UGIMA® 4511

Chemical analysis (weight %)	C	Si	Mn	Cr	P	S	N	Nb
	<0.030	<1.0	<1.0	16 to 18	<0.040	<0.030	< 0.030	12xC to 0.6

01-06-2012 – REV00

General overview

UGIMA® 4511 is an improved machinability niobium-stabilised ferritic stainless steel containing between 16 and 17% chromium.

Apart from good corrosion resistance, this grade is characterised by its high suitability for different methods of working such as machining, cold heading and welding:

- This UGIMA® version of 4511 enables bar turning productivity significantly greater than that obtained with a standard 4511 to be achieved, as well as good chip breakability.
- Stabilisation with niobium eliminates the risk of sensitisation during welding.
- It has excellent cold-heading properties.

For certain applications, it is an economical replacement for 1.4307.

Its ferritic structure ensures excellent ferromagnetic properties, good oxidation resistance (in particular to thermal cycles) and an expansion coefficient similar to that of carbon steel.

Classification

Ferritic stainless steel

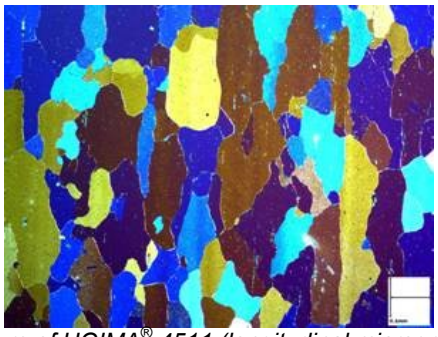
Designation

Material No.		
Europe	**USA**	**Japan**
EN 10088-3	**ASTM**	**JIS**
1.4511	-	-

USA	France	Germany
AISI	**AFNOR**	**DIN**
430	X3CrNb17	-

Microstructure

The structure of UGIMA® 4511 is entirely ferritic in the as-delivered condition. The main precipitates are Nb-carbonitrides and Mn-sulphides.



Microstructure of UGIMA® 4511 (longitudinal micrography x 100)

Mechanical properties

Tensile data

Condition	Temperature	Tensile strength	Yield strength	Ultimate elongation
	T	UTS	0.2% offset YS	A
	(°C)	(MPa)	(MPa)	(%)
Softened	20	420 to 620	≥ 200	≥ 20
Ø ≤ 16 mm work-hardened by drawing	20	480 to 750	≥ 300	≥ 10
Ø > 16 mm work-hardened by drawing	20	450 to 700	≥ 240	≥ 15

Hardness data

Temperature	Brinell hardness
(°C)	(BH)
20	≤ 200

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Physical properties

Temperature (°C)	Density (kg/dm^3)	Elasticity modulus (GPa)	Thermal conductivity ($W.m^{-1}.K^{-1}$)	Expansion coefficient ($10^{-6}.K^{-1}$)	Electrical resistivity (µΩ.cm)	Specific heat ($J.kg^{-1}.K^{-1}$)
20	7.7	220	25	-	60	460
100		215		10.0		
200		210		10.0		
300		205		10.5		
400		195		10.5		
500				11		

Magnetic properties

Ugima® 4511 is a soft ferromagnetic material (it is attracted to a magnet). Magnetic annealing is used to optimise its magnetic properties and therefore achieve high relative permeability and low coercive fields. This treatment can be carried out either on bars produced by Ugitech or on machined parts.

The magnetic properties of different ferritic grades in the form of annealed drawn bars are compared in the following table:

Grade	UGIMA® 4511	IMRE	UGI 4105Si	Ugiperm 12FM	UGI 4016L
Saturation magnetisation (T)	1.67	1.60	1.60	1.70	1.65
Coercive field* (A/m)	100 to 150	150 to 200	130 to 200	100 to 125	150 to 200
Maximum permeability	2000 to 3000	1100 to 2000	1200 to 2200	2000 to 3000	1000 to 2000
Remanent field (T)	0.5 to 1	0.25 to 0.8	0.5 to 0.9	0.5 to 0.7	0.5 to 1
Resistivity (µΩ.cm)	60	76	77	78	60

Corrosion resistance

Localised corrosion

Pitting corrosion

We assessed this type of corrosion by testing the pitting potential: the higher its mV, the greater the pitting corrosion resistance; a neutral, slightly chlorinated pH environment (0.02 moles/litre of sodium chloride) of municipal drinking water was chosen (at 23°C).
The following table gives the pitting potential values measured on samples from bars turned in the transverse direction:

Grades	*Pitting potential in mV/SCE*	*Standard deviation*
UGIMA® 4511	***358***	***18***
UGI 4511	***366***	***15***
UGI 4016L	***361***	***40***

The pitting corrosion resistance behaviour of UGIMA® 4511 and UGI 4511 is therefore identical.

Intergranular corrosion

Like UGI 4511, UGIMA® 4511 withstands intergranular corrosion after welding, or after sensitising heat treatment, the requirements of which are specified in the standards (test performed in accordance with ASTM A262-75 Practice E; DIN EN ISO 3651-2).

Hot working

Ugima® 4511 has excellent hot workability at all temperatures, due to its entirely ferritic structure. It can be hot formed by forging or rolling at between 800°C and 1150°C. The heating temperature must not exceed 1150°C to prevent excessive grain growth.

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UGIMA® 4511

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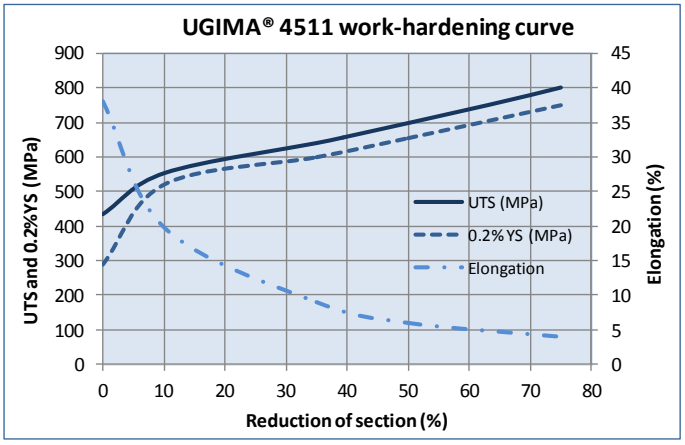
Cold working

Ugima® 4511 is easy to work using the conventional processes of cold forming: cold drawing, shaping, forming, cold heading, etc.

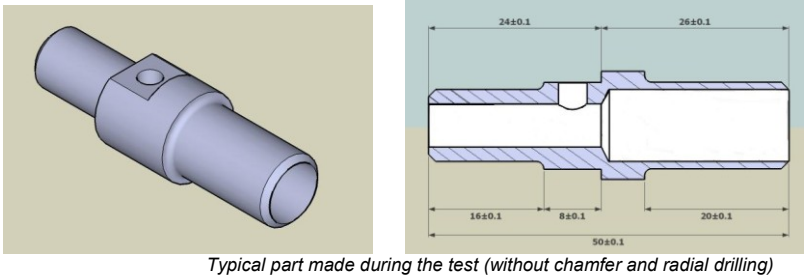
Thanks to its moderate work-hardenability, Ugima® 4511 allows to limit the stresses on the tools (thus their wear) during cold working.



Machinability

Compared to a standard 1.4511, UGIMA® 4511 provides significant productivity increases in bar turning, thanks to a slower tool wear and especially a better chip breakability for the same cutting conditions.

Tests were performed on a TORNOS SIGMA 32 industrial screw machine to compare UGIMA® 4511 with a standard 1.4511 and quantify the differences in machinability. For each grade, the test consists in defining the optimum cutting conditions for different operations to produce 1000 components (see the figure below) without having to change tool.



Typical part made during the test (without chamfer and radial drilling)

Turning (roughing and finishing)

The table below shows the cutting conditions that can be achieved to produce 1000 components without having to change any tool for each grade according to the operations (roughing and finishing) and the tools used. The results of a standardised test, the VB15/0.15, have been added to this table.

Operations	*Tools*	Standard 1.4511	UGIMA® 4511
Rough turning (a_p = 2 mm ; f = 0.30 mm/rev)	*SECO TM2000 CCMT09T308-F2*	V_c = **280** m/min	V_c = **300** m/min
Finish turning (1) (a_p = 0.5 mm ; f = 0.10 mm/rev)	*SECO TM2000 CCMT09T304-F1*	V_c = **240** m/min	V_c = **250** m/min
Turning VB15/0.15 (2) (a_p = 1.5 mm ; f = 0.25 mm/rev)	*SECO TM2000 CCMT09T308-F2*	V_c < **200** m/min	V_c = **205** m/min

(1) cutting conditions ensuring roughness < 1.6 µm on the 1000 machined parts, thanks to limited tool wear
(2) VB15/0.15: cutting speed at which 0.15 mm flank wear is noted in 15 minutes of effective machining.

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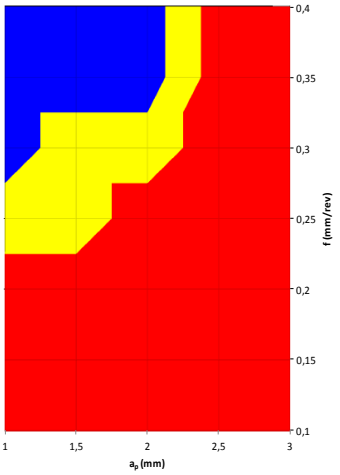
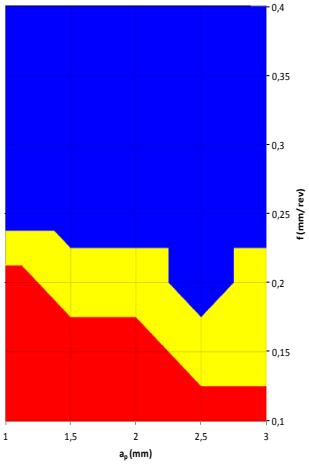
In the three turning operations, for equivalent tool wear, a potential increase in productivity by 5 to 10% was recorded with UGIMA® 4511 as opposed to a standard 1.4511.

Furthermore, a spectacular improvement in chip breakability was noted in UGIMA® 4511 as opposed to that obtained with a standard 1.4511 (see the table below). This is likely to prevent the risks that are often encountered on 1.4511, whereby balls of tangled chips are formed and not evacuated, thus requiring frequent production stoppages to allow them to be cleared manually.

Operation	*Tools*	Standard 1.4511	UGIMA® 4511
Turning (Vc = 150 m/min)	*SECO TM2000 CCMT09T308-F2*		

Fragmented chip conditions
Moderately fragmented chip conditions
Long chip conditions

Axial drilling and cross-cutting

The table below shows the cutting conditions that can be achieved to produce 1000 components without having to change any tool for each grade according to the operations and the tools used.

Operations	*Tools*	Standard 1.4511	UGIMA® 4511
Axial drilling	*GÜHRING RT100F ∅ 6 mm – DK460UF*	V_c = **80** m/min f = **0.125** mm/rev	V_c = **100** m/min f = **0.125** mm/rev
	ISCAR IC908 ∅9.9 mm – ICM099	V_c = **80** m/min f = **0.10** mm/rev	V_c = **100** m/min f = **0.10** mm/rev
Cross-cutting *	*ISCAR IC830 DGN3102JT*	V_c = **250** m/min f = **0.15** mm/rev	V_c = **250** m/min f = **0.15** mm/rev

** screw machine limit conditions achieved in terms of spindle power → does not allow differentiation between the two grades*

For axial drilling with 2 different drills (a GÜHRING full coated carbide drill and an ISCAR drill with a coated carbide tip insert), UGIMA® 4511 allows to increase productivity by approximately 25% on these operations. This significant difference is mainly due to the shorter chips obtained with UGIMA® 4511 (see photo below), which are therefore more easily evacuated, thus preventing the drill from breaking by blocking their rotation during the drilling operation.

Chips obtained from drilling with the ISCAR IC908 ∅9.9 mm drill – ICM099 at Vc = 90 m/min and f = 0.1 mm/rev

For the cut-off operation, the cutting conditions achieved are so high that the capacity limit of the TORNOS SIGMA 32 screw machine is reached, which does not allow the difference between UGIMA® 4511 and the standard 1.4511 to be quantified. These very high cutting conditions are however only achieved when

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working at a constant cutting speed and not at a constant rotational speed.

Welding

Thanks to its niobium stabilisation, UGIMA® 4511 can be welded in the same way as a standard 1.4511 by most arc welding processes (GMAW/GTAW, with or without filler metal, SMAW, plasma, etc.), by laser, resistance (spot or seam), friction or electron beam welding, etc.

No heat treatment must be carried out before or after welding so as to prevent ferritic grain growth in the grade.

If a welding filler metal is used, a homogeneous (stabilised ferritic) filler metal such as Exhaust F1 (18LNb) is preferred to ensure that the welded area (weld metal zone) [WM] and heat-affected zone [HAZ]) is a 100 % homogeneous ferritic structure; for thick welds (≥ 3mm), an austenitic filler metal such as ER308L(Si) (1.4316) is preferred, in order to eliminate the risk of inducing brittleness of the WZ through excessive grain growth.

In GMAW, as in GTAW, the shielding gas must not contain hydrogen or nitrogen. In GMAW, welds will be made under Ar (+ possibly He) + 1 to 3% O_2 or CO_2. In GTAW, welds will be made under Ar (+ possibly He).

Heat treatment

Softening
To restore ductility after cold deformation, Ugima® 4511 can be treated at a temperature between 750 and 850°C and air cooled.

Available products

Product	Shape	Finishing	Tolerance	Dimensions (mm)
Bar	Round	Rolled descaled	k13	Ø 22 to 70
		Turned	10 + 11	Ø 22 to 70
		Ground	7 + 8 + 9 + options	Ø 2 to 70
		Drawn	9	Ø 2 to 30
		Black bar	± 1% of ∅	Ø 23 to 73
Wire rod	Round	Rolled		Ø 5 to 33
		Rolled pickled		Ø 5 to 33
Billet	Square			50 to 120

Other options are possible. Contact us.

Applications

- Energy, process (solenoid valves)
- Automotive: sensor, injection, solenoid valve, valve support
- Agri-food
- Cosmetics

Usage limitations: cryogenic applications (insufficient toughness), applications requiring non-magnetic properties.