Hot and cold rolling technology in the production of aluminium rods

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Coils made in North America

Hot and cold rolling technology in the production of aluminium rods: it seems like the story of Properzi, when retracing the history of Properzi – from its beginnings with the very first continuous castings for the production of wire rod for electrical use, to the present day where sophisticated aluminium alloys are produced with hardness that is 4-5 times higher than that initially produced for electrical use.

Let's begin by defining 'Hot and cold rolling technology'. In metal working, rolling is a forming process in which metal stock, in our case continuous bar, is passed through a series of stands (two and three rolling rolls) to reduce the dimension (in our case diameters) and to make the final product (in the case of aluminium the standard is 9.53 mm). The concept is similar to the rolling of dough. Rolling is classified according to the temperature of the metal rolled. If the temperature of the metal is above its recrystallization temperature, then the process is known as hot rolling. If the temperature of the metal is below its recrystallization temperature, the process is known as cold rolling. In terms of usage, hot rolling processes more tonnage than any other manufacturing process, while cold rolling processes all varieties of final products.

Hot rolling technology

During the 1970s, when the era of Properzi continuous casting in aluminium began, the purpose of the plant was to produce a bar through the continuous wheel casting (initially U-shaped and then over time trapezoidal) and then process it utilizing a rolling mill with the aim to produce 9.53 mm wire rod. At that time, the priority was the electrical conductivity of the wire rod and therefore production was concentrated on 1xxx alloys for electrical use with 99.5% purity.

Within twenty years, all the producers of aluminium electric cables equipped themselves for the production of wire rod with these 'new generation' systems, revolutionizing the production system by giving priority to the quantity of product, initially ignoring the mechanical characteristics.

During this time, the competition from Properzi customers around the world was not only limited to the production of the 'hot rolling process' (the continuous bar always had a temperature above 430 °C) but it began to require ever more stringent tensile and elongation values depending on the final applications.

Also during this time, the production of EC Grade (Al 99.7%) with in line 'strain hardened' states, type H12, H14 and H16, began and the following designations were born to differentiate the chemical/physical characteristics in the same alloy:

F = as fabricated
O = Annealed
H = Strain hardened
W = Solution heat-treated
T = Thermally treated.

The 8xxx and 6xxx alloys with their own in line 'Temper' designations were born (in North America).

Very famous are the 6101 & 6201 – T4 alloys where T4 stands for – Solution Heat Treated & Naturally Aged. To obtain this state it was necessary to add an induction furnace to the continuous casting lines to guarantee a constant inlet temperature in the rolling mill with well-defined values and after the rolling mill a forced cooling system such as to guarantee certain characteristics to the rod produced (quenching).

About 30 years ago, in parallel with the classic electrical alloys, many manufacturers, and primarily those in Japan, began the development of alloys for the replacement of copper cables with aluminium cables in automobiles. Today, some large-engine cars with many options contain 40-50 kg of copper wire within the car. If the copper wire was partially replaced with aluminium, this weight could be reduced by half. These alloys are mainly of the 1xxx and 8xxx series. Today all manufacturers are, or have been, in production for some time with alloys for 'harnesses wire'. In the future, ever greater quantities of these 'harnesses wire' alloys will be required and ever more performant alloys as well. As such, entire wiring harnesses made of aluminium are already installed in the Airbus A380.

With the increasingly massive introduction of aluminium in the mechanical industry and

Alloy designation	Temper	Mechanical properties			Electrical properties (temperature : 20 °C)	
		Tensile strength R_m MPa		Elongation typical $A_{100\ mm}$ %	Resistivity µΩ · cm	Conductivity % IACS
		min.	max.		max.	min.
EN AW-1110 [Al 99,1]	F	125	145	15	2,97	58,0
EN AW-1370 [Al 99,7] and EN AW-1350 [Al 99,5]	H14	115	130	14	2,801	61,5
	H13	105	120	16	2,801	61,5
	H12	95	110	20	2,801	61,5
	H11	80	95	25	2,785	61,9
	O	60	80	40	2,725	63,3
EN AW-5005 [Al Mg1]	H16	165	205	20	3,31	52,0
EN AW-5154A [Al Mg3,5]	F	210	280	16	5,20	33,1
	O	210	275	20	5,10	33,8
	O3	210	260	25	5,10	33,8
EN AW-6101 [Al MgSi]	T1 [a]	190	-	17	3,50	49,2
	T4 [a]	150	-	23	3,50	49,2
EN AW-6201 [Al Mg0,7Si]	T1 [a]	205	-	17	3,60	47,8
	T4 [a]	160	-	21	3,60	47,8
EN AW-8030 [Al FeCu]	O	60	110	40	2,86	60,2
	H24	100	150	25	2,86	60,2
EN AW-8176 [Al FeSi]	O	60	110	40	2,86	60,2
	H24	100	150	25	2,86	60,2

[a] Measurements made not less than 3 days after quenching.

Rod tensile from EN 1715-2

in particular the aeronautical, military and, as already anticipated, automotive industries, many producers of continuous cast rod began the adventure of replacing the die-casting of billets and slabs about 30 years ago to obtain wire rod with the cheapest and fastest direct continuous casting process. Obviously, we started with the alloys most similar to those commonly produced but we have gone further and further. Initially the 3xxx, 4xxx alloys and subsequently the 5xxx and 6xxx mechanical alloys up to the more 'hard and difficult' alloys of the 2xxx and 7xxx series. These, which were initially niche productions, in the hands of a few producers (that could be counted on one hand), are now becoming an increasingly available production thanks to an ad hoc Properzi continuous casting line (now it takes at least two hands to count them and in a few years, it will take four!).

Simultaneously with the production of these hard alloys, and with the difficulties in drawing where only a few reductions could be made with intermediate annealing between one process and another, some welding wire producers began to look for more performant processes compared to the traditional drawing machines.

The intrinsic limit of drawing is that the rod or wire must be cold before entering the drawing die and therefore it undergoes hardening that is quite rapid for these types of alloys. For more than 20 years now, Properzi has proposed and used a Micromill for these alloys with great success, obtaining fantastic results with alloys 4047 – 5356 – 5183/5556 and 5087 where with just one step you can go from 9.53 mm wire rod to wire diameters in the range of 2.6-2.4 mm. All without the previously necessary intermediate annealing processes. Practically in a single day it is now possible to do what in the traditional drawing process would have required from several days up to one week.

Obviously, all this takes place with cold rod, hence 'cold rolling'.

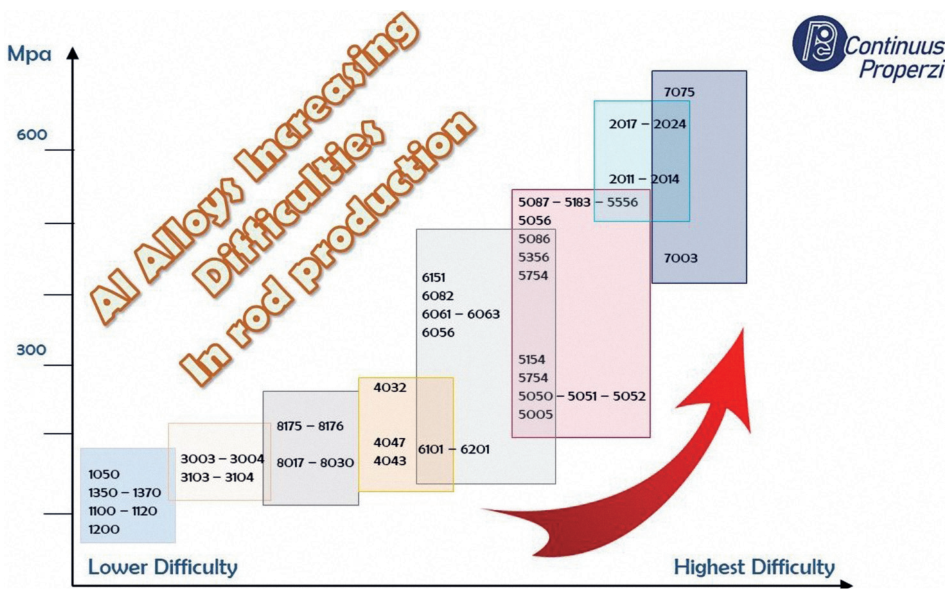
The Properzi cold rolling mill, called 'Cold Rolling Micromill', is practically the 'scale down' hot rolling mill but with exactly the same benefits.

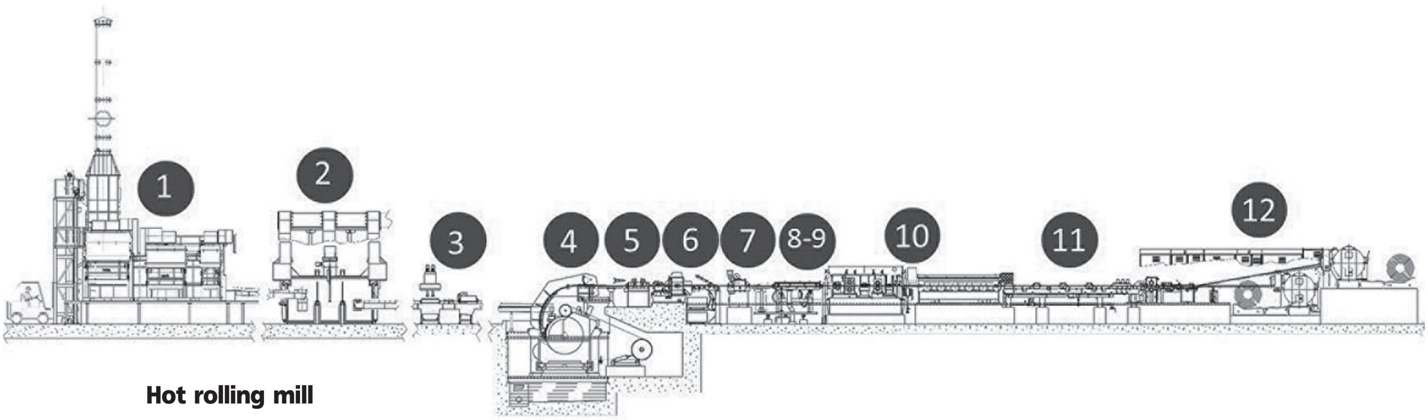
Differently from the drawing process, where the passage of the rod / wire is pulled by a capstan thereby reducing the diameter through the drawing die, the rod / wire deformation occurs by means of a rolling process with 'pull zero and compression zero'.

Furthermore, having no temperature limits, the heat released by the deformation of the material becomes an advantage since after the first few passes, it makes the material more malleable and therefore does not undergo the same work hardening as with a conventional drawing process. Even the outgoing wire, reaching almost 150-200 °C, allows, for some alloys, an elongation such as to avoid further annealing and to be processed directly until the final product is obtained.

In general, the 'Cold Rolling Micromill' has the same advantages for mechanical alloys of the 2xxx, 3xxx, 5xxx, 6xxx and 7xxx series.

But let's see in detail how these processes are: →





Hot rolling mill

1 Vertmelt furnace: it has been designed to minimize fuel consumption, grant constant and homogeneous melting rate and characteristics of the liquid aluminium.

2 Holding furnace(s): the capacity is defined in accordance with the melting rate of the VertMelt, the production rate of the casting machine, and the alloy range to be produced in order to have the proper time to homogenize the liquid metal bath.

3 Degaser, filter and Tibor feeder: these devices are usually required to carry out the liquid metal treatment just prior to casting. The main purpose is to reduce the hydrogen content, capture the solid inclusions and oxides in the metal, and inoculate the grain refiner, if needed.

4 Casting machine: a wide range of casting machine models, differing mainly in the casting wheel diameter and cross section of the cast bar, can be provided in accordance with the production rate, the alloy range to be produced, and the environmental conditions.

5 Cast bar straightener: to straighten the cast bar before entering downstream equipment such as the automatic bar shear, the induction bar heater, the cast bar cooling tunnel, and the milling machine.

6 Automatic bar shear: to cut the bar automatically during the start-up and in the unlucky event of an emergency downstream.

7 Milling machine: required when producing aluminium alloys 5xxx series to remove the upper layer of the cast bar.

8 Induction Bar Heater: when producing some alloys, electrical alloys in particular, it is required to increase the cast bar temperature before entering the rolling mill.

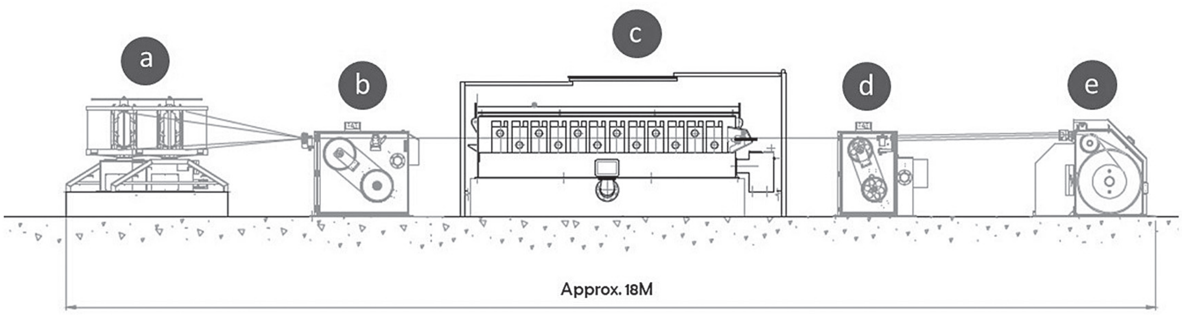
9 Cast Bar Cooling Tunnel: designed to reduce the cast bar temperature before entering the rolling mill in order to achieve the desired temper grade, particularly with 1xxx series alloys.

10 Rolling mill: we have twelve rolling mill models, with 2-roll and 3-roll rolling stands, that can be combined in several rolling train combinations defined by considering the cast bar section (linked to the production rate), the alloy range, and the rod diameters to be produced. The Properzi unique combination of a roughing mill with 2-roll rolling stands that provide the necessary high reduction rate and a finishing mill with the legendary 3-roll rolling stands ensures rod diameter tolerance and quality surpassing the applicable specifications.

11 Quenching unit: in order to cool the rod before being coiled and, in the case of some electrical alloys (particularly with 6xxx series), to achieve the desired temper.

12 Coiler: the coiler model is defined according to the preferred coil type (loose coils or tight coils), the production rate, and the coil dimensions / weight (European standard and / or American standard). The coiler is equipped with strapping and unloading units.

Cold rolling mill



a) Two vertical dynamic rod payoff: designed and motorized to be able to uncoil 9.53 mm aluminium rod.

b) Rod dancer: the rod dancers are designed to be electrically controlled and work with the rod pay-off to create the appropriate tension prior to entry to the Microrolling mill.

c) Microrolling mill: is the heart of the plant, which processes the raw material (various aluminium rod alloys 9.53 mm) down to the diameters requested (range 2.6-2.4 mm). The micromill is composed by one base frame where the transmission and the rolling stands are mounted. The peculiarity of the stands is that they are all 3-rolls and the sequence is round – triangle – round.

d) Wire dancer: positioned between the Microrolling mill and the dynamic spooler absorbing the differences of speed during ramp up and ramp down.

e) Dynamic spooler: designed to collect the wire on the spool at high temperature; it is possible to collect from 350-1,000 kg of wire depending on customer request.

Absolutely the best result from hot and cold rolling mills come from the companies that have both in the same plant. Do not hesitate to contact us. We are certain to have the perfect solution for all of your requirements.

Author

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