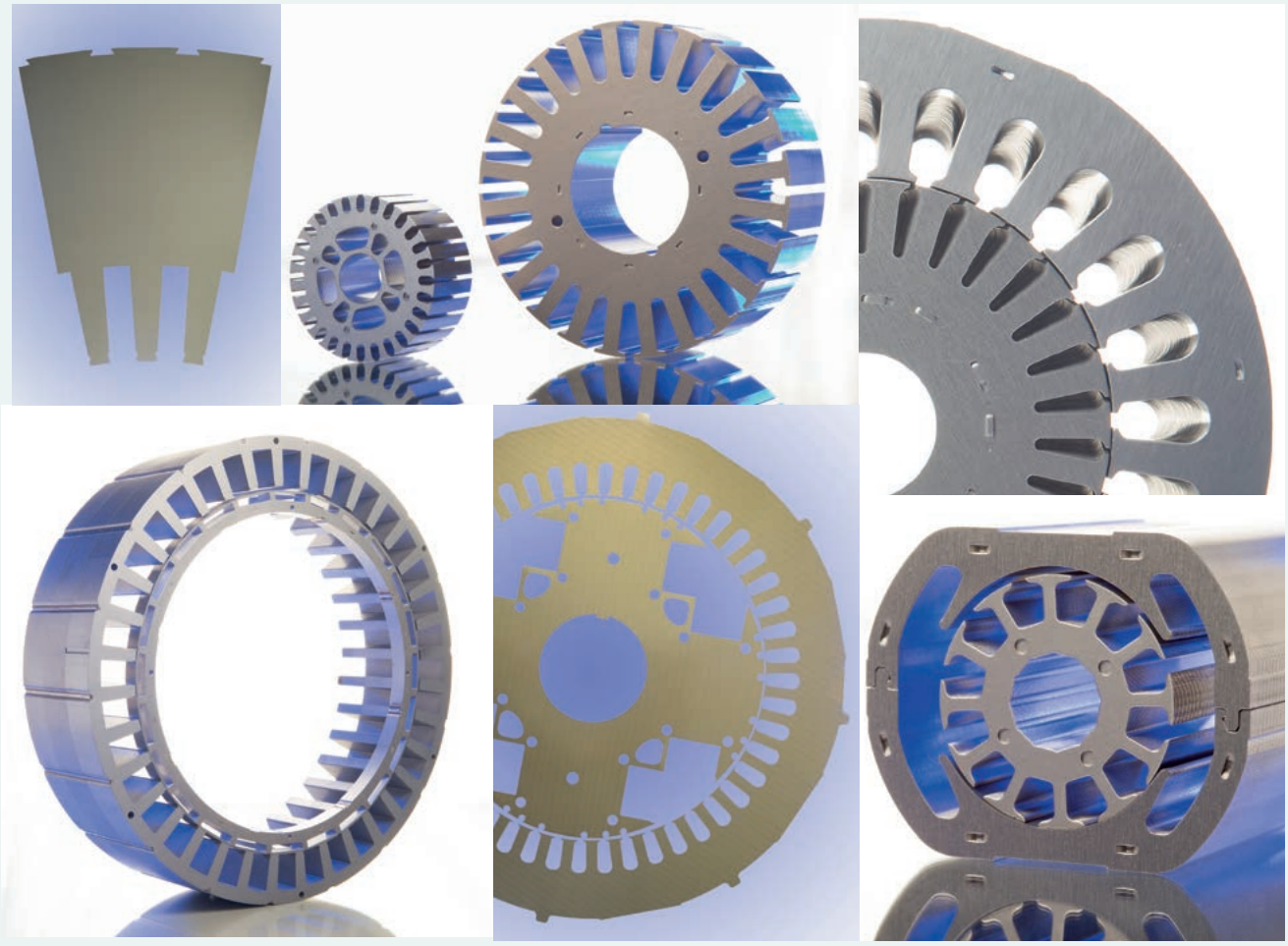
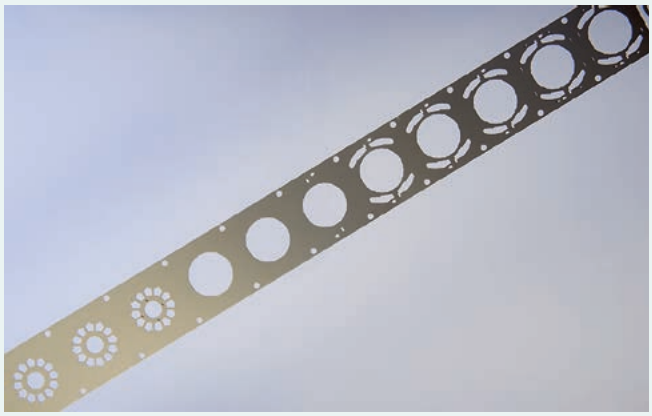
ArcelorMittal's technical support to customers in the choice of the right electrical steel for a specific application



Some machine lay-out options



Punching process

Advanced technical support for iCARe®

For automakers who wish to exploit the full potential of ArcelorMittal's iCARe® steels, we can offer advanced technical support in many areas including modelling, prototyping and material handling.
This support can also be provided without the need for the customers to share their machine design with us. Any information that is shared is treated as highly confidential.

ArcelorMittal's machine modelling services

As a steel provider, ArcelorMittal also offers our customers all the help they need to choose the most suitable steels. We can also help to design the machine. This level of assistance is possible thanks to our advanced R&D know-how and the high-tech equipment available in our research centres.

For mechanical design engineers, we can provide high temperature mechanical material characterisation at temperatures from -40 up to 250°C. This enables the engineer to determine the weakness of the material at exploitation temperatures, rather than using accepted rules of thumb. Along with static testing, ArcelorMittal can provide dynamic evaluations such as low and high cycle fatigue testing on different sample geometries. This enables engineers to predict, in detail, the transient regime behaviour of the machine.

For the magnetic design engineer, ArcelorMittal can provide full magnetic characterisation of our steels, up to 10k Hz in sine conditions. We can also provide any non-sine data, which is interesting for pulse-width modulation (PWM) fed machines or harmonic calculations. As well as magnetisation curves up to saturation for field calculations, ArcelorMittal has developed a specific loss model which allows better accuracy in post-processing loss calculations. This model can run independently from the field calculations, so the customers do not need to share their machine design with us.

For the thermal engineer, we provide thermal conductivity data at machine exploitation temperatures. Data is available for both our steel grades and our coating solutions.

Prototyping services

Our technical support for magnetic, mechanical and thermal machine modelling enables design engineers to make precise machine calculations. This enables them to reduce the number of prototypes needed before pre-series and series production can begin.

A minimal amount of prototyping is still needed to prove that the development has led to the expected machine performance. For prototyping purposes, ArcelorMittal can offer small quantities of sheets for first stage Epstein and tensile testing, and for the next stage of laser cutting. In the industrial validation phase, ArcelorMittal can provide small slit coils for punching and machine assembly development.

Material handling issues

Even when ArcelorMittal has provided the best possible steel solution for a given electrical application, our job is not over. The production of prototype or series machines can involve production processes that have the potential to degrade the properties of the fully processed steels we have supplied.

Advanced R&D support is available to help customers quantify the impact of material handling processes (such as laser cutting or punching, stress-relief annealing, stack assembly, welding, shaft shrink fitting, and housing fitting) on the magnetic performance of the machine's lamination stack.

Further information

For more information about ArcelorMittal's iCARe® range of electrical steels and the support we can provide, please visit: automotive.arcelormittal.com/icare

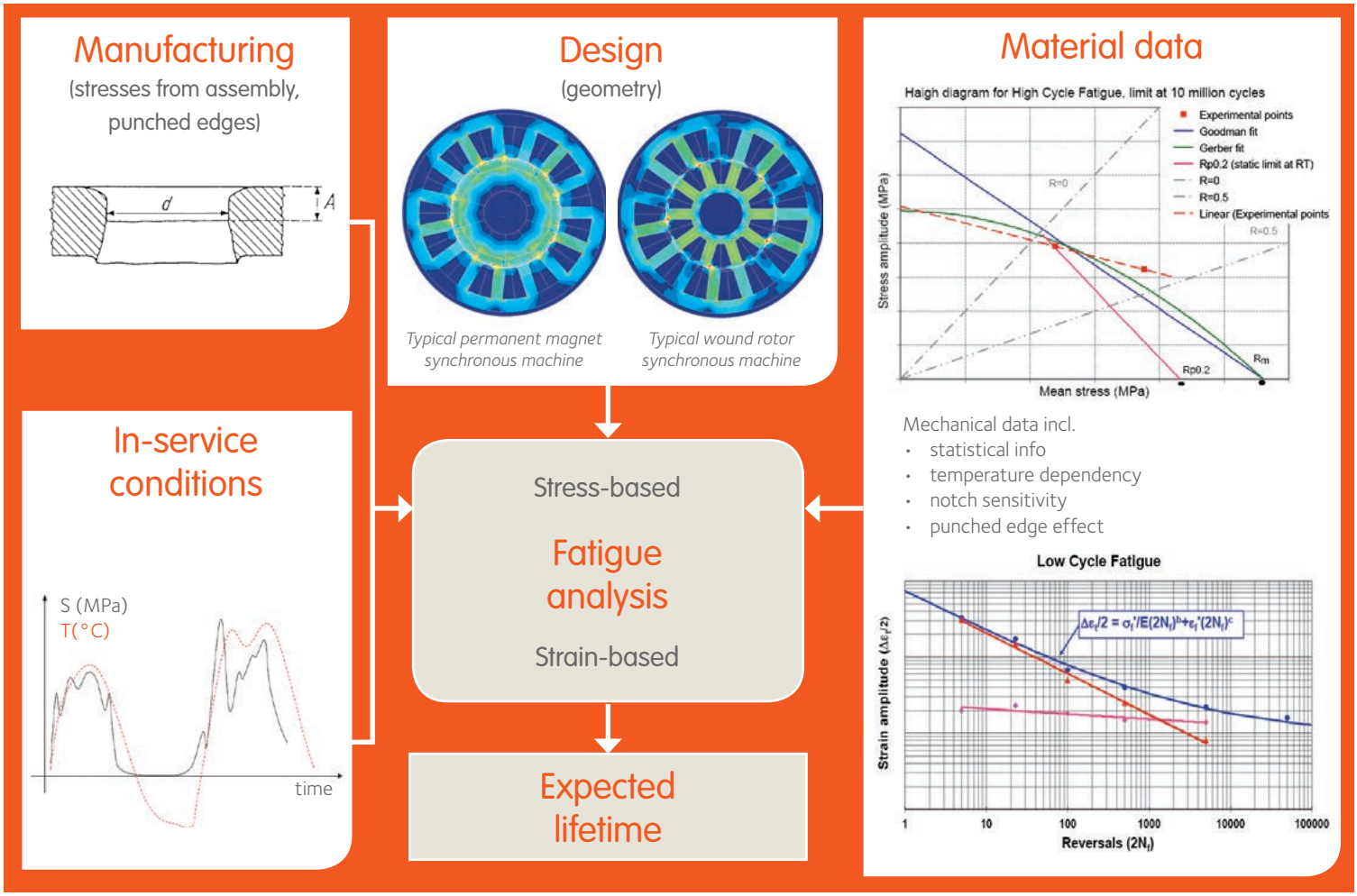
Advanced mechanical characterisation for iCARe®

Mechanical design aspects

Our customers' mechanical design departments need to be able to predict the structural integrity of the rotor and stator based on in-service loads, manufacturing aspects, component geometry and statistical material data obtained using laboratory samples.
The main aspects are summarised in the figure below:

- In-service conditions
  - Load/deformation during rotation, acceleration and deceleration (centrifugal, electromagnetic)
  - Temperature (e.g. as a function of load and ambient temperature)
  - Etc
- Manufacturing aspects such as punched edges and stresses introduced during assembly of the electrical motor parts
- Design, mainly the radii used and the amount of material that remains to transmit the load
- Material properties (statistical variation, temperature dependency, notch sensitivity, punched edge effect etc)

Fatigue design and analysis: different aspects



Static material properties

The yield stress is an important parameter for the design of electrical machines. In the simple case of a constantly spinning rotor, the magnitude of the yield strength determines the maximum rotation speed at which the material can withstand centrifugal forces without plastic deformation. The iCARe® Speed grade is specifically developed for high-speed rotors for the automotive market.
ArcelorMittal can supply elevated temperature tensile data to correctly assess the mechanical behaviour of e-machines under static loads at operating temperatures.

Dynamic material properties

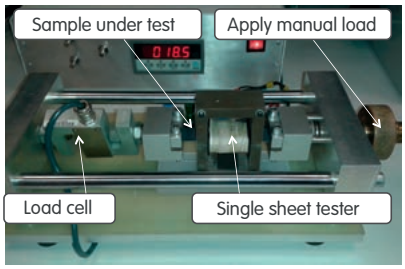
As a material supplier, ArcelorMittal can provide material fatigue data for its electrical steels for the two existing design and analysis approaches, i.e.:

- Stress-based design and analysis (high cycle fatigue, HCF)
- Strain-based design and analysis (low cycle fatigue, LCF)

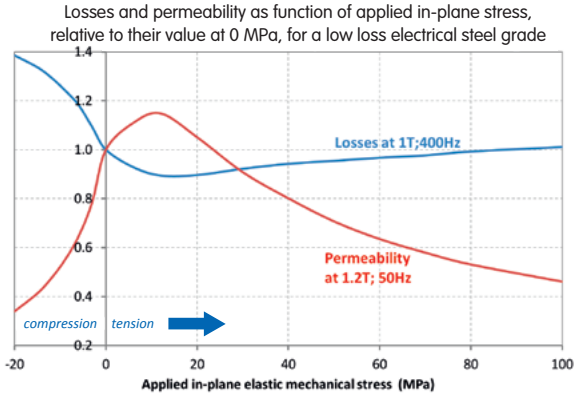
This data is based on standardised tests.
On request, specific machine design features can be experimentally assessed using specific laboratory set-ups.

Advanced magnetic characterisation for iCARe®

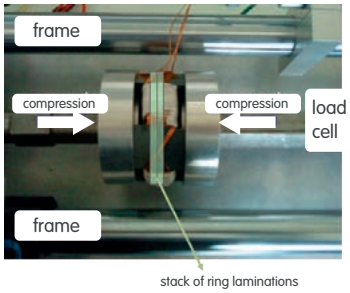
In-plane magnetic properties as function of in-plane compression and tension



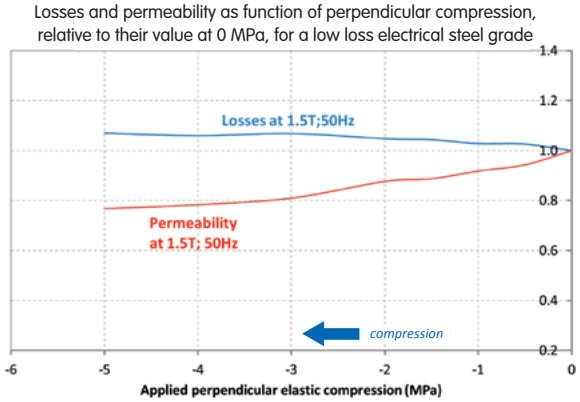
Losses and permeability as function of applied in-plane stress, relative to their value at 0 MPa, for a low loss electrical steel grade



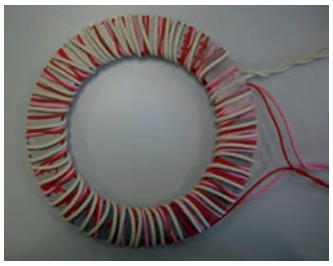
In-plane magnetic properties as function of axial compression (perpendicular to laminations)

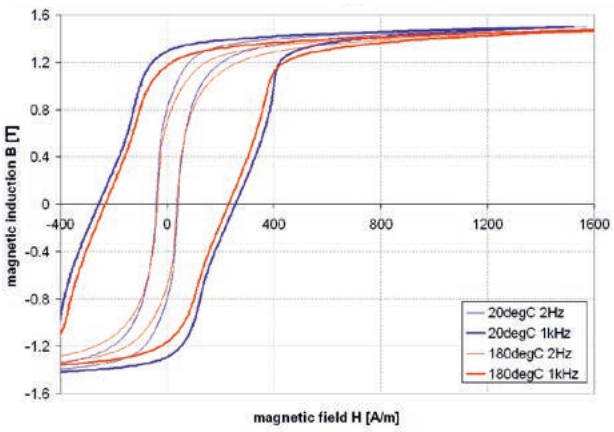


Losses and permeability as function of perpendicular compression, relative to their value at 0 MPa, for a low loss electrical steel grade

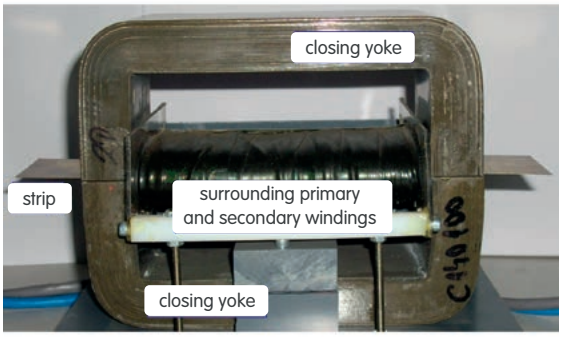


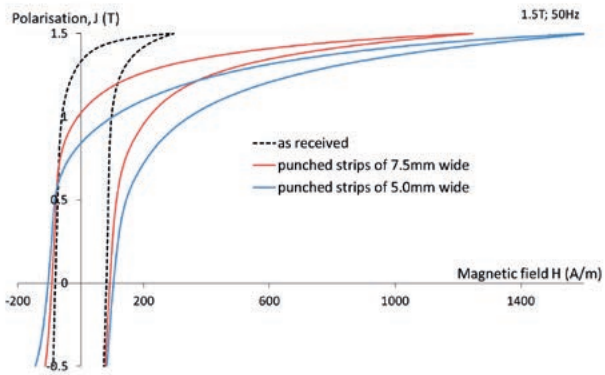
Ring core magnetic measurements, as function of temperature



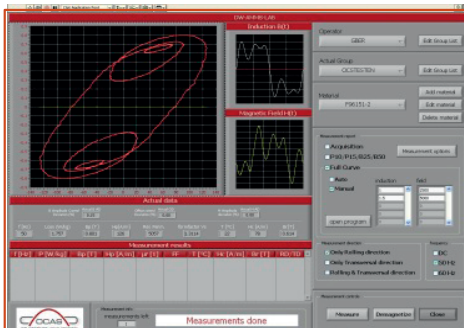


Single Sheet Tester to measure cut edge effect (on strips cut in different widths)

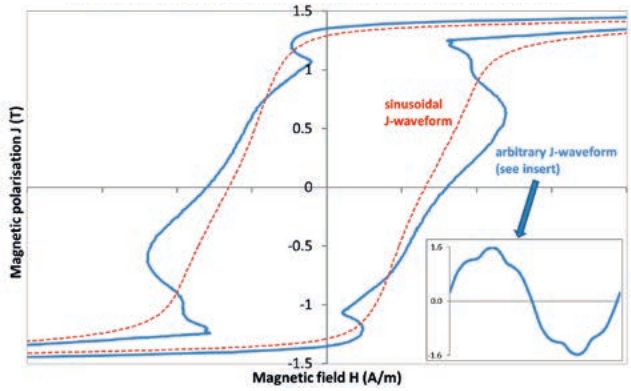




Magnetic measurements according to user-defined waveforms, including higher harmonics and minor loops

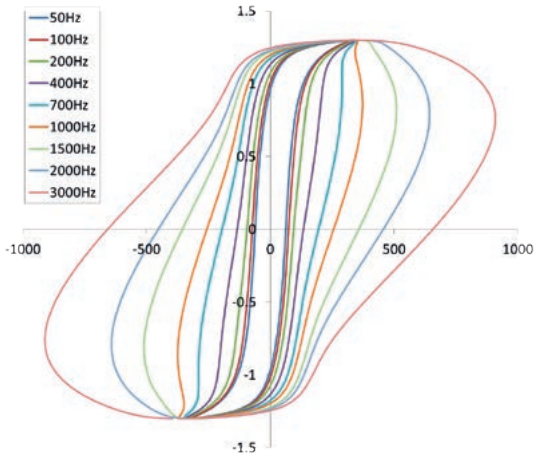


Magnetisation loops (at 500Hz; 1.6T) for sinusoidal and arbitrary J-waveforms

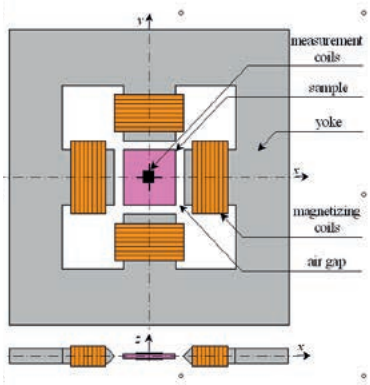


Magnetic measurements in wide frequency range

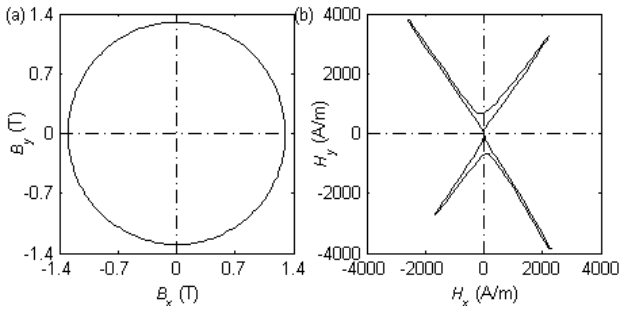
Epstein frame



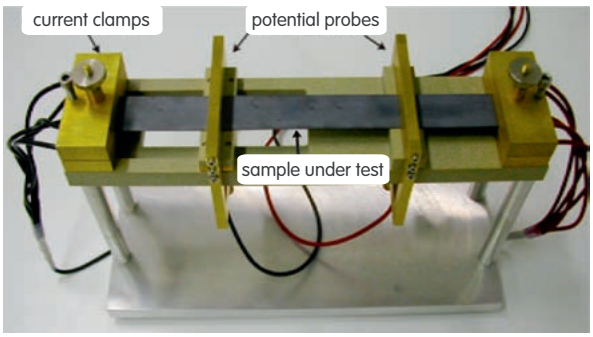
Magnetic measurements under rotational field conditions



B- and H-loci for a grain-oriented material.
Circular magnetic induction.



Electrical conductivity, as function of temperature



Electrified power train optimisation with iCARe®

iCARe® electrical steels for enhanced machine performance: Save, Torque, Speed

Save is steel with very low losses, to save weight, to save energy, to improve efficiency.

Save is in particular useful for stators of high frequency machines.

Torque is steel with high permeability, to improve air-gap flux, to obtain high motor torque or to generate high current.

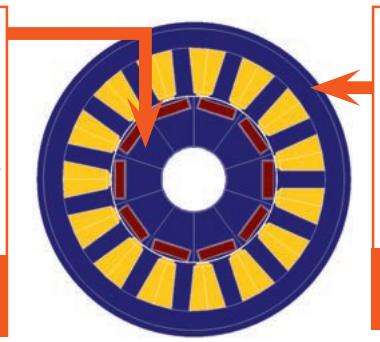
A stator using Torque improves the motor's break-away torque.

Speed steel has high strength for high speed rotors which maintain high levels of magnetic performance.

These grades allow the machine to be more compact and have a higher power density.

Rotor ES:
high mechanical solicitation due to
1. thin steel bridges between buried magnets and air-gap
2. high speed for high power density

Speed



Stator ES:
1. high air-gap flux for high torque
2. low energy dissipation for high efficiency

Save or Torque

iCARe® steels are optimised for high frequencies (>400Hz)

- Optimal grain size (δ) gives best trade-off between hysteresis and excess losses at 400Hz and above (this is quite different than the optimum for 50Hz industry grades)

$$\frac{P_{Fe}(J_p,f)}{f} = k_{hyst}J_p^2 + k_{eddy}J_p^2 f + k_{exc}J_p^{1.5} f^{0.5}$$

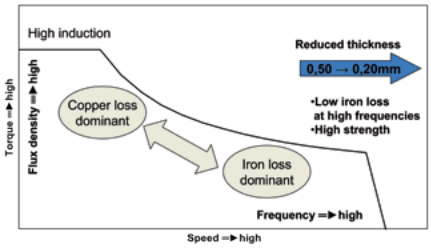
$$k_{hyst} = k'_{hyst}.\frac{1}{\delta} \quad \& \quad k_{exc} = k'_{exc}.\delta$$

- Alloying content is either chosen for lowest eddy current losses (Save) or highest polarisation (Torque)
- Optimised texture and structure to maximise ease of magnetisation
- Apart from these magnetic optimisations, optimal mechanical properties are achieved via alloying and structure choices

iCARe® advanced technical support: optimal electrical steel use

Electric traction motors: operating over wide speed and torque range
- conflicting requirements for electrical steels over such wide range
- compromise needed between high polarisation and low iron losses

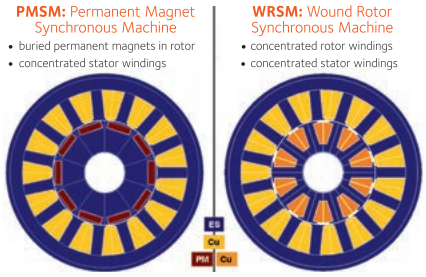
→ Numerical comparison of electrical steel grades in different types of machine topologies for vehicle traction (cars and trucks)



STUDY 1: synchronous machines (permanent magnet/wound rotor)

- Traction motors for hybrid and electric cars
- P_{nom} = 31kW; f_{nom} = 400Hz
- Numerical approach: material comparison for equal mechanical power, with varying axial length

* Two synchronous motor topologies under study (same stator): the WRSM produces less torque per meter, but is less costly (no rare-earth materials involved)



PMSM	Industry Standard M330-35A	Industry High Permeability M330P-35A	iCARe® - Save			iCARe® - Torque			
			Save 20-13	Save 30-14.5	Save 30-15	Torque 25-12.5	Torque 27-13.5	Torque 30-14.5	Torque 30-15
Torque density (Nm /m axial length)	Ref.	+2.2%	-0.4%	+0.7%	+0.4%	+1.1%	+0.8%	+1.3%	+1.6%
Compactness (m³)	Ref.	-2.1%	+0.4%	-0.7%	-0.4%	-1.1%	-0.8%	-1.3%	-1.6%
Active material loss (nominal)	Ref.	+15%	-21%	-16%	-15%	-21%	-19%	-16%	-14%
Active material efficiency (nominal)	Ref.	-0.52%	+0.77%	+0.56%	+0.54%	+0.72%	+0.68%	+0.55%	+0.52%

WRSM	Industry Standard M330-35A	Industry High Permeability M330P-35A	iCARe® - Save			iCARe® - Torque			
			Save 20-13	Save 30-14.5	Save 30-15	Torque 25-12.5	Torque 27-13.5	Torque 30-14.5	Torque 30-15
Torque density (Nm /m axial length)	Ref.	+4.4%	-1.7%	+0.5%	+0.2%	+1.0%	+0.6%	+1.5%	+2.1%
Compactness (m³)	Ref.	-4.2%	+1.8%	-0.5%	-0.2%	-1.0%	-0.6%	-1.5%	-2.1%
Active material loss (nominal)	Ref.	+8%	-17%	-12%	-12%	-17%	-15%	-13%	-13%
Active material efficiency (nominal)	Ref.	-0.33%	+0.67%	+0.49%	+0.47%	+0.66%	+0.61%	+0.50%	+0.51%

Electrical steel comparison at nominal speed and drive cycle averaged. All values are relative compared to the values for M330-35A, except the efficiency values are absolute changes compared to the reference grade.

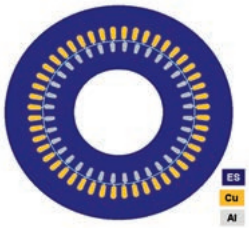
The efficiency when using the reference grade is 96.4% for the PMSM and 96.1% for the WRSM.

STUDY 2: induction machine

- Traction motor for trucks
- P_{nom} = 78 kW; f_{nom} = 200Hz
- Numerical approach: material comparison for equal torque (~mechanical power), with varying slip

IM	Industry Standard M330-35A	Industry High Permeability M330P-35A	iCARe® - Save		iCARe® - Torque		
			Save 20-13	Save 30-15	Torque 27-15	Torque 30-17	Torque 30-15
Stator current (at nominal operation)	Ref.	-7.4%	+2.9%	-0.7%	-1.3%	-2.8%	-4.3%
Energy losses due to active materials (at nominal operation)	Ref.	+11%	-18%	-14%	-16%	-9%	-14%
Active material efficiency (at nominal operation)	Ref.	-0.44%	+0.72%	+0.53%	+0.61%	+0.37%	+0.53%

Electrical speed comparison at nominal frequency. All values are relative compared to the values for M330-35A, except the efficiency values are absolute changes compared to the reference grade.
The efficiency when using the reference grade is 96.1% for the IM.



IM: Induction Machine (= asynchronous machine)
- Aluminium squirrel cage rotor
- distributed stator windings

Conclusion

iCARe® Save: high efficiency (= best use of battery power)

- **high efficiency** due to low iron losses
- **smaller batteries** possible for same drive range
- if best efficiency is important, regardless extra cost, then Save 20-13 comes first
- change of torque density is limited

iCARe® Torque: less copper windings

- good compromise between **high torque production** and **low iron losses**
- higher torque density enables **smaller machines**, hence saving on copper and magnets

iCARe® Save and Torque grades in 0.3 mm: the market reference today

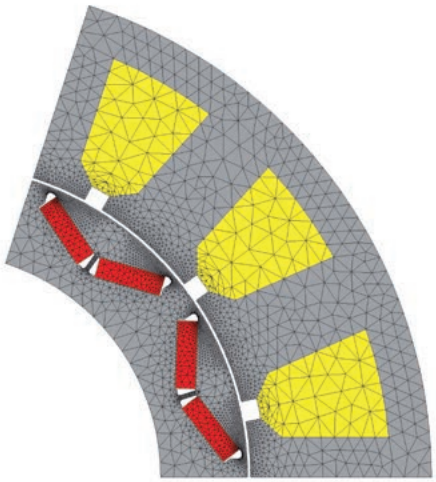
- appear to be effective materials
- best value/cost ratio (during construction and exploitation)
- higher performance machines benefit from 0.27 or 0.25 mm grades

Electrifying efficiency

Partnership sees ArcelorMittal electrical steels included in world's most advanced modelling tool

As one of the world's leading suppliers of electrical steels, ArcelorMittal has partnered with JMAG – a very advanced software modelling tool for electrical machines developed by Japan's JSOL Corporation. The partnership ensures machine manufacturers have access to the latest data on ArcelorMittal's fully processed electrical steels, enabling them to create more efficient and compact motors.

Demand for highly efficient electrical motors is growing rapidly. The main drivers behind this growth are increased demand for electric vehicles and new regulations on machine efficiency. To achieve these targets, a complete redesign of electrical machines is necessary. This includes new geometries, new materials, and new types of machine.



Example of a motor model created in the JMAG software

ArcelorMittal data available for simulations

In the past, new electrical machines were developed using a series of mathematical calculations which were proven by prototyping. The higher the precision of the calculations, the fewer prototypes were needed to achieve the final design.

The JMAG suite of software facilitates these calculations and reduces the number of prototypes required. "Advanced material information enables our customers to make successful and accurate simulations, but it is not always easy for them to obtain the latest data," notes Yusaku Suzuki, marketing manager at JMAG. "Now all manufacturers can access the ArcelorMittal information they need and use it to perform simulations."

JMAG selected ArcelorMittal as a partner due to our advanced research work, especially in modelling finite elements analysis. "ArcelorMittal's geographical presence is also important for us, especially in the development of electrical vehicles," explains Dr Yamada, product leader for JMAG. "ArcelorMittal's electrical steels are primarily produced in Europe, where electric vehicle development is proceeding very quickly. Through our partnership, JMAG can offer the most advanced and accurate level of simulation for hybrid and fully electric vehicles."

JMAG includes many modules and features which allow designers to analyse the electromagnetic, thermal, and mechanical aspects of machines. This allows manufacturers to create compact machines with higher power density.

Data on magnetic and electrical fields, stress distribution, vibration, and a range of other criteria can be analysed. "You can even integrate the control mechanisms required to drive the machine into the JMAG modelling tool. Using other software, this step has to be done manually," explains Sigrid Jacobs, electrical steels portfolio director for ArcelorMittal Global R&D.

Improved mechanical stress calculations in JMAG allow designers to create smaller electrical machines

ArcelorMittal's range of iCARe® electrical steels are specifically designed for mobility applications

JMAG®
Simulation Technology for Electromechanical Design

"JMAG provides very advanced technical assistance for modelling"

notes Sigrid Jacobs. "It can simulate both the magnetic and mechanical behaviour of an electrical steel in a machine. But it can also account for the effects of manufacturing on the electrical steel. That way the OEM knows how the real machine will behave during use."

Fostering communication

Information on ArcelorMittal's fully processed electrical steels was added to JMAG on 1 May 2016. "Customers with a JMAG licence can access this information now," notes Sigrid Jacobs. "They can then contact us for additional information or support."

Dr Yamada believes this will foster communication between machine engineers and ArcelorMittal's R&D specialists: "JMAG creates a community of users who have a lot of ideas for improving electrical machines. We recommend our customers make direct contact with ArcelorMittal to discuss these concepts."

More info:

jmag-international.com

iCARe® electrical steels for mobility

While JMAG now includes details of ArcelorMittal's fully processed grades, our range of electrical steels is far more extensive.

iCARe® is ArcelorMittal's dedicated range of electrical steels for mobility solutions. Produced at ArcelorMittal St.-Chély d'Apcher (France), the range includes:

- iCARe® Save: steels with very low losses.
- iCARe® Torque: steels with high permeability.
- iCARe® Speed: steels for high-speed rotors.

ArcelorMittal is already working with OEMs on the second generation of iCARe® grades which are tailor-made to meet OEM requirements. Many of these new electrical steels will start to appear in production vehicles around the end of the decade. ArcelorMittal will add the most promising solutions to our catalogue of electrical steels in the near future, enabling OEMs to develop the next generation of highly efficient electrical mobility solutions.

More info about iCARe®:

automotive.arcelormittal.com

ArcelorMittal's non-oriented fully processed electrical steels have guaranteed magnetic properties which meet or exceed the requirements of EN 10106:2015.
We also offer a fully processed high frequency grade with guaranteed magnetic properties in accordance with EN 10303:2015. This norm defines standards for thin electrical steels used at frequencies above 100 Hz.

ArcelorMittal's complete NO offer includes low alloy grades which have excellent magnetic permeability, thermal conductivity, and punchability. We also offer alloyed grades with very low losses, even at higher frequencies. A wide range of coatings are available, allowing manufacturers to enhance punchability, reduce inter-laminar losses, and improve corrosion protection.

Credits

Pictures:

Cover image created by frankandbold
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D20 Siemens
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D40 Tom D'Haenens
D50 Siemens
D52 Voith
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p. 75 Bourgeois – pictures Jeroen Op de Beeck

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