

**CAST<sup>®</sup>  
LOS**

**Special steel grades for  
Aluminum TWIN ROLL CASTER  
upgraded by LUCCHINI MAMÉ FORGE**

## 1. CastLOS: Steel for forged products for Aluminum processes

Lucchini RS Group is one of the few European fully integrated manufacturers of forged steel products, from steel-making to finished products and with a world-class laboratories and R&D dept.; the pursue of delivering value to customers drives the intensive analysis of new challenging applications for forged products such as shell for the Twin Roll Caster lines, used to produce Aluminum Flat Rolled Product directly from molten metal.

Aluminum is one of the most promising non-ferrous material in some industrial sectors such as:

- Automotive and other transportation
- Aerospace;
- Construction;
- Food & Beverage;
- Electronics.

The market is expected to have a tremendous increase of global demand of the Aluminum due to its excellent properties and the Company proposes CASTLOS, its proven steel solution for forging to use in Twin Roll Casters.

Solid know-how and customer orientation make Lucchini RS Group a sound and reliable partner, delivering High Added Value industrial solutions to support the Aluminum processes.



## 2. Steel-Making and Forging

- steel melting in a basic Ultra-High Power UHP Electric Arc Furnace EAF;
- ladle refining in Ladle Furnace LF and vacuum degassing in VD/VOD devices;
- bottom pouring with Ar pouring protection of ingots with weights and dimensions suitable for forgings with min. forging ratio: 3.5 / 1.

### 2.1. Chemical Analysis

#### 2.1.1. Heat Analysis (Ladle Analysis)

The heat analysis obtained during the pouring of the steel (ladle analysis) shall be in accordance with requirements in TABLE below. Here you can read the typical average values of chemical elements obtained by Lucchini RS Group in the production of this special grade.

Chemical elements	CASTLos	
	Requirements Heat analysis/Ladle analysis	Typical average obtained values For information only
<b>C [%]</b>	0.30 ÷ 0.36	0.33
<b>S [%]</b>	≤ 0.005	0.001
<b>P [%]</b>	≤ 0.013	0.010
<b>Mn [%]</b>	0.40 ÷ 0.60	0.45
<b>Cr [%]</b>	3.10 ÷ 3.40	3.18
<b>Ni [%]</b>	0.25 ÷ 0.40	0.30
<b>Mo [%]</b>	0.85 ÷ 1.20	1.04
<b>Cu [%]</b>	≤ 0.15	0.12
<b>Si [%]</b>	0.25 ÷ 0.45	0.30
<b>V [%]</b>	0.15 ÷ 0.30	0.215
<b>Al [ppm]</b>	50 ÷ 200	100
<b>Nb [ppm]</b>	≤ 200	80
<b>Ti [ppm]</b>	≤ 100	32
<b>Co [ppm]</b>	≤ 200	180
<b>Zr [ppm]</b>	≤ 30	10
<b>B [ppm]</b>	≤ 8	4
<b>Ca [ppm]</b>	10 ÷ 30	22
<b>Sn [ppm]</b>	≤ 100	90
<b>As [ppm]</b>	≤ 100	61
<b>Sb [ppm]</b>	≤ 30	28
<b>W [ppm]</b>	≤ 200	96
<b>Bi [ppm]</b>	≤ 30	10
<b>Pb [ppm]</b>	≤ 30	11
<b>H [ppm]</b>	≤ 1.5	1.2
<b>O [ppm]</b>	≤ 25	21
<b>N [ppm]</b>	≤ 70	60

### 2.1.2. Product analysis

In order to consider the possible deviations between the heat analysis and the product analysis, the range of the chemical composition applicable to product analysis shall be wider than the one applicable to the heat analysis.

### 2.2. How does Lucchini RS manage “sampling plan for a proper process control”

By applying the classic criteria of the “sampling plan for a proper process control” with a single piece considered representative of the entire lot, a single forged piece will be tested for verification of destructive metallurgical properties.

A forged representative of the heat and of the heat treatment lot will be manufactured with an extension in length of 50 mm, intended for the mechanical and tech tests required.

### 2.3 Mechanical Characteristics

#### 2.3.1 Hardness in a transversal section of the prolongation

To provide the customer with an index of homogeneity of the characteristics of the forged as the thickness decreases as a result of use, Lucchini RS Group introduced the hardness

test in the cross section taken from the prolongation of the forging.

On a transversal section of the prolongation, two lines of hardness shall be made from the outside to the inside.

Each line of hardness shall be composed of 5 locations:

- 1 close to the external surface (Position A);
- 1 close to the inner surface (Position E);
- 1 central half thickness (Position C);
- 1 halfway between position A and C (Position B);
- 1 halfway between position C and Position E.

The values obtained shall be certified for informational purposes only (FOR INFORMATION ONLY = FIO).

For hardness tests in the section, the use of a Brinell HB5/750/15 hardness tester or, alternatively, a EQUOTIP sclerometer is required.

		Basic requirements	Values in this column come from LRS database; they are TYPICAL OBTAINED AVERAGE VALUES, FOR INFORMATION ONLY (FIO). They are not a guarantee of maximum or minimum values					
Brinell test on the forging surface	HB	390 ÷ 430	415					
	HB	FIO	/	A	B	C	D	E
Hardness on a transversal section of the prolongation	HB	FIO	L1	413	405	400	407	412
	HB	FIO	L2	412	404	402	406	410
Tensile test in transversal direction	YS0,2% [MPa]	≥ 1.050	1.120					
	UTS [MPa]	1.250 ÷ 1.400	1.320					
	YS/UTS	FIO	0.85					
	A [%]	≥ 14	15					
	Z [%]	≥ 50	55					
Impact test in transversal direction	Kv RT [J]	≥ 35	46-45-47					
Microstructure	100 magnification 500 magnification	Tempered martensite and bainite	Tempered martensite					
Grain size	ASTM A112	≥ 7	7.5 - 9					



### 2.3.2 Tensile Test

The mechanical tests are performed for each heat and heat treatment batch from the over-length of the forging chosen as representative of the batch.

The test samples are extracted in transversal direction.

The values required for the mechanical characteristics are indicated in previous table (page 4).

The samples must be prepared according to the standard specification UNI EN ISO 6892-1; the standard specimen has a diameter of 10 mm and a useful length (L0) of 50 mm.

### 2.3.3 Impact Test

Three test pieces “V notched” shall be prepared in accordance with the requirements of standard UNI EN ISO 148 - 1.

The required values shall be those detailed in the table on page 4.

### 2.3.4 Microscopic aspects

#### 2.3.4.1 Microstructure

Microstructure at 500x will be documented on one impact test sample.

Microstructure shall be prevalently tempered martensite and bainite as reported for example, in FIGURE 1. Grain size shall be in accordance with ASTM E112, equal or bigger than degree 7.

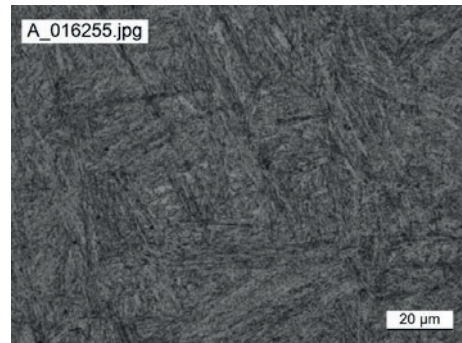


Figure 1. 500X

#### 2.3.4.2 Microscopic Cleanliness: Standard test methods used by Lucchini RS for determining the inclusion content of its steel production

Lucchini RS Group performs a rating of non metallic inclusions on its whole production (each batch).

The rating of non metallic inclusion is made, by Lucchini RS Group, on one impact test specimen of each heat (batch), taken from the product, selected as representative sample.

Specimen, after metallographic preparation of surface, is tested at 100x magnification by an optical microscope. The test shall be carried out in accordance with the following:  
 ✓ ISO 4967 Method “A” (rating of the worst fields, with levels reported in 1/2 increments, like in the ANNEX A of ISO 4967).

The cleanliness is checked to ensure that is in accordance with the value shown in TABLE below.

**INCLUSION CONTENT DETERMINATIONS (according to ISO 4967 Method .A)**

Grade	A (sulfides)		B (aluminas)		C (silicates)		D (oxides)		B + C + D		DS Single globular type	D sulf Circular oxide-sulfide
	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin		
	≤ 1.5	≤ 1.5	≤ 1	≤ 1.5	≤ 1	≤ 1.5	≤ 1	≤ 1.5	≤ 2	≤ 3	≤ 1.5	≤ 1.5

### 2.3.4.3 Microscopic Cleanliness: Standard test methods used by Lucchini RS for determining the inclusion content of its steel production

Lucchini RS Group performs a rating of non metallic inclusions on its whole production (each batch).

The rating of non metallic inclusion is made, by Lucchini RS Group, on one impact test specimen of each heat (batch), taken from the product, selected as representative sample.

Specimen, after metallographic preparation of surface, is tested at 100x magnification by an optical microscope. The test shall be carried out in accordance with the following:

- ✓ ISO 4967 Method "A" (rating of the worst fields, with levels reported in 1/2 increments, like in the ANNEX A of ISO 4967).

The cleanliness is checked to ensure that is in accordance with the value shown in the previous table.

## 3. Ultrasonic examination UT

The UT examination shall be conducted in accordance with ASTM A 388:

- probes used: normal and angled at 45°;
- exam frequency: 2 Mhz;
- surface roughness: 250 μm;
- couplant: oil.

The operator shall have an ASNT SNT-TC-1A or ISO 9712 qualification level II in course of validity.

### Acceptability

- a) examination with flat probes:
  - background echo attenuation: 20% max;
  - indications of a larger entity than those relating to the reference block are not acceptable.
- b) examination with angled probes:
  - indications of a larger entity than those relating to the calibration notch are not acceptable.

### Sensitivity calibration

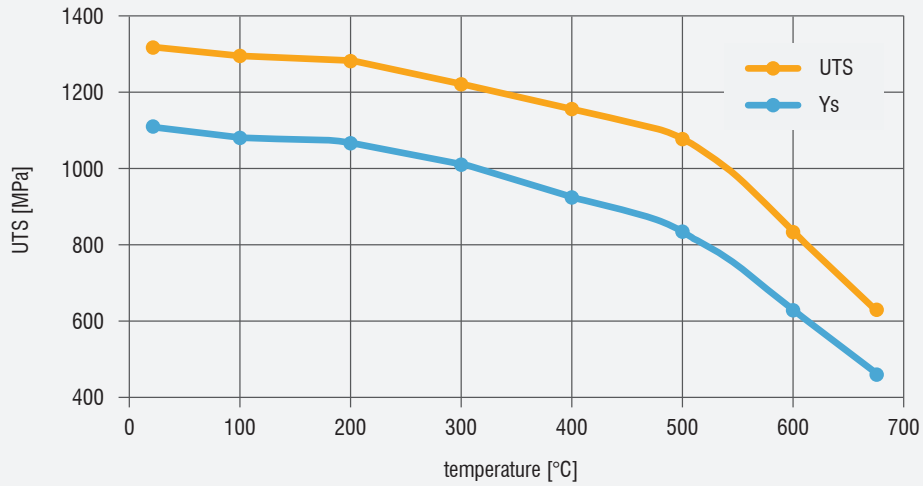
- background echo: 100% screen height;
- reference curve: on a 60 ° "V" notch with a length of 25 mm and a maximum equal depth at 3% of the thickness to be examined;
- reference block: type "V1".

### Physical properties of

Values in this table come from Lucchini RS Group database; they are TYPICAL OBTAINED AVERAGE VALUES, FOR INFORMATION ONLY (FIO). They are not a guarantee of maximum or minimum values; applications specifically suggested herein are made solely for the purpose of illustration to enable the reader to make his own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes.

MECHANICAL CHARACTERISTICS AT HIGH TEMPERATURE	T [°C]	YS [MPa]	UTS [MPa]	E [GPa]
<b>Range: RT ÷ 660°C</b>  Since the melting temperature of Aluminum is around 660°C, it was decided to measure the physical parameters even in this extreme condition.	RT	1.120	1.320	206
	100°C	1.095	1.300	210
	200°C	1.080	1.285	209
	300°C	1.020	1.225	195
	400°C	940	1.160	179
	500°C	840	1.080	166
	600°C	630	825	138
	660°C	495	660	127

**Mechanical Characteristics at High Temperature**



<b>THERMAL CONDUCTIVITY [W/mk]</b>	RT	30.3
	400°C	31.2
	600°C	32.8
<b>THERMAL EXPANSION [10<sup>-6</sup>/k]</b>	20°C ÷ 200°C	11.9
	200°C ÷ 400°C	12.8
	200°C ÷ 600°C	13.9

## 4. Inspection and testing

### 4.1 Subdivision into batches

For inspection and testing, forgings are assembled into batches.

Each batch consists of forgings from the same cast (metallurgical batch), which were heat-treated under the same conditions.

### 4.2 Nature of inspection and tests

A good test and inspection program is defined by Lucchini RS Group, based on written procedures and an accompanying MIP (Manufacturing Inspection Plan), in which defines responsibilities for each test and inspection. At each process step, acceptability criteria are defined,

by referring to the I.T. MET F001 rev. 0 and to the sale agreement.

The inspections and tests laid down will be carried out and supervised by the manufacturer, without the customer being present (no Hold points), because the Company assumes the responsibility for execution and report of all the required tests.

This proposed procedure save time, because hold points potentially introduce production delay. The results of inspections and tests will be communicated to the customer, in suited testing reports.

### 4.3 Final Documentation

At the end of the process, a report must be issued according to EN 10204, type 3.1, which includes:

- final dimensions detected;
- chemical analysis;
- mechanical characteristics;
- hardness measurements;
- result of the structural micrographic test;
- heat treatment cycle;
- result of the UT examination.

NATURE OF INSPECTIONS AND TESTS (description)	
Chemical analysis	Tensile test
Micrographic examinations	Impact tests
Hardness on the surface of the forging	Hardness in a transversal section
Inclusions rating	Ultrasonic examination

### 4.4 Process and materials selection for product recyclability

According to the potential of steel recycling, Lucchini RS Group is adopting a strategy for environmental excellence in designing and manufacturing of its innovative wheels steel grades, putting eco-effectiveness into practice.

The main adopted steps are:

- conducting an environmental assessment on processes and products, with the minimum use of virgin materials and non-renewable forms of energy;
- moving toward zero-waste manufacturing processes, considering that the ultimate destiny of scrapped wheel becomes food for next steel making process, that is the “waste equals food” philosophy;
- conducting a life cycle assessment for each product and process, minimizing the environmental cost of product and service over its entire life cycles, from creation to disposal, that is “Cradle to Cradle” philosophy.

## 5. Reference Standard

Reference	Title
<b>UNI EN ISO 6506-1</b>	Metallic materials – Brinell Hardness Test – Part 1: Test method
<b>ASTM E415</b>	Standard Test Method for Analysis of Carbon and Low-Alloy Steel by Spark Atomic Emission Spectrometry
<b>ISO 14284</b>	Steel and iron. Sampling and preparation of samples for the determination of chemical composition
<b>ISO 4967</b>	Steel – Determination of content of nonmetallic inclusion – micrographic method using standard diagrams
<b>ASTM E112</b>	Standard Test Methods for Determining Average Grain Size
<b>UNI 4227</b>	Metallographic microstructures of iron materials – Definitions
<b>EN 10204</b>	Metallic products: types of inspection documents
<b>ASME B89.7.3.1</b>	Guidelines for decision rules: Considering measurement uncertainty in determining confirmation to specifications
<b>UNI CEI EN ISO/IEC 17025</b>	General requirements for the competence of testing and calibration laboratories' standard

Lucchini RS Group applies the documents mentioned in this table in the latest edition in force.





**Lucchini RS S.p.a.**

Via Giorgio Paglia, 45  
24065 Lovere (BG) - Italy  
Phone +39 035 963566  
info@lucchinirs.com

**Lucchini Industries S.r.l.**

Via Oberdan, 6/A  
25128 Brescia - Italy  
Phone +39 035 963566  
info@lucchinirs.com

**Lucchini Mamé Forge S.p.a.**

Via delle Cave, 1  
25040 Cividate Camuno (BS) - Italy  
Phone +39 0364 347711  
info@lucchinirs.com

**Lucchini Tool Steel S.r.l.**

Via dei Piazzoli, 1  
24040 Suisio (BG) - Italy  
Phone +39 035 4936611  
info@LucchiniToolSteel.com