

SUPRA 50 - SP 510

Fe-Ni SOFT MAGNETIC ALLOYS

(ArcelorMittal based material)

I. INTRODUCTION

The Imphy Alloys range of soft magnetic alloys based on the 50% nickel composition includes the following grades :

- SUPRA 50 / SUPRA 50 SP
- SUPRA 50 G / SUPRA 50 GSP
- SUPRA 50 T
- SP 510

- The common feature of all the SUPRA 50 alloys is the maximum saturation induction level attainable in the Fe-Ni system. The individual grades are differentiated by their permeability and coercive field values.

- The SP 510 grade is distinguished by its good compromise between magnetic properties (saturation induction, coercive field, permeability) and corrosion resistance.

The table below indicates the nominal alloy compositions in weight % :

	Ni	Mn	Si	C	Cr	Fe
Supra 50 Supra 50 SP Supra 50 G Supra 50 GSP Supra 50 T	47.5	0.5	0.1	0.005	-	Balance
SP 510	50	0.5	0.2	0.01	10	Balance

II. APPLICATIONS

The principal applications of these alloys are :

- Ground fault circuit breakers (relays)
- Railway signalling (relays)
- Watch and clock making (stepper motors)
- Telephony (receivers and telephone exchanges)
- Magnetic sensors (current, angular position, displacement)
- Gas equipment (safety caps)
- All applications requiring the use of a high induction low loss magnetic material : motor rotors and stators, synchro resolvers
- Electron gun components for cathode ray tubes.

III. PRESENTATION OF THE DIFFERENTES GRADES

III.1 SUPRA 50 and SUPRA 50 SP

These basic grades (isotropic quality) concern all the common applications (typical coercive field value : $H_c = 2.8$ A/m). Their high performance levels and their chemical purity make them particularly suitable for applications requiring high sensitivity and great accuracy.

The SUPRA 50 and SUPRA 50 SP differ from one another by their cold rolling processes and surface conditions, their dimensional tolerances and the range of thicknesses available.

They are principally used in telephony (receiver components), for safety functions (components for gas equipment safety caps) and in electrical engineering (transformers, signalling relays, sensors). They are also used in watch and clock making (motor parts for analog quartz watches), in aeronautical engineering (hyper-frequency oscillator bodies) in computer peripherals (printer head pole pieces), in electrical safety devices (relay components for ground fault circuit breakers) and for medical devices (hearing aids).

III.2 SUPRA 50 T

This semi-isotropic grade is supplied in the form of non-annealed cold rolled strip (typical thicknesses : 0.08 mm – 0.35 mm), for the stamping of various profiles, or for the production of tape wound cores.

After appropriate heat treatment, the profiles possess a giant-grained secondary recrystallisation structure which ensures very high initial permeabilities and a very low coercive field ($H_c = 1.4$ A/m).

The principal uses are in telephony, telematics (impedance transformers) and in power control and measurement systems (current transformers, inductances).

III.3 SUPRA 50 G and SUPRA 50 GSP

These isotropic grades have an improved aptitude for mechanical cut-out compared to the basic SUPRA 50 and SUPRA 50 SP products.

III.4 SP 510

This grade is characterized by a saturation induction level close to that of Fe-80% Ni, together with a low coercive field and good corrosion resistance. Because of this property combination, the major application is in watchmaking, for necked stepper motor stators.

IV. PHYSICAL PROPERTIES

Property	Units	SUPRA 50 – SUPRA 50 SP SUPRA 50 G – SUPRA 50 GSP SUPRA 50 T	SP 510
Density *	g.cm ⁻³	8.2	8.2
Specific heat *	J.kg ⁻¹ .°C ⁻¹	500	-
Thermal conductivity *	W.m ⁻¹ .°C ⁻¹	13	-
Thermal expansion : mean CTE between 0°C and 100°C	10 ⁻⁶ .°C ⁻¹	8	10
Electrical resistivity *	μΩ.cm	45	100
Curie point	°C	450	230
Coefficient of magnetostriction at saturation Δl/l	10 ⁻⁶	24	-
Melting temperature	°C	1 425	-
Saturation induction *	Tesla	1.6	0.75

* measured at +20 °C

V. MAGNETIC PROPERTIES

The tables below give the magnetic properties determined after optimum heat treatment, in compliance with the following standards:

- ASTM : A596
- DIN : 50460
- IEC : 60404

V.1 DC magnetic properties for cold rolled strip

The measurements were made after the optimum heat treatment of 4 hours at 1150°C in pure dry hydrogen, on ring specimens with 36 mm outside diameter, 25 mm inside diameter and 0.34 mm thickness for Supra 50, Supra 50 SP, Supra 50T and SP 510 and 1.5 mm thickness for Supra 50 G and Supra 50 GSP. The figures given below are typical values.

Grade	Bs ⁽¹⁾ (Tesla)	Br ⁽¹⁾ (Tesla)	B at 100A/m (Tesla)	μ _{max}	Hc (A/m)
Supra 50 Supra 50 SP	1.5	1.1	1.2	190 000	2.8
Supra 50 T	1.5	0.6	1.2	165 000	1.4
Supra 50 G Supra 50 GSP	1.5	1.1	1.2	100 000	5.1
SP 510	0.75	0.25	0.6	30 000	3.2

(1) practical saturation Bs and remanent induction Br measured for H = 800 A/m.

V.2 AC magnetic properties for cold rolled strip

The measurements were made after the optimum heat treatment of 4 hours at 1150°C in pure dry hydrogen, on ring specimens with 36 mm outside diameter, 25 mm inside diameter and 0.34 mm thickness for Supra 50, Supra 50 SP, Supra 50T and SP 510. The figures given below are typical values.

Grade	60 Hz	
	μ_{4z} (1)	μ_{z8} (2)
Supra 50 Supra 50 SP	10 400	54 000
Supra 50 T	16 500	52 000
Supra 510	7 000	-

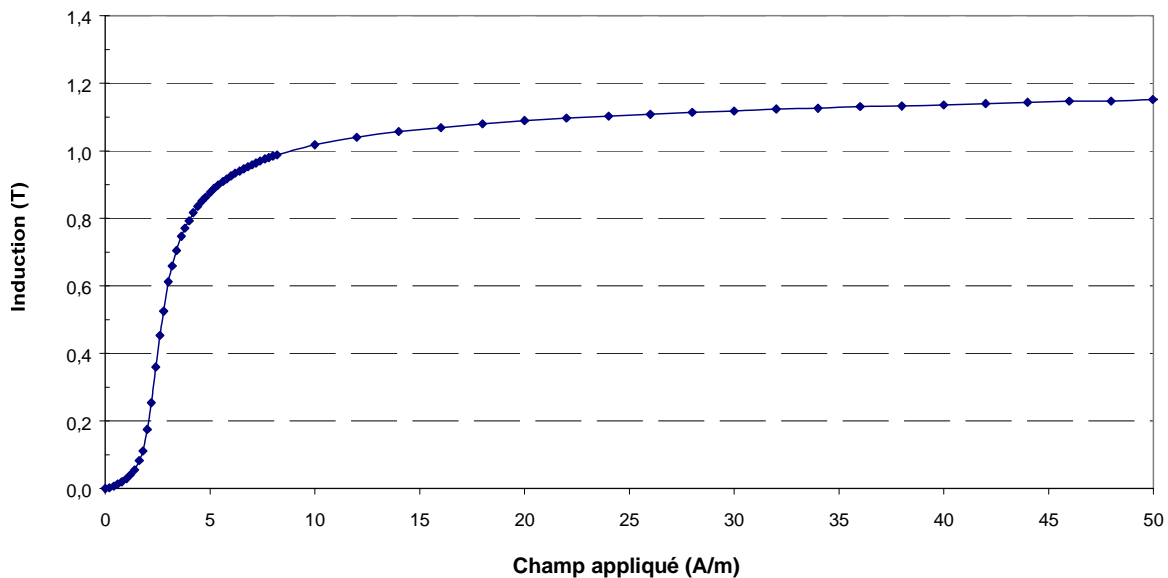
- (1) Initial impedance permeability for a sinusoidal exciting field of 0.4 A/m (peak value)
 (2) Impedance permeability for $B = 0.8$ T

V.3 DC magnetic properties for massive products

The DC measurements are made on 24*20*10 mm core samples after heat treatment for 4 hours at 1150°C in pure dry hydrogen. The figures given below are typical values.

Grade	Bs (1) (Tesla)	Hc (2) (A/m)	$\mu_{max_{cc}}$
Supra 50	1.5	4.8	80 000

- (1) practical saturation measured for $H = 800$ A/m.



- (2) coercive field H_c measured from $H = 800$ A/m.

Figure 1 : DC magnetization curve for 0.34 mm thick Supra 50 cold rolled strip heat treated for 4 hours at 1150°C in pure dry H₂

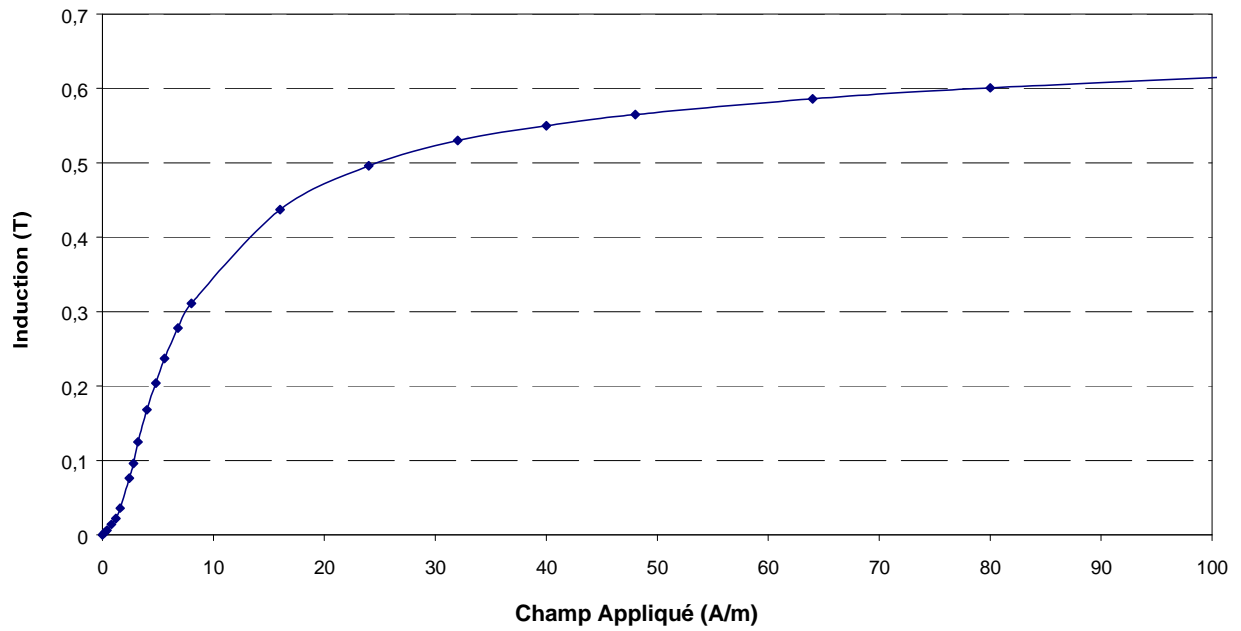


Figure 2 : DC magnetization curve for 0.50 mm thick SP 510 cold rolled strip heat treated for 4 hours at 1150°C in pure dry H2

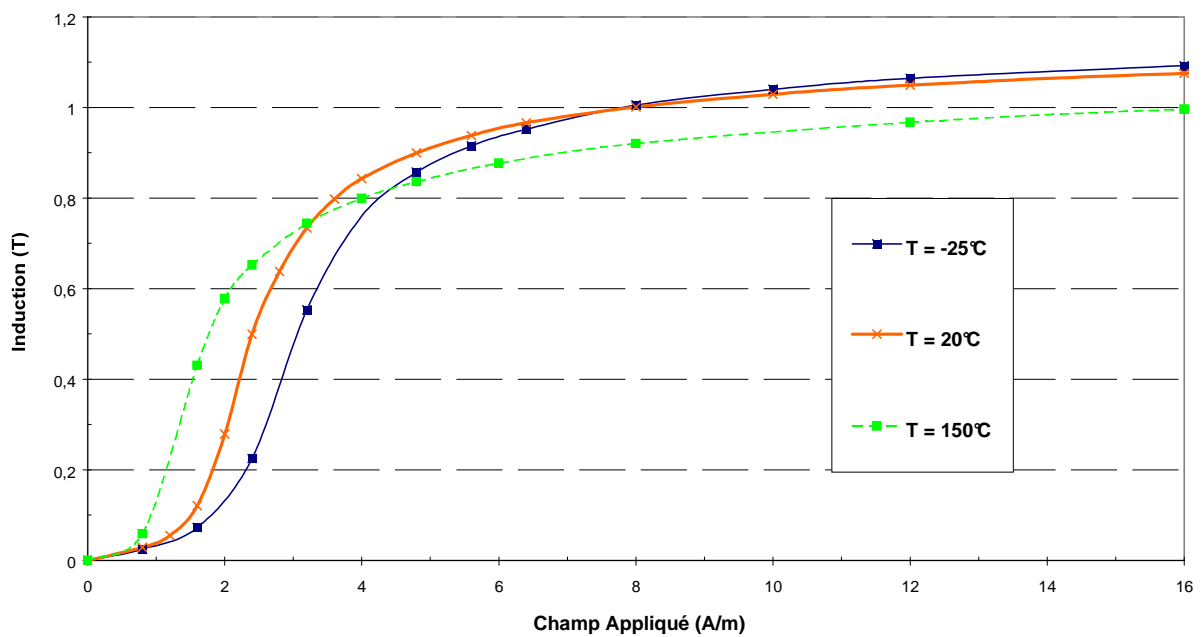


Figure 3: DC magnetization curves at -25°C, +20°C and +150°C for 0.34 mm thick Supra 50 cold rolled strip heat treated for 4 hours at 1150°C in pure dry H2.

On request, Imphy Alloys can provide customers with the corresponding data points in computer format.

VI. HEAT TREATMENT OF FINISHED PARTS

The optimum magnetic properties for the Supra 50 and SP 510 alloy families are obtained by high temperature heat treatment on the finished components.

- The heat treatment is first of all designed to recrystallize the metal. The treated parts must be handled with great care, since even the slightest amount of plastic deformation will degrade the magnetic properties.
- A protective atmosphere is essential to avoid oxidizing the metal. The role of the atmosphere is extremely important. The use of a reducing atmosphere composed of pure dry hydrogen is recommended, since it promotes the elimination of certain residual impurities in the metal, such as carbon, particularly on thin components.
- All necessary precautions must be taken to guarantee the purity of the atmosphere. The parts to be treated must be degreased and cleaned before annealing. The inert powder (alumina, magnesia) often used to insulate the parts from one another must be perfectly anhydrous. The hydrogen must be purified, upstream of the furnace, by the use of a deoxidizing treatment and a molecular sieve. A hydrogen flow rate of the order of 7 volumes per hour is recommended to continually renew the atmosphere.

During the heating ramp, a 1 to 2 hour hold should be performed at around 400°C, if necessary, to improve the dew point in the furnace chamber. The dew point should be less than -40°C during the high temperature heat treatment.

Imphy Alloys' 47.5% Ni grades are little sensitive to the heating and cooling rates. Common industrial heating and cooling rates from a few tens to a few hundreds of °C/h are perfectly satisfactory.

VI.1 Oxidation heat treatment

For certain applications, the finished parts must be coated with a thin layer of oxide (for example, to electrically insulate rotor sheets or profiles). This can be achieved by holding the parts at around 500°C in an atmosphere with controlled oxygen partial pressure (e.g. : 1 hour in air).

VI.2 Supra 50 / Supra 50 SP

The table below illustrates the influence of heat treatment temperature between 1050°C and 1150°C, for a holding time of about 4 hours. The measurements were made on 0.34 mm thick ring specimens with an outside diameter of 36 mm and an inside diameter of 25 mm. A high temperature promotes both coarsening of the primary grains and purification of the metal. This results in higher permeability values.

Property	Heat treatment temperature	
	1050°C	1150°C
$\mu_{\max_{cc}}$ (1)	135 000	190 000
Hc (A/m)	3.8	2.8
μ_{4z} (2)	7 400	10 400

(1) Maximum DC permeability

(2) Initial impedance permeability for a sinusoidal exciting field of 0.4 A/m (peak value)

VI.3 SUPRA 50 T

Heat treatment at a high temperature (1 150 – 1 175°C) is essential to ensure satisfactory secondary recrystallization and very high permeabilities. In this case also, holding for 4 hours is perfectly adequate.

Thickness (mm)	1050 °C		1150°C	
	$\mu 4z$ (1)	Hc (A/m)	$\mu 4z$ (1)	Hc (A/m)
0.34	9 500	3	16 500	1.4
0.08	6500	4.4	11 000	3

(1) Initial impedance permeability for a sinusoidal exciting field of 0.4 A/m (peak value)

VII. MECHANICAL PROPERTIES

VII.1 Mechanical properties on cold rolled strip

The figures given below are typical values. The measurement techniques comply with the standards :

- NF EN 10002 for tensile testing
- EN ISO 6507 for hardness
- NFA 04102 for grain size

Property	Supra 50 / Supra 50 SP Supra 50 G / Supra 50 GSP			Supra 510		
	Cold worked	Annealed	Finished parts treated at 1 150 ° C	Cold worked	Annealed	Finished parts treated at 1 150 ° C
Hardness (HV)	250	140	100	275	110	100
UTS (MPa)	850	500	450	900	520	-
0.2% PS (MPa)	820	250	200	850	210	-
EI (%)	3	40	35	1	40	-
Grain size	-	9	0	-	8	-

On request, Imphy Alloys can supply any non standard condition desired by the user.

VII.2 Mechanical properties on massive products (typical values)

Property	As-hot processed condition (bars, sheets, forgings)
UTS (MPa)	540
Hardness (HV)	170 +/- 50
Grain size	4 - 10

On request, Imphy Alloys can supply any non standard condition desired by the user.

VIII. IMPLEMENTATION

VIII.1 Cut-out and shearing

These operations are performed on metal in the cold worked condition. It is recommended to perform several trials on materials of different hardness to adapt the grade to the cutting tools.

VIII.2 Bending, deep drawing, stretching and lathe spinning

For these forming processes, the metal is used in the annealed condition. Difficult deep drawing operations must be clearly specified, since Imphy Alloys has a condition particularly adapted for this purpose.

When the initially annealed metal is subjected to marked plastic strain, the resulting increase in hardness and UTS can be estimated from the following table :

Plastic strain (% reduction in thickness)	10	25	50	75
Hardness (HV)	200	225	250	265
UTS (MPa)	590	710	850	930
Elongation (%)	20	7	3	2

It will therefore sometimes be necessary to perform an intermediate softening treatment during component forming sequences.

Imphy Alloys recommends holding for a minimum of 1 hour at 800°C–850°C. It is essential to take all necessary precautions to avoid contamination of the metal, including a clean furnace and clean parts, and a protective atmosphere, which may even be reducing, with a dew point less than –40°C.

VIII.3 Machining

Supra 50 is the grade used for machining parts from bulk feedstock, such as bars or hot rolled sheet.

Supra 50 is a « sticky » alloy with chips that tend to adhere to the tool. Relatively low cutting speeds are therefore required.

	Turning		Milling	Drilling
	Peeling	Cutting		
Tool	S3 or S4 carbide	High speed steel	High speed steel	High speed steel
Lubricant	Soluble oil	Soluble oil	Soluble oil	Soluble oil
Cutting angle (°)	12-17	7-10	15	-
Rake angle (°)	5-8	6-10	3-7	9-13
Cutting speed (m/minute)	50-75	15-20	10-15	10
Advance rate	0.2 to 0.5 mm/rev	0.03 to 0.07 mm/rev	0.05 to 0.10 mm/tooth	0.10 mm/rev

The parts must be carefully cleaned after machining to reduce the risk of contamination, particularly by the lubricant.

VIII.4 Welding

The rules for welding the 47.5% Ni alloys are comparable to those for austenitic stainless steels, but it is recommended to perform a prior stress relieving treatment at 600°C-800°C.

All welding techniques can be employed, including resistance spot welding, electron beam welding and argon arc welding. When a filler metal is necessary, it is preferable to use the same alloy (47.5% Ni).

Welding must normally be carried out before final heat treatment of the parts, even in the case of spot welding.

Large size welds, which impair the magnetic properties of the product, must preferably be situated in places where the degradation is of less importance.

VIII.5 Brazing

It is imperative to perform any brazing operations after the final high temperature heat treatment. The magnetic properties of the braze zones will generally be impaired.

VIII.6 Corrosion resistance

The corrosion resistance of Supra 50 is better than that of carbon steels due to the presence of nickel. However, these alloys are not stainless and their oxidation resistance must be verified in each particular case.

IX. AVAILABLE FORMATS

Grade	Treated cores (1)	Treated parts (1)	Cold rolled strip	Long and massive products (2)
SUPRA 50	■	■	■	■
SUPRA 50 SP	■	■	■	
SUPRA 50 G	■	■	■	
SUPRA 50 GSP	■	■	■	
SUPRA 50 T	■	■	■	
SP 510	■	■	■	

(1) : cores, profiles, stacked laminations, rotor and stator sheets, shielding, plates for chemical machining sold by MECAGIS, a subsidiary of Imphy Ugine Précision, like Imphy Alloys

(2) : bars, profile sections, forgings, hot rolled sheets

IX.1 FLAT PRODUCTS

SUPRA 50, SUPRA 50 SP, SUPRA 50 G, SUPRA 50 GSP			
Format	Thickness (mm)	Maximum width (mm)	Condition
Cold rolled strip delivered in coils	0.025 to 0.07	300	Cold worked or annealed
	0.07 to 3	640	Cold worked or annealed
Cold rolled strip delivered as cut-to-length sheets (maximum length 3500 mm)	0.10 to 3	10 to 640	Cold worked or annealed
Hot rolled strip (Supra 50 only)	5 to 50	500 to 2 000	As-rolled and pickled

SUPRA 50 T			
Format	Maximum thickness (mm)	Maximum width (mm)	Condition
Cold rolled strip delivered in coils	0.35	640	Cold worked

SP 510			
Format	Typical thicknesses (mm)	Maximum width (mm)	Condition
Cold rolled strip delivered in coils	0.5-0.7	640	Cold worked or annealed

Please consult Imphy Alloys for the dimensional tolerances and for any specific requirements.

IX.2 BARS

SUPRA 50	
Diameter ϕ (mm)	Standard lengths (mm)
$\phi \leq 13$	2000 to 3000
$14 \leq \phi \leq 80$	3000 to 4000
$\phi > 80$	Dependent on the diameter and the quantity ordered

Please consult Imphy Alloys for the dimensional tolerances and for any specific requirements.

IX.3 FORGINGS AND CASTINGS

Please consult us for an estimate.