Industeel

ArcelorMittal

VIRGO™ 39

VIRGO™ 39: A 16% Cr 5% Ni 1% Mo martensitic stainless steel

VIRGO™ 39 is a low carbon martensitic stainless steel. The grade is specially designed to combine high mechanical properties including toughness and improved corrosion resistance properties when compared to other martensitic stainless steels, like 13 Cr and 13 Cr 4 Ni grades.
The alloy has been primarily designed to resist to erosion-corrosion or cavitation encountered in hydraulic applications. The alloy is also used for hydrofoils legs, as anti-seismic compounds or offshore structures, boats, landing grids for helicopters... where the combined mechanical and corrosion resistance properties are needed. Mining, cement plants, and hydraulic applications take also advantage of its combined abrasion-corrosion resistance properties.

PROPERTIES

STANDARDS

> EURONORM EN 1.4418 X4 Cr Ni Mo 16-5-1

CHEMICAL ANALYSIS - WEIGHT %

Typical values (Weight %)

C	Cr	Ni	Mo
.045	16	5	1

PHYSICAL PROPERTIES

Density: 7.7 kg/dm³

Interval Temperature (°C)	Thermal expansion $\alpha \times 10^{-6} K^{-1}$	Temperature		Resistivity (μΩ.cm)	Thermal conductivity ($W.m^{-1}.K^{-1}$)	Specific heat ($J.kg^{-1}.K^{-1}$)	Young modulus E (GPa)	Shear modulus G (GPa)
		(°C)	(°F)					
20-100	10	20	68	75	20	460	210	78
20-200	11	100	212	85	25	520	180	72

MECHANICAL PROPERTIES

Tensile properties (quenched tempered grades)

Temperature		Y.S. 0.2%		UTS		Elongation
C°	F°	MPa	ksi	MPa	ksi	%
20	68	615	89	850	123	15
100	212	603	87	830	120	19
200	392	595	86	770	112	17
300	572	590	85	730	106	15

Mechanical properties are strongly dependant upon the heat treatments: 700 MPa (102 ksi) or 800 MPa (116 ksi) minimum yield strength can be guaranteed. With 800 MPa (102 ksi) yield strength, the UTS will be included in the 1030 - 1150 MPa (149 - 167 ksi) range. The grade may be hardened.

Impact value

Typical at +20°C (68°F)	100 J/cm²
Guaranteed KCV at -20°C (-4°F)	L Direction: 60 J/cm² / T Direction: 35 J/cm²
Guaranteed NDT Temperature	≤ -80°C (-112° C)
Guaranteed fracture toughness KIC at-50°C (-58°F)	≥ 10OMPa √m

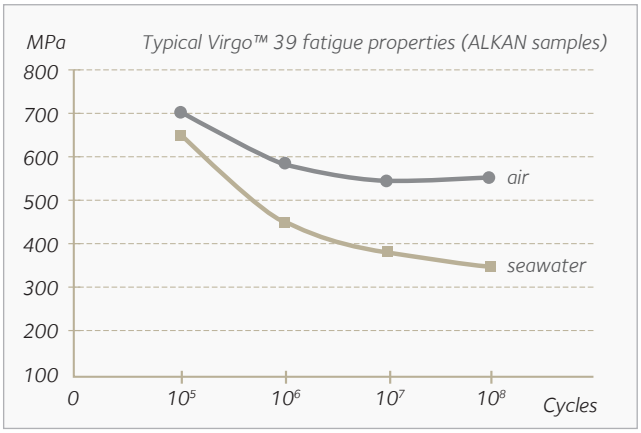
Hardness values
(typical values - Average of 5 tests)

The improved fatigue properties of VIRGO™ 39 grade are mainly due to the combined chromium and nickel additions. Note that the **fatigue properties** are related to the final heat treatment performed on the grade.

Hardness values
(typical values - Average of 5 tests)

May be optimized with appropriate heat treatment

Standard	HV_{10}: 260-320	HB 230-320
High strength	HV_{10}: 320-390	HB 320-370



IN SERVICE CONDITION

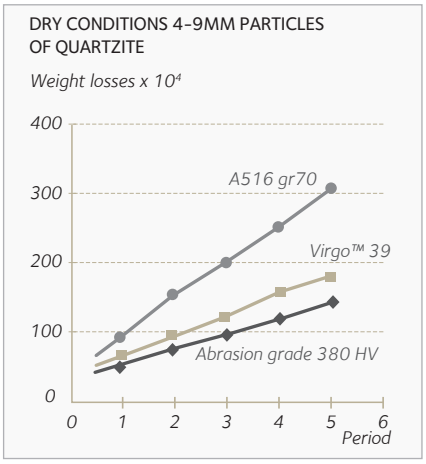
CORROSION RESISTANCE

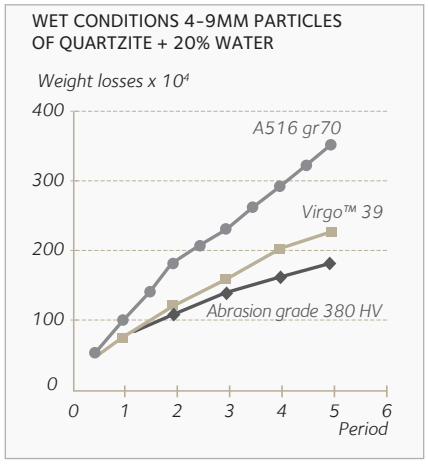
Due to its high nickel chromium and molybdenum content, and its low carbon concentration, VIRGO™ 39 has a good resistance to atmospheric corrosion. It has same resistance to seawater atmosphere, similar to 304 and higher 13% Cr grades. VIRGO™ 39 has a poor resistance to pitting corrosion (chloride attack when considering stagnant water).

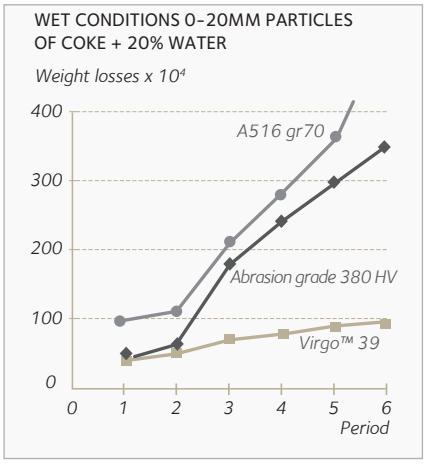
Abrasion resistance : High tensile values combined with good corrosion resistance make VIRGO™ 39 excellent in wet abrasive conditions. Its abrasion resistance is up to 5 times better than that of high carbon steel (C = 0.40 type).

IN SERVICE CONDITION

Tests performed in rotating blades in different media







DELIVERY CONDITIONS

SIZE RANGE

	Hot rolled plates
Thickness	5 up to 150 mm 3/16" up to 6"
Width	Up to 4000 mm Up to 157"
Length	Up to 12000 mm Up to 39.4"

Other sizes are available on request, including 4 100 mm (161,4") width plates.

PLATE PROCESSING

CUTTING

VIRGO™ 39 can be cut by plasma or oxygen + iron powder without any difficulty.

COLD FORMING

Bending and rolling can be performed without any problem on suitable machines. Nevertheless, the edges must be carefully prepared and free of notch of any type, due to cutting, in order to avoid crack propagations.

HEAT TREATMENT

It consits in a quench (air or water) at 900 - 1000°C (1652 - 1832°F), followed by a stress relieving heat treatment at 600 - 620°C (1112 - 1148°F). Different strength toughness combinations can be obtained by appropriate heat treatment. Please, consult if needed.

HOT FORMING

For products hot forming between 900 and 1000°C (1652 - 1832°F) is equivalent to a normalization heat treatment and must be followed by a tempering (temperature about 610°C - 1130°F). For products heated above 1000°C (1832°F), the forming must be followed by Normalization + Tempering treatments.

WELDING

Due to its residual austenite content, VIRGO™ 39 steel is easier to weld than most of high alloying steels. VIRGO™ 39 can be welded without pre-heating, using a low hydrogen welding procedure. All common welding techniques can be used. Selection of welding consumables can be made taking into account the following recommendations and according to the type of joint.

Homogeneous welding : VIRGO™ 39/VIRGO™ 39 with matching filler metal

Weld metal is of the same chemical composition as the parent material to maintain equivalent mechanical and corrosion properties.

GENERAL RECOMMENDATIONS

- **> Avoid welding wet plates**
- **> Use of basic coating with drying procedure**
- **> The interpass temperature must be kept below 100°C (212°F).**
- **> Use of the lowest energy possible. It's better to make several runs instead of one wide run.**

OBSERVATIONS ON WELDING TECHNIQUES

TIG - The joint may be used without stress relief treatment after welding. MIG or Manual Arc Welding : a PWHT in the range of 560 - 600°C (1040 - 1112°F) is needed to obtain good toughness in weld metal. Some examples of filler materials for homogeneous weldings :

SOME EXAMPLES OF FILLER MATERIALS FOR HOMOGENEOUS WELDINGS :

Supplier	Grade	Welding process
SOUDOMETAL	Soudinox 17-4	SMAW
UTP	6655 Mo	SMAW
OERLIKON	Citochrom 17.4	SMAW
THYSSEN	Thermanit 17.06	SMAW
FP SOUDAGE	Finox 17-4 Mo	GMAW
THYSSEN	Thermanit 17-06	GMAW
FP SOUDAGE	Finox 17-4 Mo	GTAW
THYSSEN	Thermanit 17-06	GTAW

Heterogeneous welding : VIRGO™ 39/C.Mn or VIRGO™ 39/VIRGO™ 39 with austenitic-ferritic filler metal

Such welded joint restrictes uses in Abrasion/Corrosion applications. The welds will present lower mechanical properties. The main interest of VIRGO™ 39 steel is that it can be welded without preheating. The weld metal must be chosen to maintain this advantage, despite the problem of dilution of carbon from the CMn plate to the weld metal. The use of adapted austenitic or austeno-ferritic electrodes can solve this problem.

General recommendations

- **> Dry plates before welding**
- **> Use of basic coating with drying procedure**

Observations on welding electrodes

Electrodes type 308 Mo 309 are recommended. The resulting yield strength will then be about 450 MPa after a PWHT at 560 - 600°C (1040 - 1112°F) When a higher yield strength is required, type 312 austeno-ferritic electrode can be used. The yield strength will be about 650 MPa in the as welded condition but lower toughess properties will be obtained. PWHT must not be performed in this case.

APPLICATIONS

- Landing grids for helicopters (French/Deutch/USA Navies)
- Turbine hoops and labyrinth components of hydraulic power stations, as well as water cooling devices for nuclear power stations
- Slide-gates of hydraulic power stations
- Penstock wear plates
- Valve-gate components
- Anti-seismic plates for Nuclear power station

Castings of VIRGO™ 39 alloy are used for Pelton wheels, Francis wheels, Kaplan blades.

YOUR CONTACTS

Pierre Petit
Tel. +33 6 42 06 00 39
pierre.petit@arcelormittal.com

https://industeel.arcelormittal.com

Industeel France
Le Creusot Plant
56 rue Clemenceau
F - 71202 Le Creusot Cedex