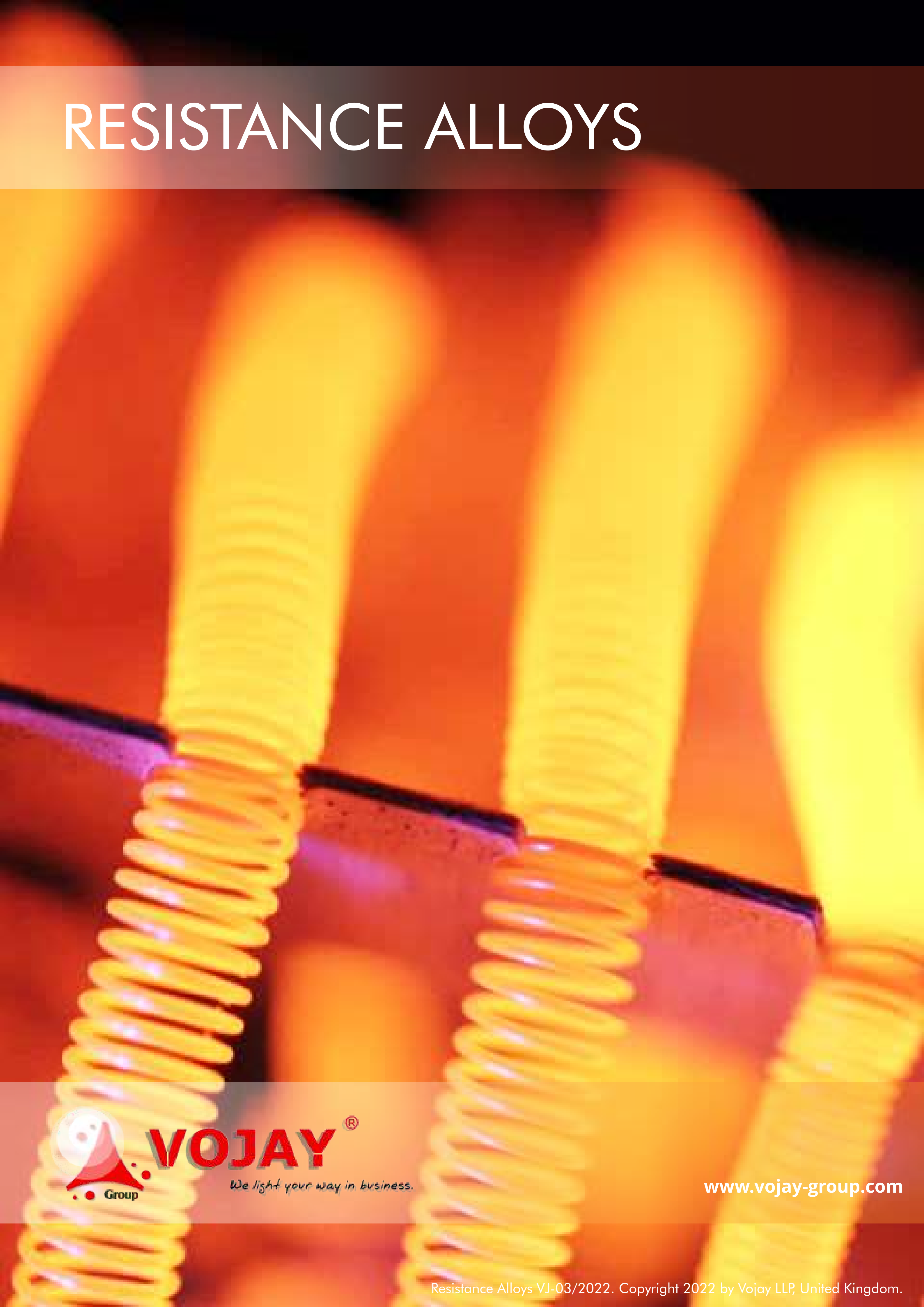
RESISTANCE ALLOYS



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FERRITIC ALLOYS (FeCrAl)

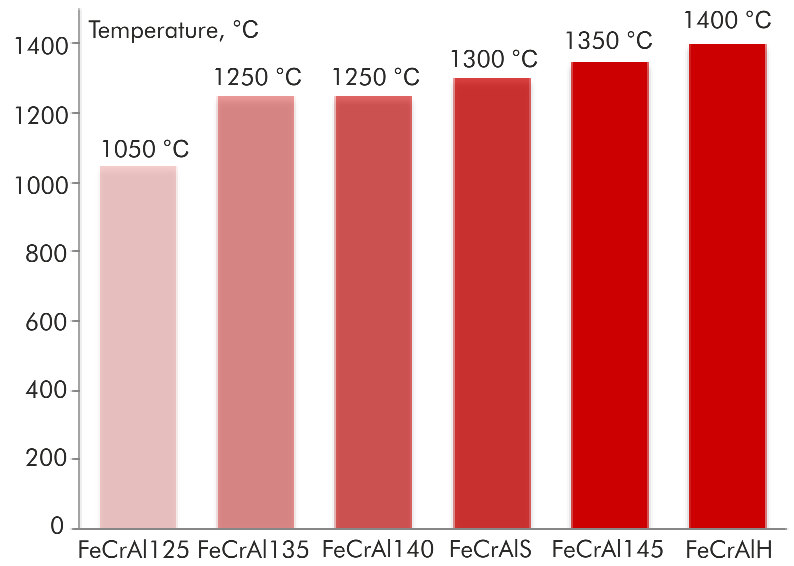
Iron-Chromium-Aluminium

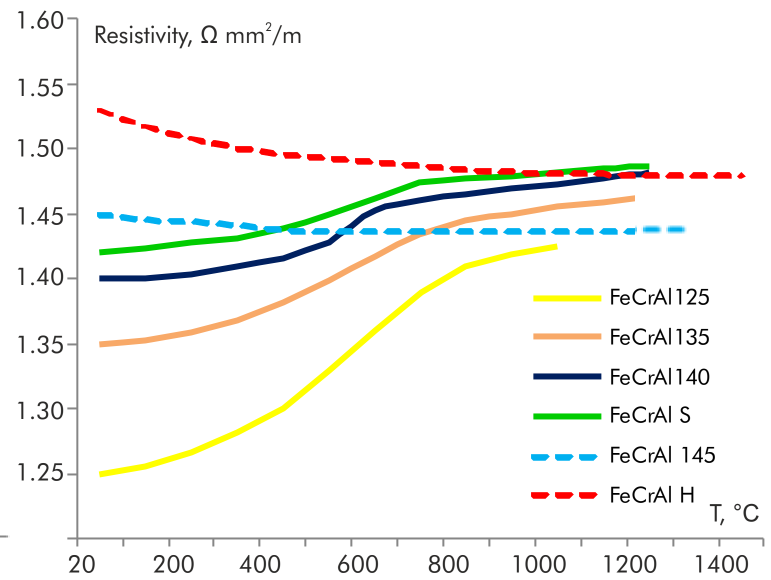
A family of iron-chromium-aluminium (FeCrAl) alloys consist mainly of iron, chromium (12-27%) and aluminium (4,0 - 7,0%) and are used in a wide range of resistance and high-temperature applications.
These alloys are known for their ability to withstand high temperatures (up to 1400°C (2550°F)) and having intermediate electric resistance (1,20 – 1,60 μΩ · m) due to their ability to create a protective alumina scale on the surface.

Physical and mechanical properties:

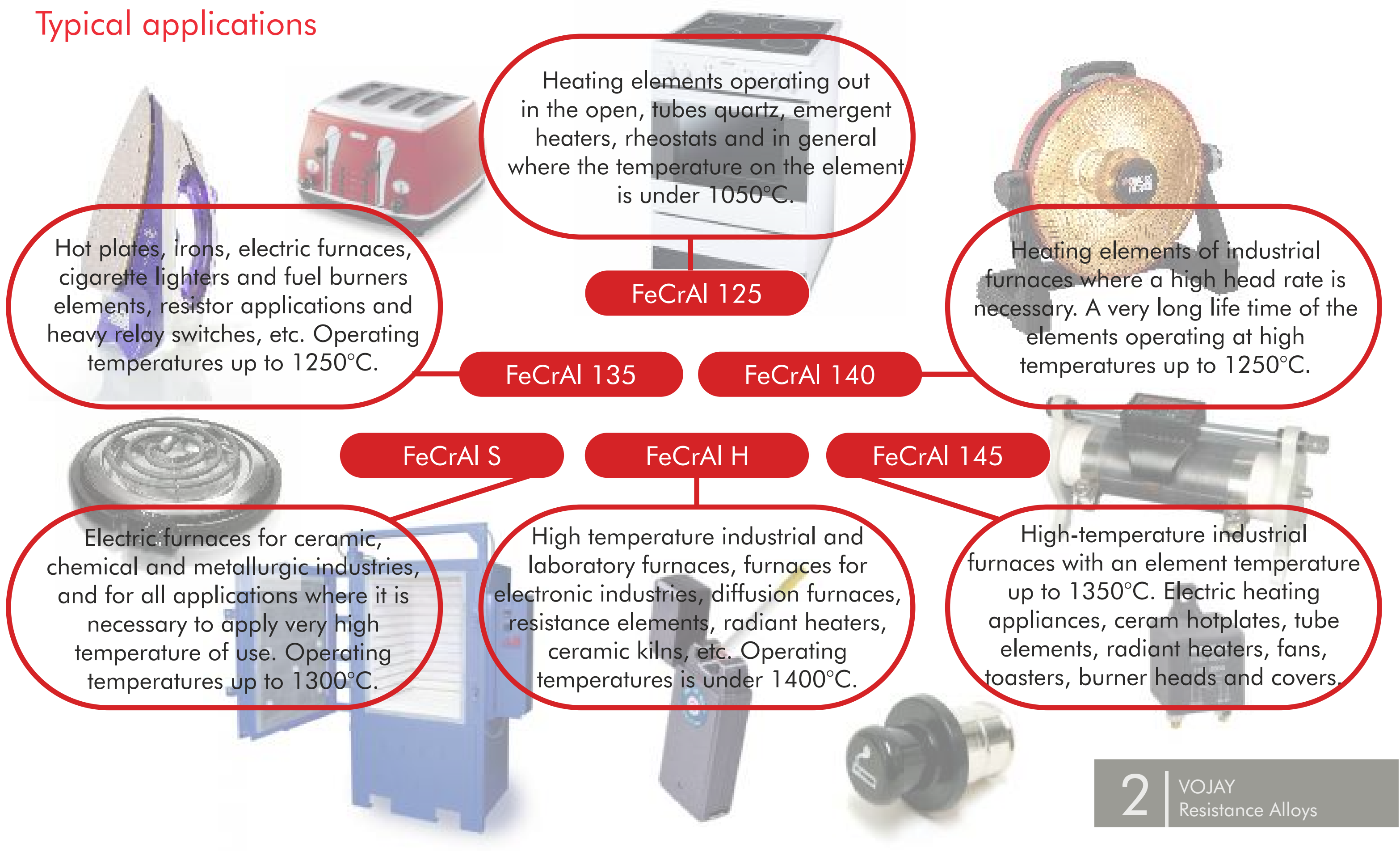
Alloy		FeCrAl 125	FeCrAl 135	FeCrAl 140	FeCrAl S	FeCrAl 145	FeCrAl H
Designation	DIN	CrAl 14 4	CrAl 23 5	CrAl 20 6	CrAl 25 5	CrAl 21 6 S	CrAl 27 7
	W.N.	1.4725	1.4765	1.4767	1.4765	1.4765	-
	UNS	K91670	K92500	K92400	K92500	K92500	-
Chemical composition %							
Iron (Fe)		rest	rest	rest	rest	rest	rest
Chromium (Cr)		14.00-16.00	20.50-23.50	19.00-21.00	23.00-26.00	21.00-23.00	26.50-27.80
Aluminium (Al)		4.00-5.50	4.20-5.30	5.00-6.00	4.50-6.50	5.00-7.00	6.00-7.00
Nickel (Ni)		≤ 0.40	≤ 0.60	≤ 0.60	≤ 0.40	≤ 0.60	≤ 0.50
Other		-	-	Ti,Nb,Y,Zr,Hf	-	Nb ≤ 0.50	Mo 1.80-2.20
Physical properties							
Maximum operating t, °C		1050	1250	1250	1300	1350	1400
Melting point, ° C		1500	1500	1500	1500	1500	1520
Resistivity at 20°C, Ω mm²/m		1.25	1.35	1.40	1.42	1.45	1.53
Density, g/cm³		7.30	7.25	7.20	7.10	7.10	7.10
Thermal conductivity, W/mK		15.00	13.00	13.00	13.00	13.00	16.00
Coefficient of linear thermal expansion, $x10^{-6}$/K	20° C	-	-	-	-	-	-
	200° C	11.00	11.00	11.00	11.00	11.00	11.00
	400 °C	12.00	12.00	12.00	12.00	12.00	12.00
	500 °C	-	-	-	-	-	-
	600 °C	13.00	13.00	13.00	13.00	13.00	13.00
	800 °C	14.00	14.00	14.00	14.00	14.00	14.00
	1000 °C	15.00	15.00	15.00	15.00	16.00	16.00
Mechnical properties							
Tensile Strength, N/mm²		700	630	640	725	790	770
Yield Strength, N/mm²		500	460	450	550	660	620
Hardness, HV		200	210	200	210	210	220
Elongation, %		≥ 18	≥ 12	≥ 14	≥ 12	≥ 12	≥ 10

*Note: the values in the table apply for diameters up to 1.00 mm maximum. Any other specification is subject to discussion and available upon request.





Typical applications



AUSTENITIC ALLOYS (NiCr)

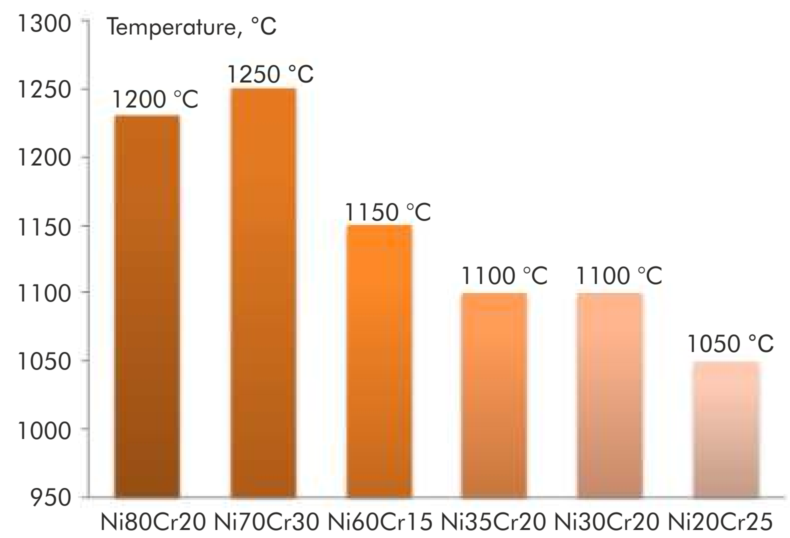
Nickel-Chromium

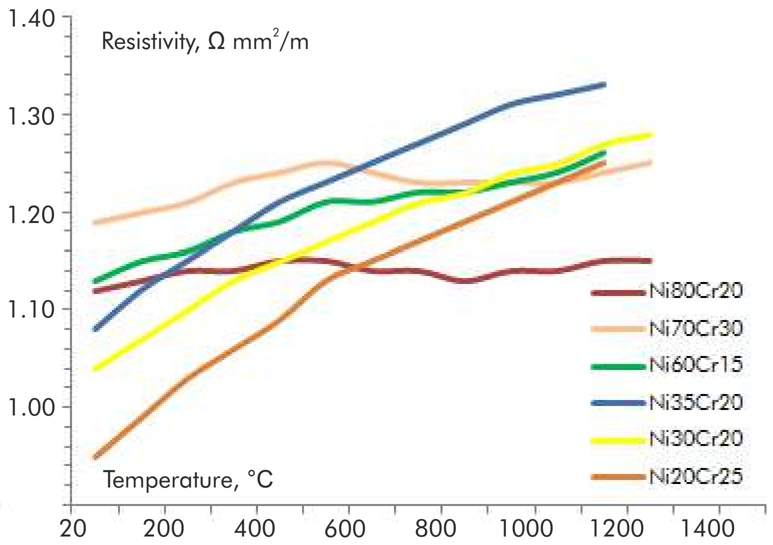
Nickel-Chromium (NiCr) - is a group of alloys with Ni content of 55-78%, Cr content of 15-23%, depending on the grade, and additives of Mn, Si, Fe and Al. NiCr alloys have excellent resistance to high temperature oxidation and corrosion and good wear resistance. Due to its resistance to oxidation and stability at high temperatures (up to 1250ºC (2280ºF), it is widely used in electric heating elements, such as in appliances and tools. NiCr alloys have higher hot and creep strength than FeCrAl alloys.

Physical and mechanical properties:

Alloy		Ni80Cr20	Ni70Cr30	Ni60Cr15	Ni35Cr20	Ni30Cr20	Ni20Cr25
Designation	DIN	NiCr8020	NiCr7030	NiCr6015	NiCr4020	NiCr3020	NiCr2025
	W.N.	2.4869	2.4658	2.4867	1.4886	1.4860	1.4843
	UNS	N06003	N06008	N06004	N08330	-	S31400
Chemical composition, %							
Nickel (Ni)		rest	rest	≥59.00	34.00 - 37.00	30.00 - 34.00	19.00 - 21.00
Chromium (Cr)		19.00 - 21.00	29.00 - 31.00	14.00 - 17.00	18.00 - 21.00	18.00 - 21.00	23.00 - 25.00
Iron (Fe)		≤ 1.00	≤ 1.00	rest	rest	rest	rest
Aluminium (Al)		≤ 0.20	≤ 0.20	≤ 0.30	≤ 0.30	≤ 0.30	≤ 0.30
Copper (Cu)		≤ 0.50	≤ 0.50	≤ 0.50	-	-	-
Physical properties							
Operating temperature,°C		1200	1250	1150	1100	1100	1050
Melting point, °C		1400	1400	1390	1390	1390	1380
Resistivity at 20°C, Ω mm²/m		1.12	1.19	1.13	1.04	1.06	0.95
Density, g/cm³		8.30	8.10	8.20	7.90	7.90	7.80
Thermal conductivity, W/mK		14.60	13.80	13.40	13.00	13.00	12.90
Coefficient of linear thermal expansion, x10⁻⁶/K	20 °C	-	-	-	-	-	-
	200 °C	14.00	13.50	14.00	15.00	15.00	16.00
	400 °C	15.00	14.50	15.00	16.00	16.00	17.00
	500 °C	15.40	14.80	-	-	-	-
	600 °C	15.50	15.00	15.50	17.00	17.00	17.50
	800 °C	16.00	16.00	16.00	18.00	18.00	18.00
	1000 °C	17.00	17.00	17.00	19.00	19.00	19.00
Mechnical properties							
Tensile Strength, N/mm²		710	870	750	675	675	675
Yield Strength, N/mm²		420	450	370	340	335	335
Hardness, HV		170	185	180	180	160	160
Elongation, %		≥ 18	≥ 18	≥ 18	≥ 18	≥ 18	≥ 18

Note: the values in the table apply for diameters up to 1.00 mm maximum. Any other specification is subject to discussion and available upon request.





Typical applications

- **Ni80Cr20**: Industrial furnaces (up to 1200°C), high temperature elements, heating batteries, electric cooking equipment, precision resistors.
- **Ni70Cr30**: Industrial furnaces (up to 1250°C) with alternating oxidizing/ reducing atmosphere, precision resistors.
- **Ni60Cr15**: Heating elements operating at a temperature up to 1150°C, which include all sorts of heating elements and resistances (toasters elements, potentiometer resistances and other household and industrial appliances).
- **Ni35Cr20, Ni30Cr20, Ni20Cr25**: Heating appliances (up to 1050°C), furnaces in carburising or semi-reducing atmosphere, heating elements of cooking equipment.

DELIVERY PROGRAMM

WIRE

FLAT WIRE

STRIP

SIZE & TOLERANCE RANGE

FORMS	DIAMETER, mm	Tolerance	THICKNESS, mm	Tolerance	WIDTH, mm	Tolerance	FINISH
Wire	0,02 - 0,05	± 0,005	*	*	*	*	Cold drawn, bright, annealed, oxidized.
	0,05 - 0,10	± 0,007	*	*	*	*	
	0,10 - 0,30	± 0,010	*	*	*	*	
	0,30 - 0,50	± 0,015	*	*	*	*	
	0,50 - 1,00	± 0,020	*	*	*	*	
	1,00 - 3,00	± 0,030	*	*	*	*	
	3,00 - 6,00	± 0,040	*	*	*	*	
	6,00 - 8,00	± 0,050	*	*	*	*	
	8,00 - 12,00	± 0,40	*	*	*	*	
Flat wire	*	*	0,05 - 0,10	± 0,010	2,00 - 5,00	± 0,20	Cold rolled, bright, annealed, oxidized.
	*	*	0,10 - 0,20	± 0,015			
Strip	*	*	0,05 - 0,10	± 0,010	5,00 - 10,00	± 0,20	
	*	*	0,10 - 0,20	± 0,015	10,00 - 20,00	± 0,20	
	*	*	0,20 - 0,50	± 0,020	20,00 - 30,00	± 0,20	
	*	*	0,50 - 1,00	± 0,030	30,00 - 50,00	± 0,30	
	*	*	1,00 - 1,80	± 0,040	50,00 - 90,00	± 0,30	
	*	*	1,80 - 2,50	± 0,050	90,00 - 120,00	± 0,50	
	*	*	2,50 - 3,50	± 0,060	120,00 - 250,00	± 0,50	
	*	*	3,50 - 5,00	± 0,025	*	*	

* Please check with us for specifications not listed above.

FeCrAl ADVANTAGES

1. High operating temperature.

Ferritic alloys FeCrAl can be used in average up to 1400°C while austenitic alloys NiCr have maximum operating temperature up to 1200°C (see the Figure 1).

2. High resistivity

The resistivity of FeCrAl alloys is higher than NiCr alloys (see the Figure 2). This makes it possible to choose the materials with larger cross-section thereby prolonging the life of the elements.

Considerable weight savings can be obtained especially in the applications of thin wire - the higher resistivity the less materials are used. Also, the resistivity of FeCrAl alloys is less affected by cold working and heat processing comparing to NiCr alloys.

3. Longer life

FeCrAl alloys can be used from 2 to 4 times longer than NiCr alloys being operated at the same temperature in the atmosphere.

4. Higher surface load

Higher operating temperature and longer life of FeCrAl alloys ensure the capabilities to sustain high surface load.

5. Low weight & low cost

The weight of FeCrAl alloys is lower than NiCr alloys. Due to the fact that FeCrAl alloys do not include nickel its price is lower than for NiCr alloys. As a result in a great number of applications considerable savings in weight and elements cost can be achieved.

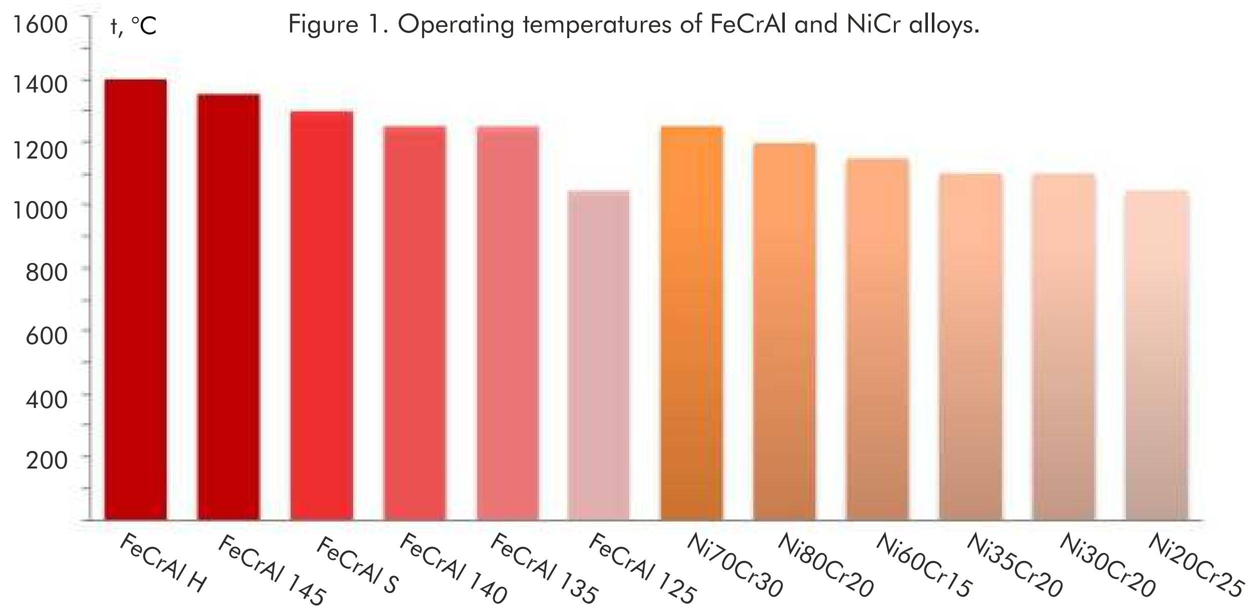


Figure 1. Operating temperatures of FeCrAl and NiCr alloys.

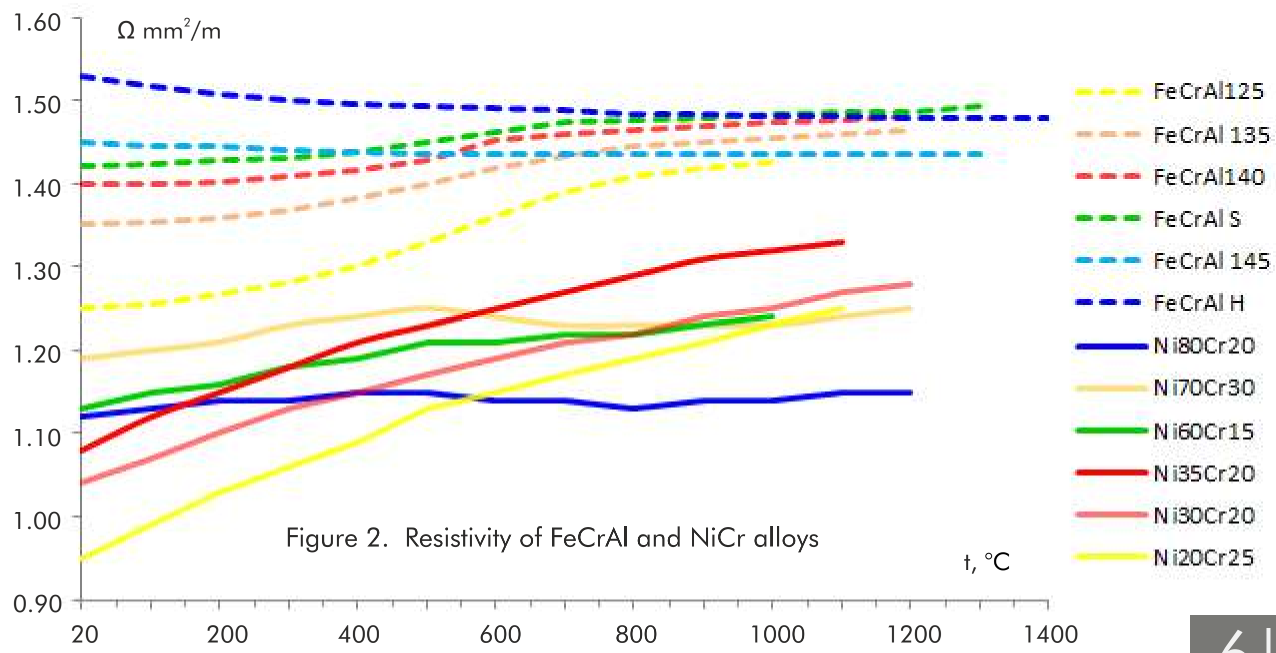


Figure 2. Resistivity of FeCrAl and NiCr alloys

6. Perfect oxidation properties

The aluminum oxide (Al_2O_3) generated on the surface of FeCrAl alloys has better adhesion properties and therefore less contaminating. It is an excellent antioxidant, diffusion barrier, electrical insulator and has better carburization resistance than the chromium oxide (Cr_2O_3) generated on the surface of NiCr alloys.

7. Sulfur resistance

FeCrAl alloys can resist corrosion for atmospheres and materials contaminated with sulphur or sulfur compounds. NiCr alloys are subject to heavy erosion under such conditions.

NiCr ADVANTAGES

1. Perfect form stability under high temperatures

NiCr alloys are resistant to deformation and keep a very good form stability under high temperatures due to the fact that they have higher hot and creep strength than FeCrAl alloys.

2. Non-magnetic properties

NiCr alloy is non-magnetic material that can be used in low temperature applications. Meanwhile, FeCrAl alloy is non-magnetic under temperatures above 600 °C.

3. Good ductility after long-term use

NiCr alloys stay ductile after long-term use. This property makes heating elements more durable and be repaired after damage.

4. High emissivity

NiCr alloys have higher emissivity than FeCrAl alloys in fully oxidized condition. Having the same surface load, the temperature of NiCr alloy elements is lower than FeCrAl alloys.

5. Corrosion resistance

Generally, NiCr alloys have better corrosion resistance at room temperature than non-oxidized FeCrAl alloys (except sulfur environments and controllable atmospheres).

OPERATING LIFE FACTORS

Operating life of resistance alloys depends on several factors:

- chemical composition of alloy;
- size (diameter / thickness);
- surface condition;
- atmosphere & environment;
- contamination.

Of course, there are a lot of applications different from each other. Therefore it is impossible to provide general solution how to prolong the usage of resistance alloys. Here are some important issues:

1. Oxidation

At the time of heating resistance alloys form an oxide layer on their surface which protect the material from further oxidation. To be protective, the oxide layer must have the following essential properties:

- to be dense (without cracks or other malfunctions which could facilitate the penetration into the metal and enable internal corrosion;

- must not evaporate;

- must be slow-growing even at elevated temperatures;

- must have a certain ductility to prevent spalling;

- should be resistant to dissolution by deposits of metals or salts;

The oxide layer of NiCr alloys (Cr_2O_3) meets these requirements under many process conditions. However at temperatures above 1000 °C or under certain gas conditions, the oxide layer Al_2O_3, which is formed on FeCrAl alloys, is more protective. It shows low growth rates even at temperatures above 1000 °C. Unlike Cr_2O_3, Al_2O_3 does not evaporate at high temperatures and it is even stable in oxygen-deficient atmospheres.

2. Carburization

The rate of internal carburization is subject to the solubility of carbon, the rate of carbon diffusion into metal and the rate of penetration into the metal. Internal carburization basically occurs at high temperatures (above 1100 °C)

RESISTANCE ALLOYS SUMMARY

where diffusion of carbon into the metal is fast. To obtain high resistance to internal carburization, materials with low solubility and diffusivity of carbon should be chosen. Solubility and diffusivity of carbon in NiCr alloys are significantly lower than in FeCrAl, therefore generally they are less susceptible to internal carburization.

3. Vapour

The materials heated in the furnace, as a rule, generate a lot of water vapour, which impedes the formation of protective oxide layer on the surface of alloy thereby making it loose and less adhesive. The impact of vapour on FeCrAl alloys is more serious than on NiCr alloys.

4. Nitridation

If alloy materials are exposed to nitrogen, nitrogen/hydrogen or ammonia atmospheres at high temperatures, they suffer nitridation: nitrogen penetrates into alloy and causes the formation of internal nitrides (basically chromium nitrides), which may cause severe loss of ductility during exposure or even cracks along grain boundaries. NiCr alloys are generally less susceptible to internal nitridation than FeCrAl because of the low nitrogen solubility.

5. Halogen

In the atmosphere of halogen or its compounds (fluorine, chlorine, bromine, iodine) both NiCr and FeCrAl alloys are very sensitive and seriously attacked even at low temperatures.

6. Sulphur

Sulphidising gases are encountered in processes in chemical industry and in coal conversion processes. Under high sulphur concentrations metal sulphides may be formed in contact with sulphur. FeCrAl alloys have considerably better durability and are particularly stable in oxidizing gases containing sulphur. NiCr alloys are very sensitive to sulphur and could form low-melting compounds NiS.

7. Salts

In high concentrations the salts of alkaline metals, molten salts, borate compounds, carbonate, etc. can increase alloy wastage rate significantly. It is impossible to predict material behavior and corrosion rate in complex corrosive environments with variety of possible gas-metal and gas-salt reactions at high temperatures.

8. Molten metals

Some molten metals such as zinc, brass, copper, aluminum and lead are able to react with resistance alloys. Due to their low melting point they are easy to evaporation and splash that can affect the durability of the alloy.

WELDING METHODS

Resistance alloys can be welded. Proper welding ensures not only the stability of the welding parts, but the operating life of the whole electric alloy component.

There are many types of welding, but it is better to use argon shielded arc welding (GMAW/GTAW). For welding the material should be in the soft annealed condition and be free from scale, grease and markings. During welding it is advisable to keep maximum cleanliness and avoid the draughts. To ensure the usage of electric alloy component at highest temperature and for a long time it is better to adopt the welding electrodes/wire of the same specification with the component.

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