TALAT
Training in Aluminium Application Technologies

TALAT Lecture 1301

The Rolling of Aluminium: the Process and the Product

24 pages, 29 figures

Basic Level

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Objectives:

- to provide sufficient information on the rolling of aluminium and the characteristics of rolled products to ensure that students, users and potential users can understand the production features that affect properties and economics
- to show how, in consequence, alloy choice for an end application depends not only on the characteristics required for that end use but also on semi-fabrication requirements.

Prerequisites:

- General knowledge in materials engineering
- Some knowledge about aluminium alloy constitution and heat treatment

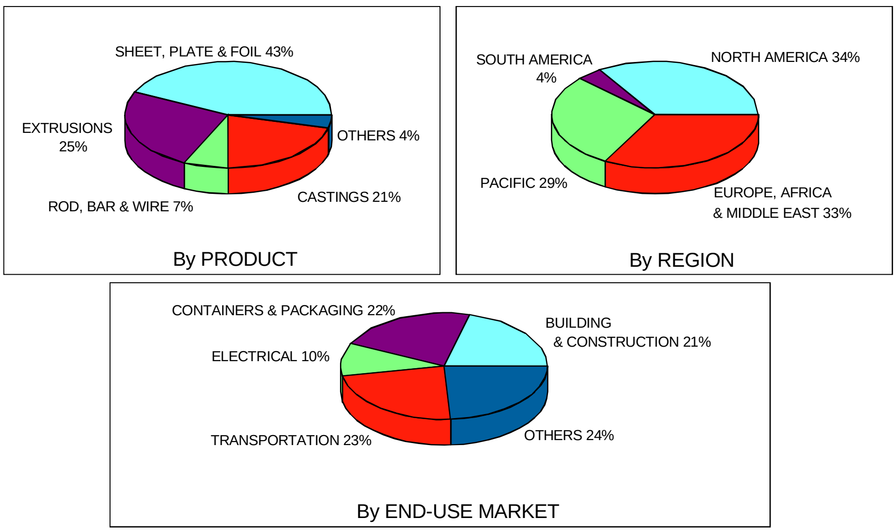
Date of Issue: 1994

1301 The Rolling of Aluminium: the Process and the Product

Table of contents

1301.01 Introduction

Rolled products, i.e. sheet, plate and foil constitute almost 50 % of all aluminium alloys used (see **Figure 1301.01.01**). In North America the packaging industry consumes the majority of the sheet and foil for making beverage cans, foil containers and foil wrapping (**Figure 1301.01.02**). Sheet is also used extensively in building for roofing and siding, in transport for airframes, road and rail vehicles, in marine applications, including offshore platforms, and superstructures and hulls of boats. Also, while relatively little is currently used in the manufacture of high volume production automobiles, it is expected that the next decade will see sheet used for both space frames and body panels, a market that could easily match the 2 million tons now used for beverage cans. Plate is used for airframes, military vehicles and bridges, ships superstructures, cryogenic and chemical vessels and as tooling plate for the production of plastic products. Foil applications outside packaging include electrical equipment, insulation for buildings, lithographic plate and foil for heat exchangers (this lecture deals only with sheet and plate).



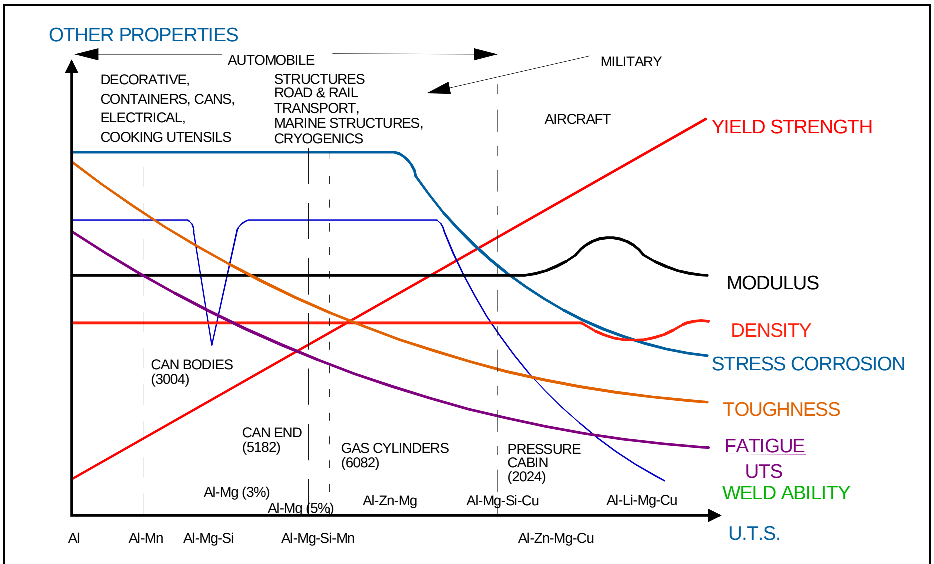
TALAT	Western World Shipments of Aluminium 1991	1301.01.01

This wide range of products demands combinations of properties that span the whole range available from the aluminium alloy portfolio (see also TALAT lecture 1501.05), i.e. high strength, good corrosion resistance, good formability, good machinability, high toughness, good ballistic performance etc. (**Figures 1301.01.03 and 1301.01.04**) Also since in many cases the materials with which the aluminium alloys compete are relatively low cost, for example tin-plate, paper, wood, mild steel and plastics**,** it is essential that the cost of the aluminium products are themselves as low as possible, consistent with the achievement of the required properties. Since the cost of smelting aluminium is unlikely to be further reduced to any degree it is, therefore, essential that semi-fabrication costs are kept to a minimum.

	K TONNES
CANS	2,013
OTHER PACKAGING	361
ROAD VEHICLES	298
RESIDENTIAL SIDING	190
OTHER BUILDING	155
AIR CONDITIONERS / APPLIANCES	140
HOUSEHOLD & FOIL	133
AIRCRAFT PLATE	110
AIRCRAFT SHEET	96
COOKING UTENSILS	50
LITHOGRAPHIC SHEET	50
MOBILE HOMES	35

Source: Aluminum Association

TALAT Training in Aluminium Application Technologies | 1990 Sheet, Plate & Foil Markets by Product Type (N. America) | 1301.01.02

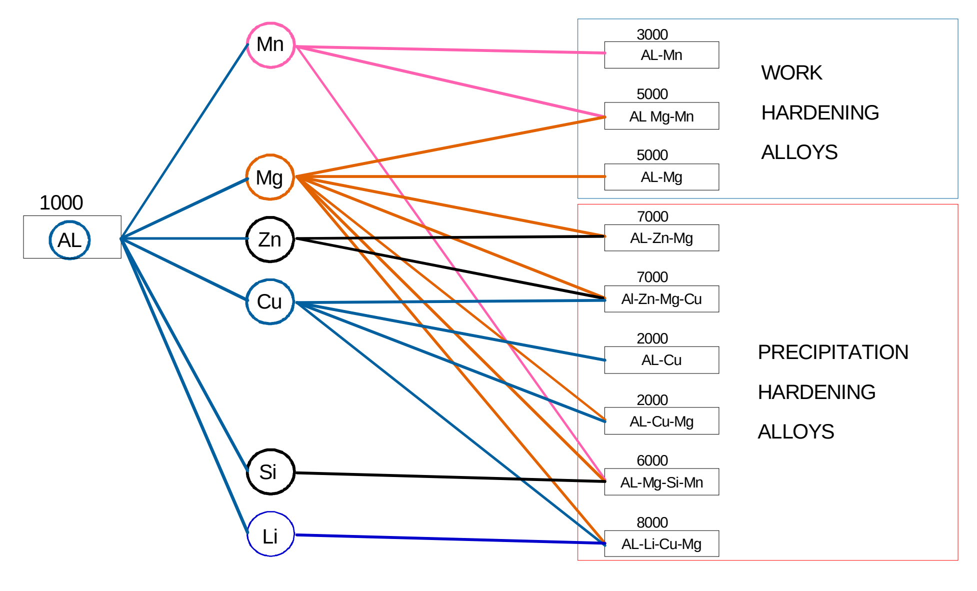


TALAT Training in Aluminium Application Technologies | Range of Properties and Uses of Aluminium Alloys | 1301.01.03

All aluminium alloys can be rolled to sheet but, with a few notable exceptions mentioned below, the ones utilised are from the 1000, 3000 and 5000 series which are work hardening alloys (**Figure 1301.01.05**). However, the 2000, 7000 and 8000 heat treatable alloys are used for airframes, 2000 and 6000 series for automobiles and the 6000 series for some pressure vessels and containers. Examples exist for the use of plate in all alloys while foil is almost all from the 1000 series. **Figure 1301.01.06** shows some typical alloys used for specific end-use applications. (As indicated in other lectures, while there are some 300 different wrought aluminium alloys, probably 80 % of the applications are covered by perhaps 30 alloys).

REQUIRED CHARACTERISTIC	ALLOYING ELEMENT	PRODUCT
LOWER MELTING POINT	Si	BRAZING SHEET, FOIL
INCREASED CONDUCTIVITY	B	CONDUCTOR STRIP
INCREASED ELASTIC MODULUS	Li	AEROSPACE SHEET
DECREASED DENSITY	Li	AEROSPACE SHEET
STRESS CORROSION RESISTANCE	Cr, Zr, Ag	AIRCRAFT SHEET
SACRIFICIAL CORROSION	Zn	HEAT EXCHANGERS CLAD PRODUCTS
VACUUM BRAZING RESPONSE	Mg	HEAT EXCHANGERS
RESPONSE TO CHEMICAL or ELECTROCHEMICAL TREATMENT	Si, Cu, Cr	DECORATIVE APPLICATIONS

TALAT Training in Aluminium Application Technologies | Some Alloying Elements Employed to Give Special Characteristics | 1301.01.04

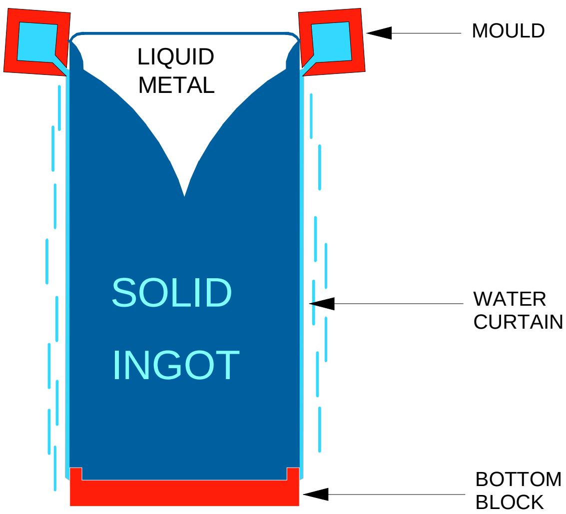


TALAT Training in Aluminium Application Technologies | Main Alloy Types Available as Sheet and Plate | 1301.01.05

ALLOY	APPLICATION
WORK-HARDENING ALLOYS	
1060	CHEMICAL EQUIPMENT, TANKERS.
1100	COOKING UTENSILS, DECORATIVE PANELS.
3003, 3004	CHEMICAL EQUIPMENT, STORAGE TANKS, BEVERAGE CAN BODIES.
5005, 5050 5052, 5657	AUTOMOTIVE TRIM, ARCHITECTURAL APPLICATIONS.
5085, 5086	MARINE STRUCTURES, STORAGE TANKS, RAIL CARS.
5454, 5456	PRESSURE VESSELS, ARMOUR PLATE.
5182, 5356	CYROGENIC TANKS, BEVERAGE CAN ENDS.
HEAT TREATABLE ALLOYS	
2219	HIGH TEMPERATURE (eg high speed aircraft).
2014, 2024	AIRFRAMES, AUTOBODY SHEET.
6061, 6063 6082, 6351 6009, 6010	MARINE STRUCTURES, HEAVY ROAD TRANSPORT, RAIL CARS, AUTOBODY SHEET.
7004, 7005 7019, 7039	MISSILES, ARMOUR PLATE, MILITARY BRIDGES.
7075, 7079, 7050, 7010, 7150	AIRFRAMES, TOOLING PLATE.

TALAT Training in Aluminium Application Technologies | Typical Applications of some Aluminium Sheet & Plate Alloys | 1301.01.06

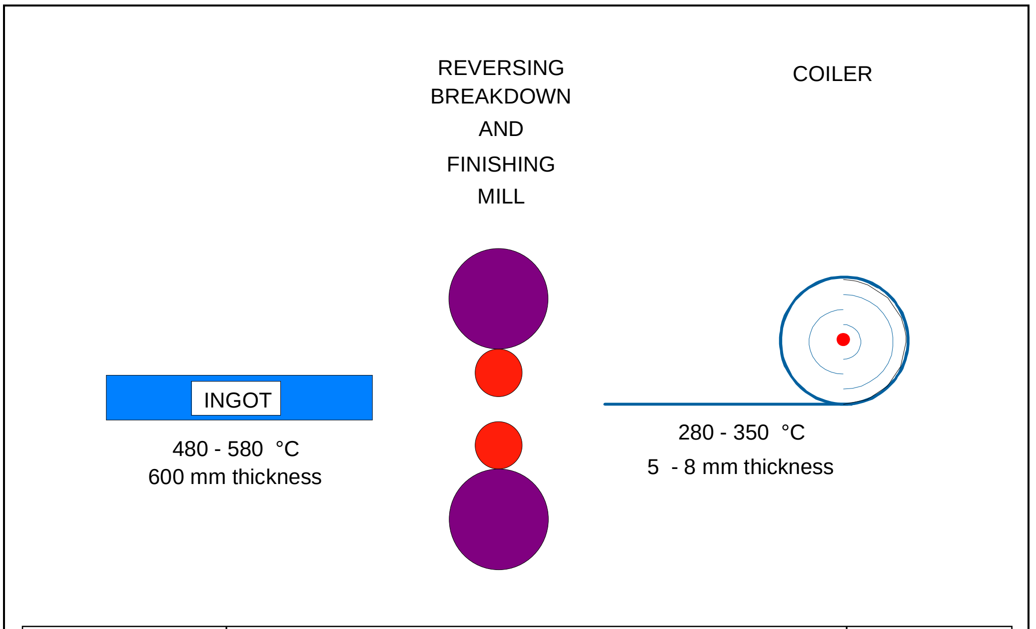
The starting stock for most rolled products is the DC (Direct Chill semi-continuous cast) ingot (see **Figure 1301.01.07**). The size of the ingot depends on the size of the DC unit available, the hot rolling mill capacity, volume required for a particular end use and to some extent the alloys being cast. Ingots up to over 20 tons in weight, 500 - 600 mm thick, 2000 mm wide and 8000 mm long are produced.



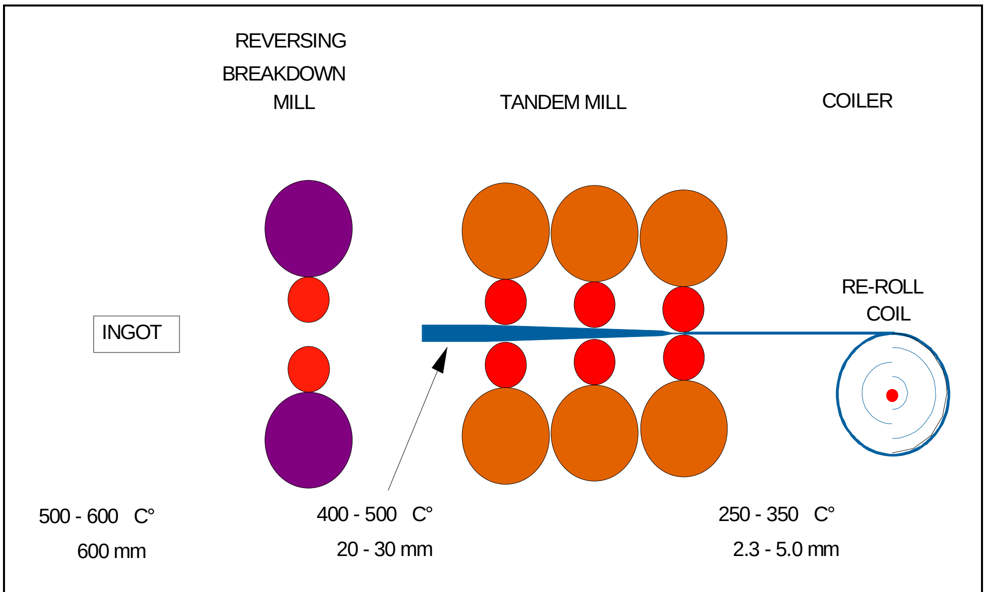
TALAT Training in Aluminium Application Technologies | D.C. Casting | 1301.01.07

1301.02 Sheet Products

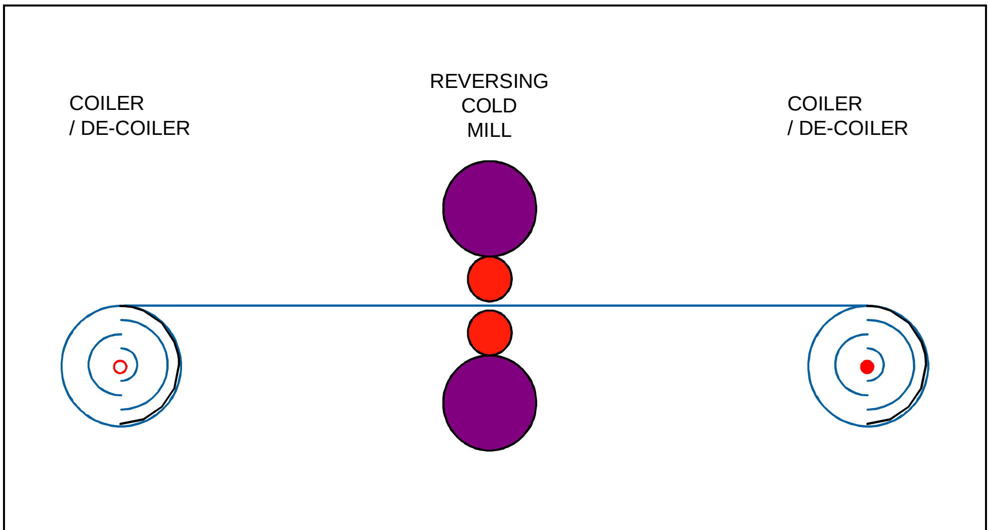
The DC ingot is usually cooled after casting to room temperature and then re-heated to around 500 °C prior to successive passes through a hot rolling mill where it is reduced in thickness to about 4 - 6 mm (**Figures 1301.02.01 and 1301.02.02**). The temperature of pre-heat of the ingot and the time held at that temperature is important for some alloys since a process of homogenisation takes place which renders the material in the best condition for rolling and the achievement of subsequent properties. The strip from the hot rolling mill is coiled for transport to the cold mill which might be on the same site or elsewhere. Cold mills, in a wide range of types and sizes are available; some are single stand, others 3 stand and some 5 stand (**Figures 1301.02.03 and 1301.02.04**). Cold rolling speeds vary but modern mills operate at exit speeds as high as 3000 m per minute. A modern complex including melting furnaces, DC casting facilities, pre-heat furnaces, hot mill, cold mill and annealing furnaces involves a very large capital investment which can only be fully justified on financial grounds if a big market is assured. Obviously, if such facilities are not fully utilised the economic viability is threatened. As indicated above, however, hot mill coil can be obtained for further reduction in cold mills of lower capacity/speed/ complexity.



TALAT Single Stand Hot Mill 1301.02.01

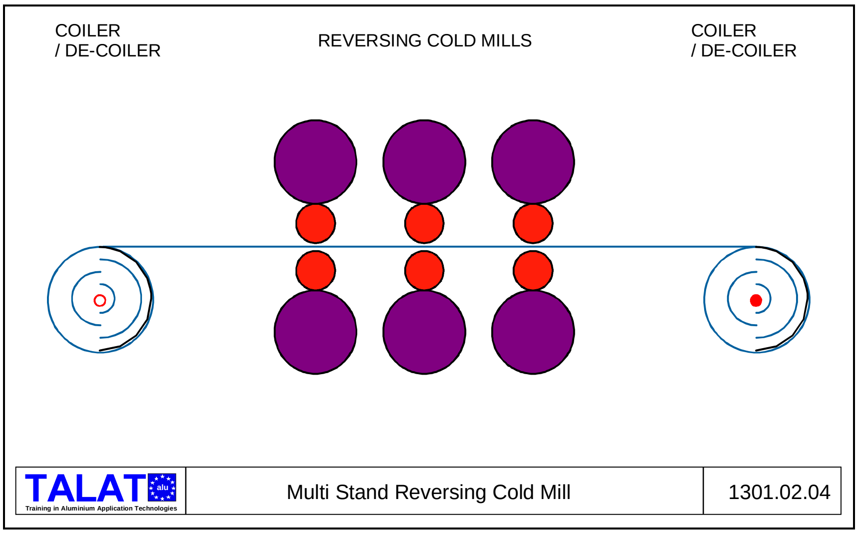


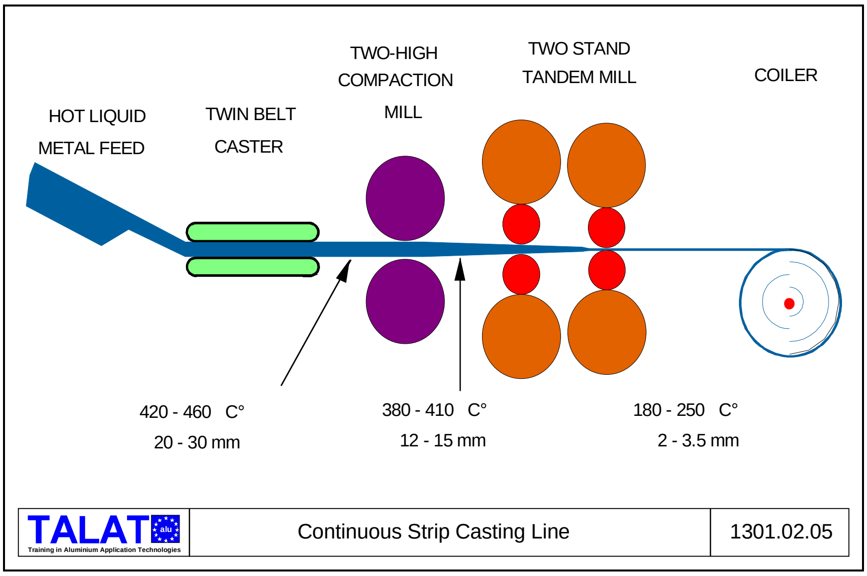
TALAT Training in Aluminium Application Technologies | Conventional Breakdown Mill / Hot Tandem Mill Operation | 1301.02.02



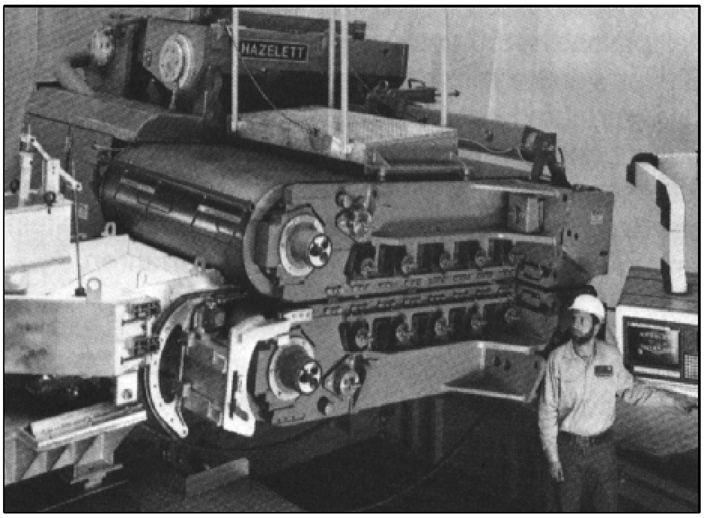
TALAT Training in Aluminium Application Technologies | Single Stand Reversing Cold Mill | 1301.02.03

Although most sheet is produced by conventional hot mills, some considerable effort has been made by aluminium producers in the United States, Canada and Europe to reduce both the capital and production costs by the development of continuous strip casting methods (**Figure 1301.02.05**) whereby hot metal is poured into some form of strip caster, thus eliminating the DC casting and hot break-down mills (**Figure 1301.02.06**). To date, however, only a limited range of alloy compositions can be produced in this way with end uses found mainly in foil and building sheet.





Final sheet properties for the work hardening alloys in the 1000, 3000 and 5000 series are achieved either by temper rolling or temper annealing. In the former case the strip is reduced by a fixed amount of cold work to achieve the required temper, in the latter it is rolled to a hard temper and then back annealed to achieve the required strength. While a given set of mechanical properties, eg proof stress, tensile strength and elongation can be achieved by both routes, other characteristics, particularly formability, can be influenced by the particular production route chosen. When 2000, 6000 and 8000 sheet is needed the cold mill strip is sometimes continuously heat treated to achieve optimum economics, but the cost of such equipment is high and when relatively small volumes are needed the sheet is either heat treated individually or in coils. Continuous heat treatment lines include tension levellers which ensure that the distortion created by water quenching is removed. For individual sheets stretching is necessary to achieve the required flatness.

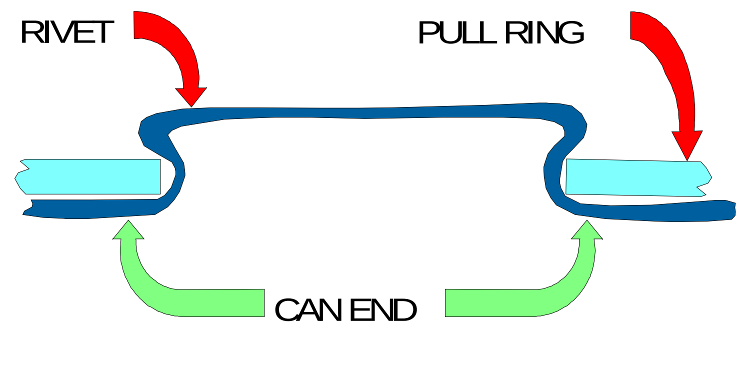


TALAT | Hazelett Twin Belt Slab Caster | 1301.02.06

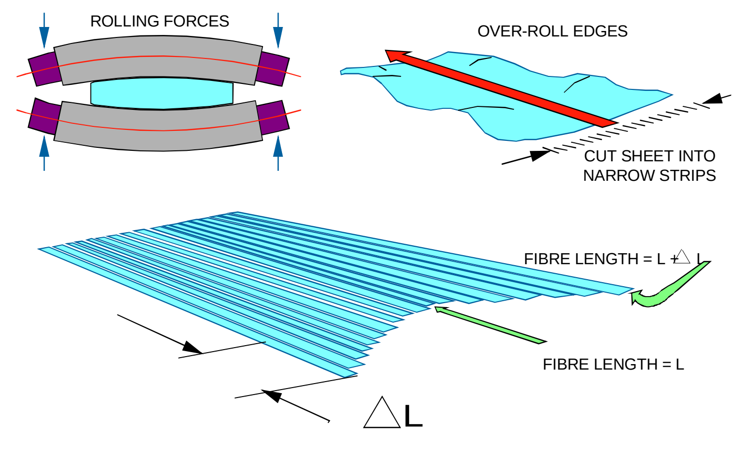
ALLOY-TEMPER	USE	COMPOSITION (wt %) MAXIMUM UNLESS SHOWN AS A RANGE					LONGITUDINAL MECHANICAL PROPERTIES		
		Cu	Fe	Mg	Mn	Si	UTS (ksi)	0.2% YS (ksi)	ELONG. (%)
3004 - H19	CAN BODY	0.25	0.70	0.8-1.3	1.0-1.5	0.30	43	41	2.0
5182-H28	CAN END	0.15	0.35	4.0-5.0	0.2-0.5	0.20	55	49	7.0
5042-H19	TAB	0.15	0.35	3.0-4.0	0.2-0.5	0.20	50	47	5.0

TALAT | Composition and Properties of Aluminium Alloys used in Can Making | 1301.02.07

In the past 20 years much effort has been made by the aluminium industry and mill producers to ensure that cold rolled products have the specific characteristics required for satisfactory end use and that they can compete from a cost point of view with competitor materials. Properties such as strength, formability, toughness and corrosion resistance are controlled in the main by alloy choice, rolling deformation schedule and thermal treatments, before, during and after rolling. Perhaps the best example is the development of the alloys used for beer can ends, bodies and tear-off tabs (**Figures 1301.02.07** and **1301.02.08**). The match of formability, strength, resistance to scoring, tearing ability and not least cost have been achieved by careful control of the parameters outlined above. However, other requirements such as surface finish, flatness and gauge uniformity have been achieved by careful attention to the mechanics and chemistry of the rolling process. The control of surface finish in sheet products is essential, particularly in applications where surface defects mar appearance, but also in those cases where the surface of the sheet influences subsequent forming operations by affecting lubricant retention and pick-up on dies. This has been shown to be very important in the production of beverage cans and will play an increasing role in the manufacture of auto-body parts. In hot rolling a knowledge of the influence of the starting stock surface condition, surface condition of the rolls and lubrication used has been necessary, as have the effect of corresponding parameters in the cold mill with the full understanding of the effect of roll coatings, arcs of contact etc achieved by very detailed study.

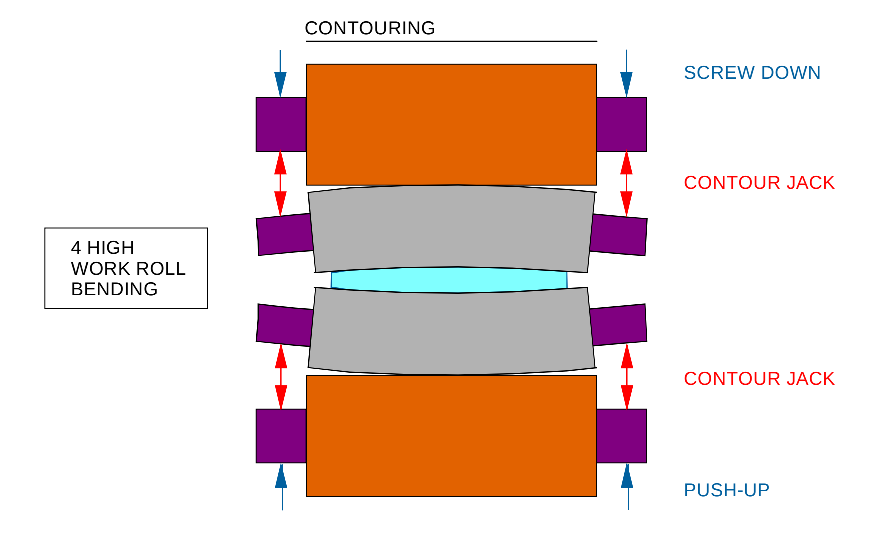


TALAT | Example of Extensive Forming Required to Produce Beverage Can Easy-Opening End | 1301.02.08

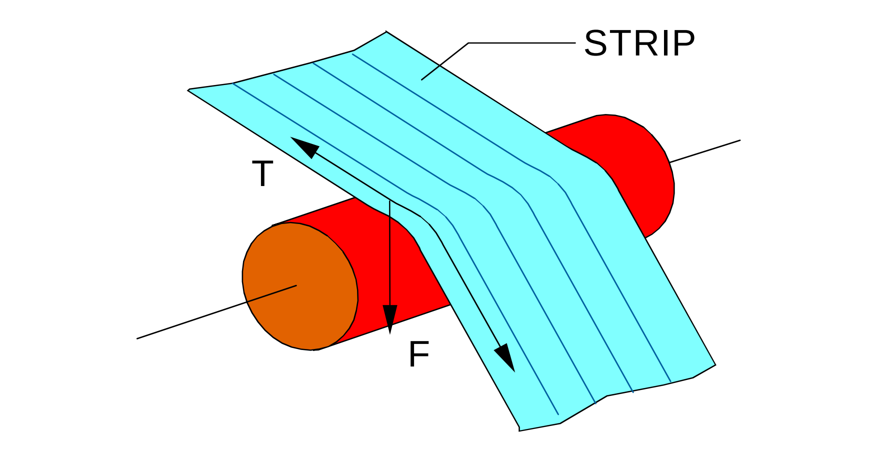


TALAT | One Way in which Rolling Produces Bad Shape Sheet | 1301.02.09

When sheet is rolled its final flatness depends on a number of characteristics of the starting stock and of mill features. If bad shape results during rolling, ie some parts of the strip are longer than others, buckling occurs and this, in many cases, can be removed by tension levelling whereby the strip is stretched sufficiently so that short parts are extended to the point where they have the same length of the long parts and the out of shape disappears (**Figure 1301.02.09**). However, attention to the cross section shape of the in-going product, i.e. DC slab or hot mill coil, can greatly improve the final shape. Also a most powerful tool is the control of the cold roll contour. This can be achieved by bending the rolls by means of jacks so that parts of the roll that want to roll long strip are adjusted and by alteration of the distribution of the rolling lubricant so that hot parts of the roll that would roll long are cooled (**Figure 1301.02.10**)

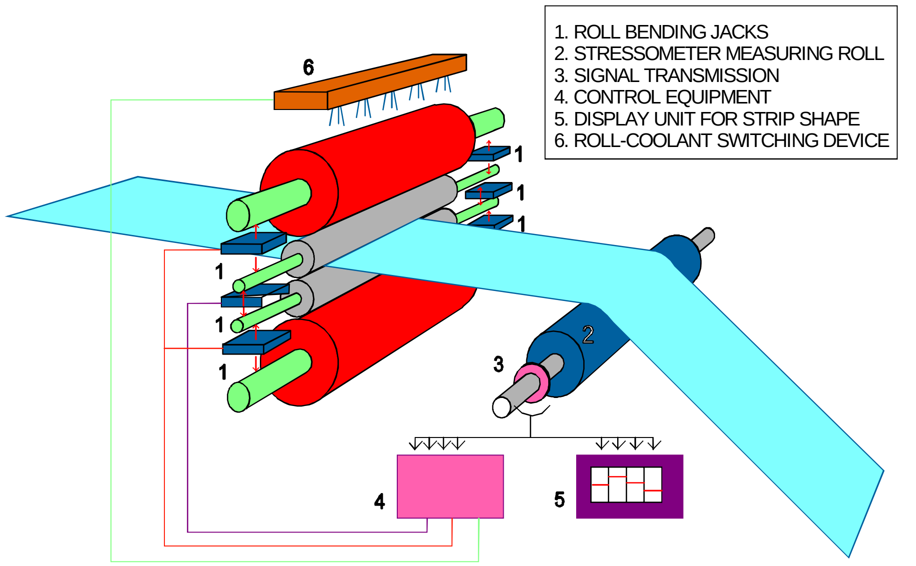


TALAT | One Method of Use of Jacks for Roll Bending | 1301.02.10

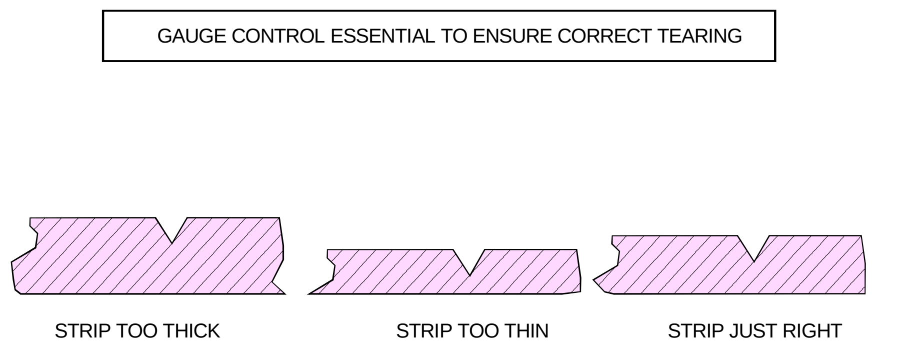


TALAT | Shape Measurement | 1301.02.11

Obviously, the mill cannot make these adjustments itself and it is necessary to measure the shape of the outgoing strip and then instruct the mill controls. It is impossible to judge the shape by slacking off the outgoing tension since this would grossly interfere with production schedules and result in considerable scrap. In consequence, methods have been devised whereby the actual shape of the outgoing strip, which, because it is under tension, can look flat, is assessed by measuring the residual stress in the strip - long parts have low stresses. Various methods have been developed (**Figure 1301.02.11**). The signal from the shape metre is fed to the mill control jacks and lubricant sprays and rapid adjustment achieved (**Figure 1301.02.12**). In many modern installations concerned with the high volume production, for instance in the canning industry, the very stringent flatness requirements are achieved by combinations of mill control and by the use of tension levellers. Gauge control is achieved in much the same way as flatness, i.e. by continuously measuring outgoing strip thickness and adjusting the roll bite accordingly. Without such control it would not be possible to produce easy-opening can-ends! (**Figure 1301.02.13**).



TALAT Training in Aluminium Application Technologies | Automatic Flatness Control System | 1301.02.12



TALAT Training in Aluminium Application Technologies | Score Line in Can Ends | 1301.02.13

1301.03 Plate

While perhaps 80 % of all sheet used is made from the 3000 and 5000 work hardening series alloys, plate, as indicated earlier, is drawn from the whole range with civil aircraft and military applications demanding the strong, heat treatable 2000, 7000 and 8000 series. All plate is produced by the DC casting/hot rolling route and while surface finish is important in some cases, the final product is often surface machined. Of great importance, however, in addition to strength are properties such as toughness, stress corrosion resistance, machinability and fatigue strength. These are achieved by careful control of alloying elements and by special thermal treatments. In this latter context it is important to note that in all cases, with the exception of the aluminium-zinc-magnesium alloys, a rapid quenching rate is needed to produce high mechanical strengths. In sheet products quenching usually results in distortion which can be seen and removed. In plate the rigidity of the product is sufficient to avoid distortion but very high residual stresses can result which, if not removed, can either adversely effect the product performance in service or cause distortion when the plate is machined. Control stretching removes this residual stress but it involves presses with load capacity of say 5000 tonnes thus adding to production costs.

1301.04 Properties of Rolled Products

Typical mechanical, physical, chemical and fabrication properties and characteristics of a range of rolled aluminium alloys, tempers and heat treatments are given in the following tables extracted from the aluminium databank ALUSELECT (**Figures 1301.04.01 till Figure 1301.04.09**). Note that these data are not guaranteed minimum properties, but have been harmonized between the various European aluminium producers and pertain also to other types of wrought products as indicated. There are in addition a great number of specialty sheet and plate alloys which are being produced for specific applications, e.g. carbody sheet metal parts. These alloys have characteristics to suit special demands such as formability. Full details can be provided by the metal producers.

To select the right alloy for a specific application is often a difficult task. Useful hints may be obtained from several other lectures within the TALAT series, e.g. **Lecture 1501** and **Lecture 1502** as well as from further information and application examples in ALUSELECT. For the selection of minimum guaranteed property values of rolled products for design and ordering purposes reference is made to the new European standards EN 485.

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
H2	85	100	60	12		30	30	
H4	105	115	70	10	9	35	36	70
H6	120	130	80	7		39		
H8	140	150	85	6	5	43	44	100
H9	170	180			3	48	51	
O	35	80	50	42	38	21	20	50

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
H2	2700	23.5	899	658	645	59.5	29.0	229.0
H4	2700	23.5	899	658	645	59.5	29.0	229.0
H6	2700	23.5	899	658	645	59.5	29.0	229.0
H8	2700	23.5	899	658	645	59.5	29.0	229.0
H9	2700	23.5	899	658	645			
O	2700	23.5	899	658	645	59.5	29.0	229.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	69000	25900	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
H2	6	6	5	6	6	6	6	6
H4	6	6	5	6	6	6	6	6
H6	6	6	5	6	6	6	6	6
H8	6	6	5	6	6	6	6	6
H9	6	6	5	6	6	6	6	
O	6	6	5	6	6	6	6	6

Anodising (2-7)

Temper	Bright	Colour	Hard	Protective
All	6	6	6	6

COLD FORMABILITY, MACHINABILITY, WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG/TIG	Spot Seam	Brazability	Solderability
H2	6				3	6	6	6	5	6	6
H4	6	5	5	6	4	6	6	6	5	6	6
H6	5				4	6	6	6	5	6	6
H8	4	4	3	4	4	6	6	6	5	6	6
H9						6	6	6		6	6
O	7	7	7	7	3	6	6	6	4	6	6

PRODUCT FORMS

Bar Foil Profile Section Shape Rod Slugs Impacts Sheet Tube Wire

Printed from: ALUSELECT Databank

TALAT alu – Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium 1050	1301.04.01

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
O	75	185	125	20	20	55	60	180
T3	340	475	290	18	18	120	125	280
T4	330	460	285	20	20	120	125	280
T8	450	485	300		6	130	140	250

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
O	2790	23.1	874	640	500	50.5	34.0	193.0
T3	2790	23.1	874	640	500	30.0	57.0	121.0
T4	2790	23.1	874	640	500	30.0	57.0	121.0
T8	2790	23.1	874	640	500	38.5	45.0	151.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	73000	27400	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
O	3	4	3	4				4
T3	3	4	3	4				4
T4	3	4	3	4				4
T8	3	4	3	4				5

Anodising (2-7)

Temper	Bright	Colour	Hard	Protective
All	3	3	5	4

COLD FORMABILITY, MACHINABILITY, WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG /TIG	Spot Seam	Brazability	Solderability
O	5	5		5	3	5	2	3	5	4	4
T3	3				6	5	2	3	5	4	4
T4	4	4		3	5	5	2	3	5	4	4
T8	3				6	5	2	3	5	4	4

PRODUCT FORMS

Bar Forging Profile Section Shape Plate Sheet Tube Wire

Printed from: ALUSELECT Databank

TALAT alu – Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 2024	1301.04.02

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
H2	115	135	80	11	11	40	40	
H4	140	155	90	9	9	45	46	130
H6	160	175	100	8	6	50	50	
H8	180	200	110	6	6	55	55	150
H9	210	240	125	4	3	65	70	
O	45	105	70	29	25	29	29	100

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
H2	2730	23.1	892	655	640	42.0	41.0	160.0
H4	2730	23.1	892	655	640	42.0	41.0	160.0
H6	2730	23.1	892	655	640	42.0	41.0	160.0
H8	2730	23.1	892	655	640	42.0	41.0	160.0
H9	2730	23.1	892	655	640	42.0	41.0	160.0
O	2730	23.1	892	655	640	50.5	34.0	190.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	69500	26100	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
H2	6	6	5	6	6	6	6	6
H4	6	6	5	6	6	6	6	6
H6	6	6	5	6	6	6	6	6
H8	6	6	5	6	6	6	6	6
H9	6	6	5	6	6	6	6	6
O	6	6	5	6	6	6	6	6

Temper	Anodising (2-7) Bright	Colour	Hard	Protective
All	4	5	5	5

COLD FORMABILITY, MACHINABILITY, WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG/TIG	Spot Seam	Brazability	Solderability
H2						6	6	6		6	6
H4	5	5		4	4	6	6	6	5	6	6
H6						6	6	6		6	6
H8	4	4	3	3	4	6	6	6	5	6	6
H9						6	6	6		6	6
O	6	6	6	6	3	6	6	6	4	6	6

PRODUCT FORMS

Bar Foil Profile Section Shape Rod Slugs Impacts Sheet Tube Wire

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TALAT Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 3103	1301.04.03

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
H2	125	145	85	13	13	45	46	
H4	145	165	95	12	11	50	50	
H6	165	185	105	9	8	55	55	
H8	185	205	115	8	7	60	60	
H9	210	225	125	5	4	65	70	
O	45	120	80	27		32	32	

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
H2	2700	23.5	899	655	630	52.0	33.0	201.0
H4	2700	23.5	899	655	630	52.0	33.0	201.0
H6	2700	23.5	899	655	630	52.0	33.0	201.0
H8	2700	23.5	899	655	630	52.0	33.0	201.0
H9	2700	23.5	899	655	630	52.0	33.0	201.0
O	2700	23.5	899	655	630	52.0	33.0	201.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	69500	26100	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7): General	Industrial	Marine	Rural	Local Corrosion (2-7): Exfoliation	Intercrystalline	Pitting	Stress Corrosion
H2	6	6	5	6	6	6		6
H4	6	6	5	6	6	6	5	6
H6	6	6	5	6	6	6	5	6
H8	6	6	5	6	6	6	5	6
H9	6	6	5	6	6	6		
O	6	6	5	6	6	6	5	6

Temper	Anodising (2-7): Bright	Colour	Hard	Protective
All	6	6	6	6

COLD FORMABILITY, MACHINABILITY, WELDABILITY

Temper	Cold Formability (2-7): General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7): Electron beam	Oxy-gas	MIG/TIG	Spot Seam	Brazability	Solderability
H2	6				3	6	5	6	6	4	5
H4	5	5	4	4	4	6	5	6	6	4	5
H6	4	4			4	6	5	6	6	4	5
H8	4	4	3	4	4	6	5	6	6	4	5
H9						6	5	6		4	5
O	6	6	6	6	3	6	5	6	5	4	5

PRODUCT FORMS

Bar Profile Section Shape Plate Sheet Tube Wire

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TALAT Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 5005	1301.04.04

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
H2	165	210	125	14	14	60	65	
H4	190	230	135	13	12	65	70	230
H6	215	255	145	9	8	70	75	
H8	240	280	155	8	7	80	80	250
H9	270	310	165	5	4	90	90	
O	80	180	115	26	25	45	46	200

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
H2	2690	23.6	898	650	605	37.5	46.0	149.0
H4	2690	23.6	898	650	605	37.5	46.0	149.0
H6	2690	23.6	898	650	605	37.5	46.0	149.0
H8	2690	23.6	898	650	605	37.5	46.0	149.0
H9	2690	23.6	898	650	605			
O	2690	23.6	898	650	605	37.5	46.0	149.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	70000	26300	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
H2	6	6	6	6	6	6	6	6
H4	6	6	6	6	6	6	6	6
H6	6	6	6	6	6	6	6	
H8	6	6	6	6	6	6	6	6
H9	6	6	6	6	6	6		
O	6	6	6	6	6	6	6	6

Temper	Anodising (2-7) Bright	Colour	Hard	Protective
All	5	5	6	6

COLD FORMABILITY, MACHINABILITY,WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG /TIG	Spot Seam	Brazability	Solderability
H2	5			4	4	6	5	6		4	4
H4	5	5		4	4	6	5	6		4	4
H6	4				5	6	5	6	6	4	4
H8	4	3		3		6	5	6		4	4
H9						6	5	6		4	4
O	6	6		5	3	6	5	6	5	4	4

PRODUCT FORMS

Bar Profile Section Shape Plate Sheet Tube

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TALAT Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 5251	1301.04.05

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
H2	185	245	150	15	14	70	75	
H4	215	270	160	14	12	75	80	250
H6	245	290	170	10	9	80	85	
H8	270	315	180	9	8	90	90	280
H9	300	340	190	5	4	95	100	
O	100	215	140	25	24	55	55	220

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
H2	2680	23.7	897	645	595	32.5	53.0	132.0
H4	2680	23.7	897	645	595	32.5	53.0	132.0
H6	2680	23.7	897	645	595	32.5	53.0	132.0
H8	2680	23.7	897	645	595	32.5	53.0	132.0
H9	2680	23.7	897	645	595			
O	2680	23.7	897	645	595	32.5	53.0	132.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	70500	26500	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
H2	6	6	6	6	6	5	6	5
H4	6	6	6	6	6	5	6	4
H6	6	6	6	6	6	5	6	5
H8	6	6	6	6	6	5	6	5
H9	6	6	6	6	6	5	6	4
O	6	6	6	6	6	5	6	6

Temper	Anodising (2-7) Bright	Colour	Hard	Protective
All	4	5	6	6

COLD FORMABILITY, MACHINABILITY,WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG /TIG	Spot Seam	Brazability	Solderability
H2	5	4		4	4	6	4	6	6	3	3
H4	4	4	4	4	5	6	4	6	6	3	3
H6	4				5	6	4	6	6	3	3
H8	3	3		3	5	6	4	6	6	3	3
H9	3				5	6	4	6	6	3	3
O	5	5	5	5	4	6	4	6	5	3	3

PRODUCT FORMS

Bar Profile Section Shape Plate Sheet Tube Wire

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TALAT Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 5754	1301.04.06

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
H2	240	330	185	17	16	90	95	280
H4	275	360	200	16	14	100	105	280
H6	305	380	210	10	9	105	110	
H8	335	400	220	9	8	110	115	
H9	370	420	230	5	5	115	120	
O	145	300	175	23	22	70	75	250

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
H2	2660	23.8	899	640	580	28.5	60.0	117.0
H4	2660	23.8	899	640	580	28.5	60.0	117.0
H6	2660	23.8	899	640	580	28.5	60.0	117.0
H8	2660	23.8	899	640	580	28.5	60.0	117.0
H9	2660	23.8	899	640	580			
O	2660	23.8	899	640	580	28.5	60.0	117.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	71000	26800	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
H2	6	6	6	6	6	5	6	5
H4	6	6	6	6	6	5	6	4
H6	6	6	6	6	6	5	6	5
H8	6	6	6	6	6	5	6	5
H9	6	6	6	6	6	5	6	4
O	6	6	6	6	6	5	6	6

Temper	Anodising (2-7) Bright	Colour	Hard	Protective
All	4	5	6	6

COLD FORMABILITY, MACHINABILITY, WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG /TIG	Spot Seam	Brazability	Solderability
H2	5	4		4	4	6	4	6	6	3	3
H4	4	4	4	4	5	6	4	6	6	3	3
H6	4				5	6	4	6	6	3	3
H8	3	3		3	5	6	4	6	6	3	3
H9	3				5	6	4	6	6	3	3
O	5	5	5	5	4	6	4	6	5	3	3

PRODUCT FORMS

Bar Profile Section Shape Plate Sheet Tube Wire

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TALAT Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 5083	1301.04.07

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
O	60	130	85	27	26	35	35	120
T1	170	260	155	24	24	70	75	200
T4	170	260	170	19	19	70	75	200
T5	275	325	195	11	11	90	95	210
T6	310	340	210	11	11	95	100	210

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
O	2710	23.1	894	650	575	55.5	31.0	216.0
T1	2710	23.1	894	650	575			
T4	2710	23.1	894	650	575	42.0	41.0	167.0
T5	2710	23.1	894	650	575			
T6	2710	23.1	894	650	575	44.0	39.0	172.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	70000	26400	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
O	5	5	5	6	5	5	5	6
T1	5	5	5	6	5	5	5	5
T4	5	5	5	6	5	5	5	5
T5	5	5	5	6	5	5	5	6
T6	5	5	5	6	5	5	5	6

Temper	Anodising (2-7) Bright	Colour	Hard	Protective
All	4	5	5	6

COLD FORMABILITY, MACHINABILITY, WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG/TIG	Spot Seam	Brazability	Solderability
O	5	5	5	5	3	5	5	6	4	5	5
T1	4				5	5	5	6		5	5
T4	4	4		4	5	5	5	6	5	5	5
T5	4	4	3	3	5	5	5	6	5	5	5
T6	4	4	3	3	5	5	5	6	5	5	5

PRODUCT FORMS

Bar Forging Profile Section Shape Plate Slugs Impacts Sheet Tube

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TALAT Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 6082	1301.04.08

TYPICAL MECHANICAL PROPERTIES

Temper	Proof Stress 0.2% (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)	Elongation A5 (%)	Elongation A50 (%)	Hardness Brinell HB	Hardness Vickers HV	Fatigue Endur. Limit (MPa)
O	105	225	150		17	60	65	230
T6	505	570	350	10	10	150	160	300
T7	435	505	305	13	12	140	150	300

PHYSICAL AND ELASTIC PROPERTIES

Temper	Density kg/m^3	Coeffic. Thermal Expans. µm/m/K	Spec. Heat Cp J/kgK	Melting Point Liquidus (°C)	Melting Point Solidus (°C)	Electr. Conductivity (%IACS)	Electr. Resistivity (nohmm)	Thermal Conductivity (W/mK)
O	2810	23.5	862	635	475	45.5	38.0	175.0
T6	2810	23.5	862	635	475	33.0	52.0	134.0
T7	2810	23.5	862	635	475	39.5	43.5	155.0

Temper	Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)	Poisson's Ratio
All	72000	27100	0.330

CORROSION AND ANODISING PROPERTIES

Temper	Atmospheric Corrosion (2-7) General	Industrial	Marine	Rural	Local Corrosion (2-7) Exfoliation	Intercrystalline	Pitting	Stress Corrosion
O	3	3	3	4		4	4	
T6	3	3	3	4	3	4	4	4
T7	3	3	3	4	4	4	4	5

Temper	Anodising (2-7) Bright	Colour	Hard	Protective
All	3	3	4	5

COLD FORMABILITY, MACHINABILITY, WELDABILITY

Temper	Cold Formability (2-7) General	Deep Drawing	Stretch forming	Spinning	Machinability	Weldability (2-7) Electron beam	Oxy-gas	MIG/TIG	Spot Seam	Brazability	Solderability
O	5	3		3	4	5	3	3	5	3	3
T6	3	2	3	2	6	5	3	3	5	3	3
T7	3	2		2	6	5	3	3	5	3	3

PRODUCT FORMS

Bar Forging Profile Section Shape Plate Rod Slugs Impacts Sheet

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TALAT – Training in Aluminium Application Technologies	Harmonised Property Data for Aluminium Alloy 7075	1301.04.09

1301.05 Literature

Aluminium Federation Ltd., U.K., Properties of Aluminium

Aluminium Taschenbuch, Edition 1984, Aluminium Verlag, Düsseldorf

ALUSELECT, European Aluminium Association, Brussels. Databank for aluminium alloys, properties, applications and standards. Edition 1990

Broner Engineering, Product overview. (Mill control systems for the metals industry). 1991

EN 485 Parts 1 - 4, Aluminium and aluminium alloys, Strip, sheet and plate products, edition 1994

Hatch, J.E.: Aluminium Properties and Physikal Metallurgy, American Siciety for Metals, ASM, Metals Park, Ohio, 1984

McDonald, I.R.: Shape control - the modern approach. Review of three decades of controlling rolling variables to ensure that the final product is to the dimensions required. Aluminium Today, May 1991, pp. 34, 40

Nardini, D., Calderbank, I.G., Waterson, K.: A critical review of the finite element modelling requirements for flat rolling. Presented at Institute of Metals Conference on Mathematical Models for Metals and Materials Applications, 12-14 October, 1987, Sutton Coldfield.

Nussbaum, A.I.: Flat rolled process technology for the nineties from molten aluminium to finished sheet (Review). Light Met. Age, April 1991, pp. 8-83

Ostermann, F.: Aluminium materials technology for automobile construction. Mechanical Engineering Publications Ltd., London, 1993

1301.06 List of Figures