InfoMine
research group
Union of Independent Experts in the Field of Mineral Resources, Metallurg
and Chemical Industry in the CIS

Aluminium Semis and Products Market Research in the CIS

Sample PDF

Moscow
September, 2009

internet: www.infomine.ru
e-mail: info@infomine.ru

CONTENTS

List of Tables

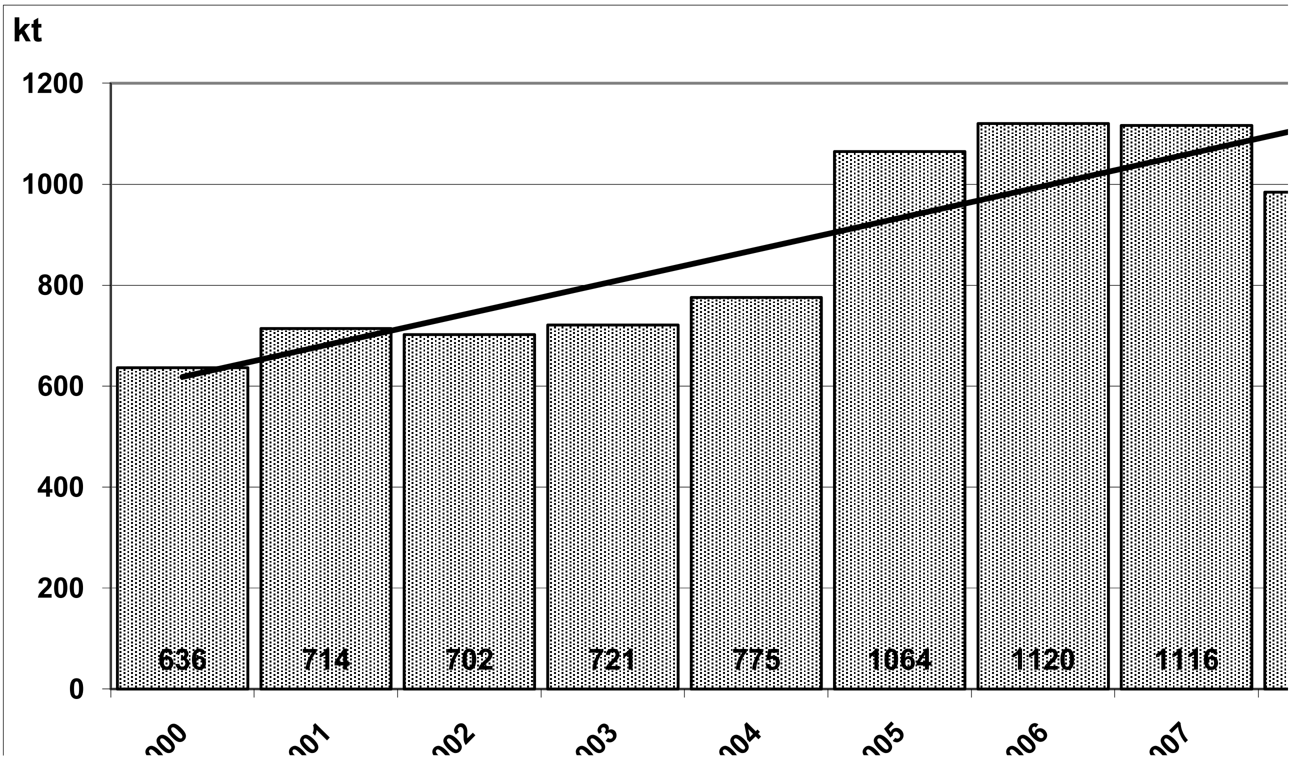
List of Figures

I.2. Production of aluminium semis in Russia

I.2.1. Production of aluminium semis and its pattern by enterprise in 2000-2008

Production of aluminium semis to a large extent reflects general stnding of industrial development of a country, as the products are used in most of major sectors of industry. For the period of interest (2000-2008), production of the semis in Russia demonstrated uptrend until 2008 (Figure 4). In 2008 the production dropped by 12% compared with 2007 in connection with the global financial-economic crisis.

Figure 4. Production of aluminium semis in Russia in 2000-2008



Source: «InfoMine»

Production of aluminium semis in Russia is conducted at 11 basic enterpises, located in Central Federal District (1 enterprise), Northwestern Federal District (1), Privolzhsky Federal District (1), Southern Federal District (1), Ural Federal District (3) and Siberian Federal District (4).

Notice that 6 enterprises produce wide mix of aluminium semis (Table 17): - flat-rolled products (sheets, plates, can sheet), cast product (ingots) and bar-shape products (bars, shapes), tubes and forge-and-pressed products. List of the enterprises includes: Samara Metallurgical Plant – JSC «SMZ Alcoa» (Samara); Belaya Kalitva Metallurgical Production Concern – JSC «Metallurg Alcoa Rus», Belaya Kalitva, Rostov Region); Krasnoyarsk Metallurgical Plant – LLC «KRAMZ» (Krasnoyarsk); Kamensk-Uralsky Metallurgical Plant – JSC «KUMZ» (Kamensk-Uralsky, Sverdlovsk Region); Stupino Metallurgical Works – JSC «SMK» (Stupino, Moscow

Region); Verkhnyaya Salda Metallurgical Production Concern – JSC «Corporation VSMZO-AVISMA» (Verkhnyaya Salda, Sverdlovsk Region).

Two enterprises - JSC «RUSAL Sayanal» and JSC «Ural Foil» -specialize mainly in production of aluminium foil.

Three more enterprise-subsidiaries of UC RUSAL produce only one kind of aluminium semis – wire rod: Irkutsk Aluminum Smelter – IrkAZ (Shelekhov, Irkutsk Region); Bratsk Aluminum Smelter - BrAZ (Bratsk, Irkutsk Region); Kangalaksha Aluminum Smelter – KAZ (Kandalksha, Murmansk Region).

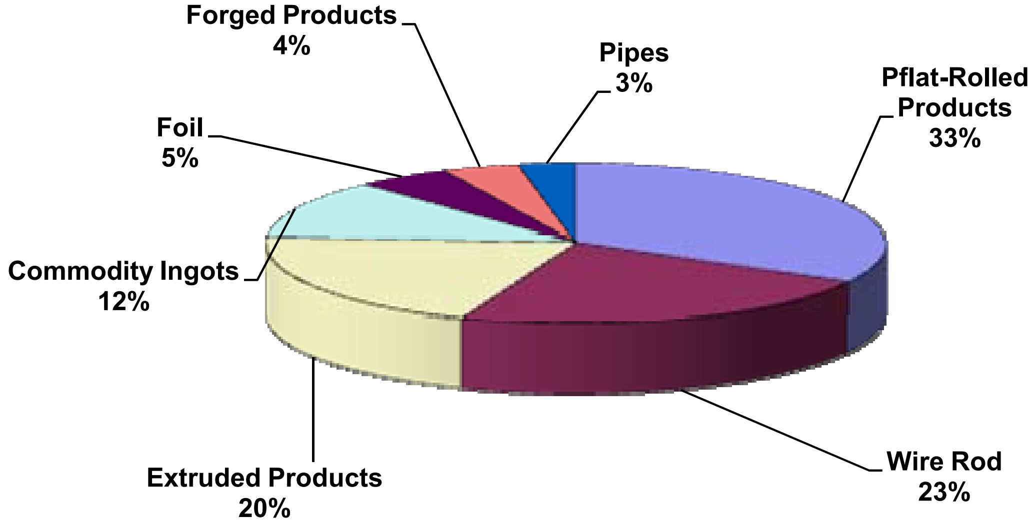
Table 17. Mix of products of Russian producers of aluminium semis

Enterprise	Ingots	Plates	Sheets	Can sheet	Foil	Shapes	Bars	Building structures	Tubes	Forged pieces	Pressed pieces	Disks	Wire rod
SMZ	■	■	■	■		■	■	■	■	■	■		
BKMPO	■	■	■	■		■	■		■	■	■	■	
KRAMZ	■			■		■	■	■	■	■	■	■	■
Sayanal			■	■	■								
KUMZ	■	■	■	■		■	■	■	■	■	■	■	
Ural foil			■	■	■								
SMK	■	■	■	■		■	■		■	■	■	■	
VILS	■	■	■	■		■	■		■	■	■	■	
VSMPO	■	■	■	■		■	■	■	■	■	■	■	
IrkAZ	■												■
BrAZ	■												■
KAZ	■												■

Source: data of the companies

From estimate of «InfoMine», at present time, pattern of production of aluminium semis and rolled aluminium in Russia is as follows – Figure 5. Dominating commodity products are flat-rolled aluminium and wire rod, to which 33% and 23% of total production of semis belong, respectively.

Figure 5. Pattern of semis production by their kind



Pattern of production of aluminium semis in Russia by enterprise in 2000-2008 is presented in Table 18.

Table 18. Volumes of aluminium semis production by Russian enterprises in 2000-2008, kt

Enterprise	2000	2001	2002	2003	2004	2005	2006	2007	2008
JSC «SMZ Alcoa»									
LLC «KRAMZ»									
JSC «KUMZ»									
JSC «Metallurg Alcoa Rus» (BKMPO)									
JSC «RUSAL Sayanal»									
JSC «Ural Foil»									
JSC «Foil-Rolling Plant» (St.Petersburg)									
Irkutsk Aluminium Smelter									
Bratsk Aluminium Smelter									
Kangalaksha Aluminium Smelter									
JSC «SMK»									
JSC «VSMZO-AVISMA»									
JSC «VILS»									
Total									

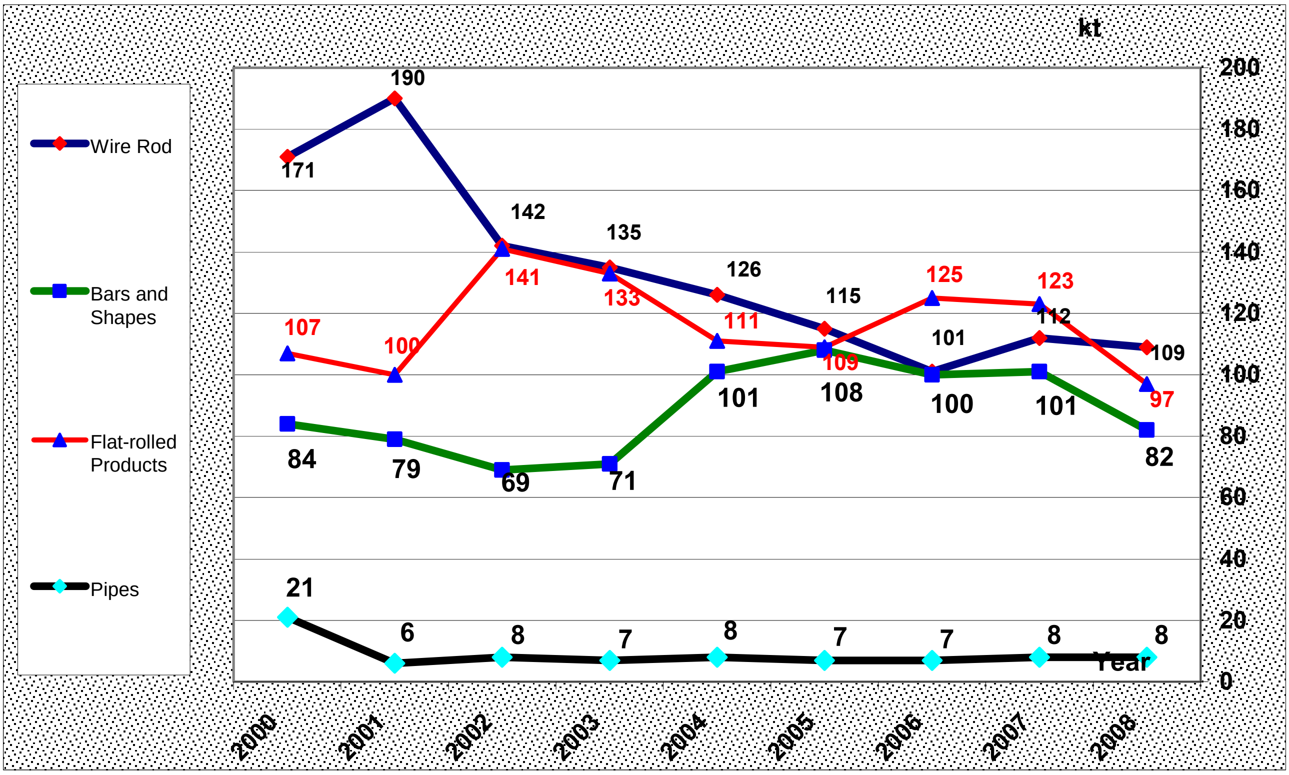
Source: estimate of «InfoMine»

Besides the listed enterprises, aluminium semis are produced by a numbr of other companies, but, from estimate of «InfoMine», their production volumes are up to 2% of the total output in Russia.

I.2.2. Foreign trade operations in aluminium semis in 2000-2008

In latest years, Russian production of aluminium semis is less focussed on exports compared with the production of primary aluminium and its alloys. In Figure 6, dynamics of export volumes of various kinds of aluminium semis – wire rod, flat-rolled aluminium, bars and shapes, tubes – in 2000-2008 is presented.

Figure 6. Dynamics of exports of aluminium semis (by kind) in 2000-2008



Source: «InfoMine» on the basis of analysis of customs statistics

On the whole, for the latest years the exports of wire rod decreased in connection with growing domestic demand. In Table 19 regional pattern of the exports of wire rod in 2000-2008 is presented (both in bulk and in money terms). Main destinations of the wire rod supplies are Greece, Ukraine, Germany, Kazakhstan, USA, Uzbekistan.

Data on the exports of bars and shapes are presented in Table 20. Decline in the exports of 2001-2002 was owed by growing domestic demand, the following growth in 2003-2005 was connected with launching new production capacities. Main destinations of the supplies are Turkey, Germany, as well as USA, Italy and Great Britain.; among CIS countries - Kazakhstan and Uzbekistan.

In Table 21. data on destinations of the export supplies of flat-rolled aluminium are presented. Leading importer of the products are USA – around 32% of total volume of Russian exports of flat-rolled aluminium in 2008, followed by Ukraine

(15.9%) and Germany (7.6%); among smaller, but also rather marked importers are Israel, Canada, South Korea, France.

The export of aluminium tubes isn latest years was rather stable at a level of 7-8 kt per year. Constant customers of the Russian tubes for the period were USA, Germany and Ukraine (Table 22), to which together around 78% of total volume of the Russian export supplies of aluminium tubes belonged in 2008.

Table 19. Regional pattern of exports of aluminium wire rod (TNVED Code 76.05) in 2000 – 2008*

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Azerbaijan																		
Great Britain																		
Vietnam																		
Germany																		
Honduras																		
Greece																		
Georgia																		
Israel																		
Italy																		
Spain																		
Kazakhstan																		
Kyrgyzstan																		
China																		
Latvia																		
Malaysia																		
Moldova																		
Netherlands																		
Norway																		
Poland																		
Portugal																		
Serbia																		
Slovakia																		
USA																		
Turkmenistan																		
Turkey																		
Uzbekistan																		
Ukraine																		
Finland																		
Czech																		
Sweden																		
Estonia																		
Other																		
Total																		

** - ignoring Belarus*

Source: «InfoMine» on the basis of analysis of customs and railage statistics

Table 20. Regional pattern of exports of aluminium bars and shapes (TNVED Code 76.04) in 2000-2008*

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Australia																		
Austria																		
Azerbaijan																		
Albania																		
Argentina																		
Armenia																		
Belgium																		
Bulgaria																		
Brazil																		
Great Britain																		
Hungary																		
Virgin Islands																		
Vietnam																		
Germany																		
Gibraltar																		
Greece																		
Georgia																		
Denmark																		
Israel																		
India																		
Iran																		
Spain																		
Italy																		
Kazakhstan																		
Canada																		
Kyrgyzstan																		
China																		
North Korea																		
South Korea																		
Latvia																		

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Lithuania																		
Malaysia																		
Malta																		
Moldova																		
Myanma																		
Netherlands																		
New Zealand																		
Pakistan																		
Poland																		
Romania																		
Serbia																		
Singapore																		
Syria																		
Slovakia																		
USA																		
Tajikistan																		
Thailand																		
Taiwan																		
Turkey																		
Uzbekistan																		
Ukraine																		
Finland																		
France																		
Czech																		
Switzerland																		
Sweden																		
Sri Lanka																		
Estonia																		
RSA																		
Japan																		
Other																		
Total																		

** - ignoring Belarus*

Source: «InfoMine» on the basis of analysis of customs statistics

Table 21. Regional pattern of exports of flat-rolled aluminium (plates, sheets, strip and can sheet, TNVED Code 76.06) in 2000-2008*

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Australia																		
Austria																		
Azerbaijan																		
Armenia																		
Belgium																		
Bulgaria																		
Brazil																		
Great Britain																		
Hungary																		
Vietnam																		
Germany																		
Hong Kong																		
Greece																		
Georgia																		
Denmark																		
Israel																		
India																		
Indonesia																		
Iran																		
Ireland																		
Spain																		
Italy																		
Yemen																		
Kazakhstan																		
Canada																		
Cyprus																		
Kyrgyzstan																		
China																		
North Korea																		
South Korea																		
Cuba																		
Latvia																		
Lithuania																		
Liechtenstein																		

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Malaysia																		
Mexico																		
Moldova																		
Netherlands																		
New Zealand																		
Norway																		
UAE																		
Poland																		
Portugal																		
Puerto-Rico																		
Saudi Arabia																		
Singapore																		
USA																		
Tajikistan																		
Thailand																		
Taiwan																		
Turkmenistan																		
Turkey																		
Uzbekistan																		
Ukraine																		
Philippines																		
Finland																		
France																		
Croatia																		
Czech																		
Switzerland																		
Sweden																		
Estonia																		
RSA																		
Jamaica																		
Japan																		
Other																		
Total																		

** - ignoring Belarus*

Source: «InfoMine» on the basis of analysis of customs statistics

Table 22. Regional pattern of exports of aluminium tubes (TNVED Code 76.08) in 2000-2008*

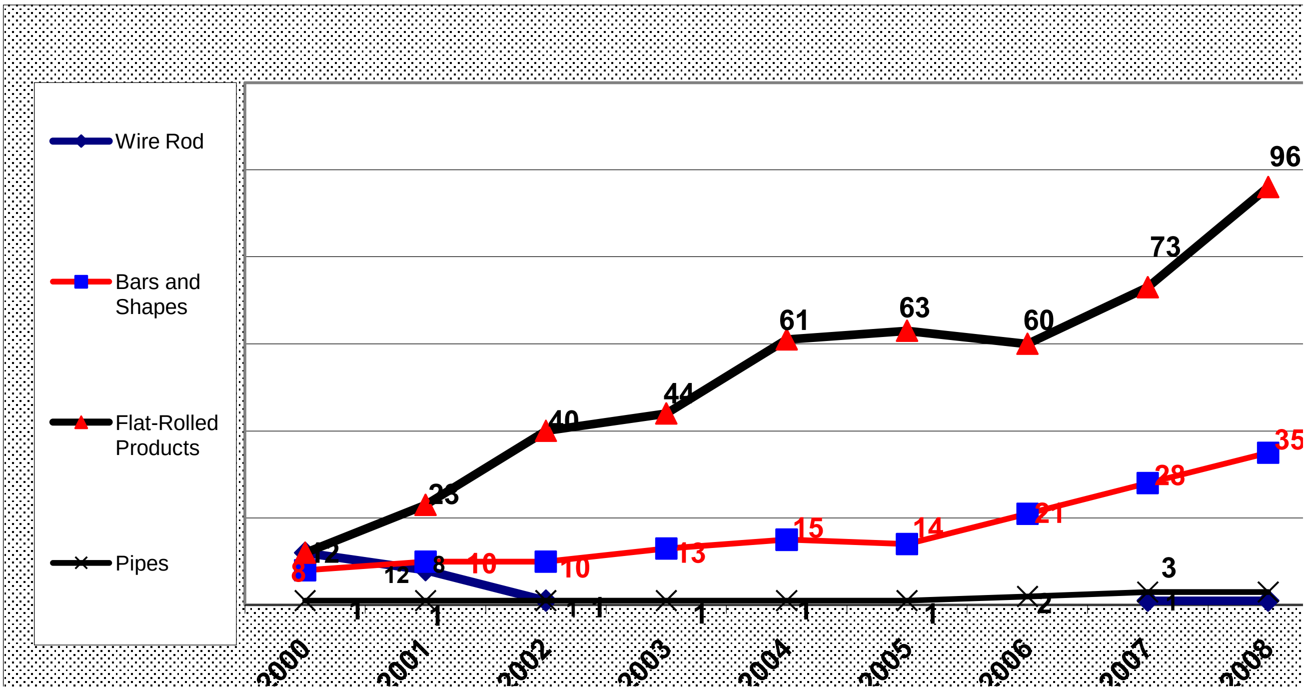
Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Azerbaijan																		
Belgium																		
Bulgaria																		
Brazil																		
Great Britain																		
Germany																		
Denmark																		
Israel																		
India																		
Spain																		
Italy																		
Kazakhstan																		
Kyrgyzstan																		
China																		
Latvia																		
Lithuania																		
Netherlands																		
Poland																		
Romania																		
Singapore																		
USA																		
Taiwan																		
Turkey																		
Uzbekistan																		
Ukraine																		
Finland																		
France																		
Czech																		
Switzerland																		
Sweden																		
Estonia																		
Other																		
Total																		

** - ignoring Belarus*

Source: «InfoMine» on the basis of analysis of customs statistics

In Figure 7 dynamics of imports of various kinds of aluminium semis – wire rod, flat-rolled aluminium, bars and shapes, tubes – in 2000-2008 is presented.

Figure 7. Dynamics of imports of aluminium semis by kind in 2000-2008



Source: «InfoMine»

In Tables 23 – 26 data on regional pattern of the imports of wire rod, flat-rolled aluminium, bars and shapes, tubes are presented (both in bulk (kt) and in money terms (thous. USD).

Import of wire rod, volume of which in 2000 was around 12 kt, later was practically stopped in connetion with growth of domestic production. In latest 2 years, supplies of wire rod from Poland to a number of Russian cable plants took place.

Russian imports of flat-rolled aluminium, bars and shapes demonstrate steady uptrend, even in crisis 2008 year. Bars and shapes are regularly imported by Russia in considerable volumes from Germany and Italy, as well as from China, Turkey and Ukraine.

Above 50% of imported flat-rolled aluminium comes to Russia from Germany (mainly can strip). The second greatest supplier is China (28.6% in 2008). Besides, the product is regularly imported from Spain, Irtaly and Norway.

Russian import of tubes is insignificant, with some increasing volumes of the supplies in latest years. Among major stable country-suppliers are Germany, Italy, Belgium, Turkey.

Table 23. Geographic pattern of imports of aluminium wire rod (TNVED Code 76.05) in 2000-2008

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Kazakhstan																		
Lithuania																		
Poland																		
Ukraine																		
Finland																		
France																		
Tajikistan																		
Total																		

Source: «InfoMine» on the basis of analysis of customs statistics

Table 24. Regional pattern of imports of aluminium bars and shapes (TNVED Code 76.04) in 2000-2008

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Australia																		
Austria																		
Azerbaijan																		
Belgium																		
Bulgaria																		
Great Britain																		
Hungary																		
Germany																		
Greece																		
Denmark																		
Israel																		
Spain																		
Italy																		
Canada																		
China																		
South Korea																		
Netherlands																		
Norway																		
Poland																		
Serbia																		
Slovenia																		
USA																		
Tajikistan																		
Taiwan																		
Turkey																		
Ukraine																		
Finland																		
France																		
Czech																		
Switzerland																		
Sweden																		
Other																		
Total																		

Source: «InfoMine» on the basis of analysis of customs statistics

Table 25. Regional pattern of imports of flat-rolled aluminium (plates, sheets, strip and can sheet), TNVED Code 76.06) in 2000-2008

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Austria																		
Armenia																		
Belgium																		
Bulgaria																		
Great Britain																		
Hungary																		
Germany																		
Greece																		
Israel																		
Spain																		
Italy																		
Canada																		
China																		
South Korea																		
Netherlands																		
Norway																		
Poland																		
Serbia																		
Slovenia																		
USA																		
Taiwan																		
Turkey																		
Ukraine																		
Finland																		
France																		
Croatia																		
Czech																		
Switzerland																		
Sweden																		
RSA																		
Japan																		
Other																		
Total																		

Source: «InfoMine» on the basis of analysis of customs statistics

Table 26. Regional pattern of imports of aluminium tubes (TNVED Code 76.08.) in 2000-2008

Country	2000		2001		2002		2003		2004		2005		2006		2007		2008	
	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous	t	$ thous
Austria																		
Belgium																		
Brazil																		
Great Britain																		
Germany																		
Greece																		
Denmark																		
Spain																		
Italy																		
China																		
South Korea																		
Lithuania																		
Netherlands																		
Norway																		
Poland																		
Portugal																		
Romania																		
Singapore																		
Slovakia																		
Slovenia																		
USA																		
Taiwan																		
Turkey																		
Ukraine																		
Finland																		
France																		
Croatia																		
Czech																		
Switzerland																		
Sweden																		
Japan																		
Other																		
Total																		

Source: «InfoMine» on the basis of analysis of customs statistics

I.2.3. Processes and equipment for production of aluminium semis

World practice process description

The starting stock for most rolled products is the DC (Direct Chill semi-continuous cast) ingot. 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.

The DC ingot is usually cooled after casting to room temperature and then re-heated to around 500C prior to successive passes through a hot rolling mill where it is reduced in thickness to about 4 - 6 mm.

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 stands and some 5 stand. Cold rolling speeds vary but modern mills operate at exit speeds as high as 3000 m per minute and alloys may be cold rolled to thickness of around 0.05 mm.

In the past 25 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 competing 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. 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. 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.

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.

At present time in Russia, technological level of ingot manufacture is much inferior of the world level. For instance, production of 100 kt of ingots at Russian enterprises requires use of 7-10 smelting-casting installations versus 2-3 installations in Western companies.

In the opinion of RUSAL specialists, Russian deformble aluminium semis are not inferior to foreign analogues in metal quality as rule, but their prime cost and labor consumption (in Russia) are much higher than abroad that is owed by obsolescence of corresponding installation, applied in Russia.

The installations and processes for production of aluminium alloys in Russia remained to a large extent at a level of 1960-1970s (including obsolete and worn above 80 plasma reverbertatory furnaces, almost 20 electric resistance furnaces, around 100 gas and electric mixers, a large number of low-efficient homogenization furnaces and so on).

A number of Russian enterprises realize projects on modernization of smelting-casting facilities. For instance, Samara Metallurgical Plant in 2000 commissioned a new 60-t smelting-casting facility, designed, however, above 10 years ago and, so, not meeting modern world requirements inpart of ingot casting automation.

Kamensk-Uralsky Metallurgical Plant in latest years has modernised 3 of 15 smelting-casting facilities that allowed to increase volume of ingot production in casting shop up to 6 kt per month.

Stupino Metallurgical Works also partially modernized its fleet of casters.

At present time, smelting-casting facilities includes stationary and mixer furnaces, and the latter is surrounded by up to 6 low-productive casters. Such layout hinders increasing productivity of the facility; at design capacity of smelting furnaces up to 8.5 tph the facility flat ingot output is 2.2-2.5 tph, and that of round ingots – 1.5-2 tph only.

This all hinders the process automation and introduction of modern processes of extra-furnacer refining and modifying, and makes ingot quality dependent on qualification of foundry man.

That is why aluminium alloy ingot production requires complete replacing (but not reconstruction, implemented at a nymber of plants) of key smelting-casting facilities (furnaces, casters, etc.) with introducing modern processes of refining, modification and high-efficient casting.

As for sheet-rolling facilities, they were mainly created for manufacturing products fro defence and aerospace industry (from alloyed heat-strengthened alloys), but not for peaceful purposes – home appliances, etc. Except for Samara Metallurgical Plant) rolling facilities were not practically modernized, their deprteciation exceeds 60% by now. That is why quality of manufactured sheets mainly doesn’t meet modern standards (in sizes). Only SMZ has rather modern rolling facilities, permanently reconstructed and replaced with more modern; besides, the plant has the sole can sheet production line with surface finishing (can sheet varnishing).

The weakest point of sheet-rolling production in Russia is availability of obsolete hot-rolling mills, exploited commonly above 40 yars (at KUMZ – since 1945, BKMPO – since 1960).

Cold-rolling mills of BKMPO, KUMZ and SMK are also obsoletye – with obsolete reversing scheme, low rolling speed (up to 4 m/sec), without automatic control of strip thickness. Only SMZ CR mills, launched in 1980s, are og modern design: non-reversing rolling, rolling rate up to 20-25 m/sec, with automatic control of strip thickness.

According to data of Alyusil company, Obsolete CR mills are unliable to reconstruction and must be removed from service completely with auxiliary and accompanying facilities.

As for production of *aluminium foil*, the most widespread process of foil manufacture in world practice is now rolling from molten condition (RMC). Russian producers also have relatively modern RMC facilities. Sayanskaya foil plant, built in mid-1990s, with capacity of 40 kt foil per year, is equipped with 3 RMC installations of firm Fata Hunter. JSC «Ural Foil» exploits 2 RMC installations of Ukrainian production, launched in early 1990s and reconstructed later (2000-01).

Extrusion production is also rathet obsolete: according to Alyusil company analysis, of 138 available extruders, age of 48% exceeds 40 years, and only 22% are younger than 20 years.

In 1990s, in extrusion shops of SMZ, KUMZ and KraMZ, 10 extrusion lines, based on extruders of force 8-25 MN, were partially modernized (but not radically).

According to Alyusil, by 2015 production of Extruded products in russia can reach 290 kt per year (100 kt shapes and 190 kt bars). For production of this volume, 63 obsolete extruders must be removed from service, whereas residual extruders need radical modernization.

Renewing of Russian extruder fleet must take into account current tendencies of market conjuncture. For instance, at present time and in future, demand for thin-walled (2 mm wall thickness) long (up to 25 m) panels will increase (for use in ship building, bridge building, railcar building, etc.). Now no Russian producer can manufacture such products – for their production, purchase of foreign 70-80-MN extruders must be purchased.

Wire rod production capacities of continuous casting-rolling installations in Russia reached around 400 kt by late 1980s. At that, grade of the wire rod (in strength, electric conductivity, etc.) met world reuirements. But by present time, casting-rolling installations of IrkAZ and BrAZ need serious reconstruction (especially in light ofg need in lage-scale replacing exhaust wires of high-voltage and other power lines with installing aluminium alloy wires (instead of previous aluminium wires).

Flat semis production process

Flat-rolled aluminium from slab to coil/sheet

The production of aluminium flat-rolled products can schematically be divided into four major steps, two first of which cover manufacture of flat-rolled semis from slabs.

In step 1 – the hot strip production process – traditionally the molten metal is cast after refining and alloying processes into 10 to 25-ton slabs in semi-continuous casters, then preannealed, hot-rolled in single-stand or tandem hot rolling mills and, at a strip thickness of 6 to 2.5 mm, coiled at a temperature of approx. 300°C.

More economical in terms of energy saving is the direct casting process into strips of 12 to 20 mm thickness in twin-belt casters with a continuing hot rolling process in a tandem hot rolling line at an hourly production rate of 25 kg per mm width. The suitability of this process is restricted to a limited number of alloys allowing a quick cooling without segregation.

The third and most economic way is hot strip casting between two rolls in a so-called twinroll caster with an exit thickness between 6 and 3 mm at low speed. This casting method can also only be used for pure aluminium or material with a low alloy content for the production of foil.

All three different hot strip production methods have advantages and limitations in terms of material quality, productivity, energy and labour intensity. The investment and operational costs are also key factors for the final decision about the optimum solution.

After the hot strip production in step 2, the cold strip rolling starts. Even though this deformation process is called "cold" rolling, the strip is heated up to approx. 100°C during each pass and large quantities of coolant have to be poured over the rolls to keep a thermal equilibrium. After each of the three to four passes, the coils have to be cooled down to room temperature for several hours.

During each cold rolling pass, a material hardening is effected by the deformation process of the strip. Depending on the grain structure mainly influenced by the alloy composition, one or two annealing sessions for recrystallisation have to be integrated into the production programme to permit a continuation of the rolling passes and to fulfil the final requirements of the product specification.

The strip rolling process itself can be done with different types of rolling mills. For small coil weights up to 5 tons, reversing rolling mills are still used. For normal coil weights between 10 and 15 tons, non-reversing single-stand rolling mills are common.

For high coil weights up to 25 tons, and large production volumes, multi-stand tandem rolling mills are used.

Key operation in production of sheet semis from aluminium and its alloys is ***hot rolling***. Hot rolling yields sheets and plates from 4 to 80 mm thick, but the bulk of products belongs to coils 2.5-10 mm thick following cold rolling. Ingot weight in domestic production reaches 20 t, thickness – 400 mm, width – up to 2100 mm, and maximal length – 4000 mm. In rolling hard-deformable alloys, ingots with side curvature are used.

Cast aluminum alloys cannot be work hardened, so they are used in either the as-cast or heat-treated conditions. Common heat treatments include homogenization, annealing, solution treatment, aging and stress relief. Typical mechanical properties for commonly used casting alloys range from 20-50 Ksi (138-345 MPa) ultimate tensile strength and 15-40 Ksi (103-276 MPa) yield strength with up to 20% elongation.

In general, the principles and procedures for heat treating wrought and cast alloys are similar. For cast alloys, however, soak times tend to be longer if the casting is allowed to cool below a process-critical temperature for the particular alloy. Solution soak times for castings can be significantly reduced to durations similar to that for wrought alloys if the castings are placed into the solution furnace while still hot (above the process-critical temperature) immediately following mold filling and solidification. The reduction of stress in complex cast shapes is achieved in large part by the control of quenching parameters such as agitation rate, quenchant temperature, rate of entry and part orientation in the quench.

Ingot preparation

Homogenization (Ingot Preheating Treatments)

The initial thermal operation applied to castings or ingots (prior to hot working) is homogenization, which has one or more purposes depending upon the alloy, product and fabricating process involved. One of the principal objectives is improved workability since the microstructure of most alloys in the as-cast condition is quite heterogeneous. This is true for alloys that form solid solutions under equilibrium conditions and even for relatively dilute alloys.

For each grade of aluminium and alloys optimal conditions are used.

Homogenization of ingots is conducted in 20-100-t furnaces with electric, gas or oil heating and forced air circulation.

After homogenization ingots are subjected to straightening at 2- or 4-roll straightening mills at 4-5 passes with 2-4% reduction in each pass for equalizing thickness.

Slabs (former ingots), designated for production of foil, special sheets, strip and other, for which high-grade surface is required, are subjected to scalping at horizontal and vertical slab-scalping mills. Scalped layer thickness ranges commonly 4-10 mm (up to 15-20 mm at special requirements to surface).

Ingots, cast into electromagnetic crystallizer, usually hava not surface defects and commonly are not subjected to scalping (alloys AMg2, AMg3, AMg5 and in a number of cases AMg6 ingots). Ingots of alloys D16, D1, AK4-1 for sheets without cladding are not also subjected to scalping.

Instead of scalping, shop deseaming is also applied. This method provides optimal primary welding cladding sheets.

Cladding

Cladding is implemented by hot rolling of scalped slab covered with aluminium sheets from both sides. Cladding protects slab surface from breakage in first passes of hot rolling (technological cladding), to protect slab from corrosion (protecting cladding) and to provide special physical or chemical properties for slab metal.

For cladding of most of alloys usually aluminium of grade AD1 (A5) is used. For cldding sheets of alloy V95, aluminium alloy ATs, containing 0.9-1.3% Zn is applied.

Slab deoiling is reached by cleaning with petrol or by washing and mechanical deseaming in special machine.

Slab cladding is conducted at flow line, including scalper, washer, cladding sheet-fixing device, roller beds and furnaces for slab homogenization and heating.

Slab heating and temperature intervals of rolling

Preheating

Preheating of aluminum ingots prior to rolling, extruding, forming, forging or melting is used to reduce energy consumption by improved process efficiency, reducing cycle time and increasing safety.

Hot rolling process consists in metal reduction by rolls at above-crystallization temperature.

Aluminum temperature is a critical parameter required for process optimization in the hot mill. Ingot and strip temperatures are used to control the speed and reduction throughout the rolling process.

A hotter ingot or strip must be processed more slowly, or with a smaller reduction, in order to assure that the aluminum does not overheat. A colder ingot or strip must be run through at a faster speed, or with a greater reduction, in order to generate more heat during deformation so that the metal will remain mailable as it passes through the entire line.

By making the appropriate adjustments on each pass, each subsequent pass may be run under more optimized conditions. Strip temperatures at the finishing mill and at the coiler are most critical to ensure that the proper material properties are obtained.

Slab is usually 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.

Rolling starts at maximal permitted temperature: 500º C and above for aluminium and low-alloyed alloys, and much lower for low-eutectic high-alloyed alloys (to avoid cracks).

Time of heating must provide uniform heating of the whole slab.

For heating aluminium alloy slabs continuous conveyer furnaces with electric or natural gas heating are applied.

Flat-rolling reduction condition choice

Reduction degree depends on physical and chemical properties of slab, is connected with temperature and speed of rolling and define quality of products and producibility of rolling mill. High reduction degree provides mitigation of deformation non-uniformity and obtaining uniform structure and stable properties of HR strip obtained.in most of cases rolling process is optimized by criterion of maximal mill productivity. For aluminium and low-alloyed alloys (AMn, AMg2, AV, MM), having high plasticity in wide temperature range, basic limiting factor in reduction condition choice is entering (nip) angle. In rolling hard-deformable alloys, with medium (D1, D16, AK4-1, AMg3, 1201) and narrow (AMg5, AMg6, 1561) rolling temperature range, basic limiting factor is rolling force torque.

To improve structure and increase strength of metal (to avoid irregular metal deformation), strip should be rolled in edger stands. Depending on strip width, this treatment is completed at strip thickness of 60-80 mm.

Minimizing quantity of passes keeps strip temperature and allows greater reduction in last passes (this is especially important for reversing mills, at which rolling is completed at strip thickness of 6-8 mm. To obtain thinner strip, drawing is used, provided by installing continuous stand group or a stand with one or two winders. The continuous stand group receives strip 25-120 mm thick. Rolling speed in reversing stands reaches 3 m/sec, in continuous - 6 m/sec (in first passes rolling speed must not exceed 1-1.5 m/sec to avoid shock).

Defects and their elimination methods

Among the most common defects (flaws) of hot-rolled strip are mechanical damage, crescent shape, ridge buckles and telescoping of coils, rolling-on and egde cracking, roll traces on surface and noncompliance with preset mechanical properties of hot-rolled metal.

Strip crescent shape is caused by irregular heating or roll skewing, as well as strip displacement in relation to rolling axis (to avoid this, centering is applied).

Ridge buckles is a result of rolling force (reduction) irregularity throughout strip width (owing to unstable rolling force by passes and nonuniform heating.

Rejects owed by noncompliance with preset mechanical properties of hot-rolled metal is connected with noncompliance with process conditions: temperature range, reduction schemes and roling speed, mode of treatment in edger stands (resulted in cracking strip edges).

Strip tightening (in width), in continuous mills, is caused by increasing strip tension between stands.

Rolling-on depends on roll polishing and is encouraged by too coarse or too fine polishing of the rolls. For eliminating the rolling-on effect, also mechanical cleaning of rolls is applied.

Hot-rolling mills

The bulk of semis from deformable aluminium alloys belongs to flat semis, manufactured initially (at the first step) at one-stand, tandem and semi-continuous hot-rolling mills. Basic type of stands used is 4-roll stand, providing high rolling pressure up to 30 MN.

At present time, semi-continuous hot-rolling mill find wide applicarion, providing higher producticivity compared with tandem mills, higher temperature of rolling, allowing to obtain up to 2.5 mm thick strip. Such mills include 1 or 2 reversing roughing stands and finishing continuous 3-6-stand group.

Hot-rolling mill structure also includes edger stands, guards, turntables, pushers, cross-cutting shears, slitting khifes, rollertable gears and coilers.

Four coiler types are used: mandrel coilers (do not providing combining rolling and coiling processes, besides, produces mechanical damage of strip surface), coilers with forming rollers (same to the first type, produces mechanical damage of strip surface), coilers with belt wrapper (provide combined rolling-coiling and regulated tension) and coiling roller machines.

Lubricants and lubricant-feeding systems

For lubrication in hot-rolling of aluminium, the following compositions are used: aqueous emulsions, water-soluble oils or water added with corrosion inhibitors plus separate technological grease feed.

The most widespread emulsifiers are soaps of alkaline metals; to provide higher stability of emulsion, sodium is often replaced with ammonia. To obtain stable emulsion, mineral oils of medium viscosity are optimal.

Hot rolling of aluminium its alloys are conducted with 0.5-6% emulsion, based on emulsol SP-3 (GOST 5702-75), using softened water.

Lubricant (emulsion)-supply system at hot-roling mill includes the following basic components: collectors with nozzles, fixed in both sides of working and support rolls, reservoirs for reception and jigging of lubricant, equippd with heaters, feed pumps, rough and fine-cleaning filters, cooler, tubeline system, fittings, instrumentation and controlling system.

Lubricant feed is calculated on the following basis: 18-22 m^3/hour per 1 cm of roll body length, providing pressure of 0.3-0.5 MPA on nozzle outlet.

Lubricant is spreaded over roll body by tube collectors and nozzles.

To provide effective lubrication, high purity of lubricant is required, providing by filters to remove particles of 0.2 mm in size and more (0.1 mm for obtaining high grade surface).

Hot-rolling process

Large-size aluminium slabs are used in hot-rolling process. Grade of slabs icreases which casting into electromagnetic crystallizer. To avoid decreasing ductility of slabs, sodium content is to be limited by a level of $5x10^{-4}$ %.

One of the most complicated and large-scale productions is manufacture of large-size coils from AMg2 alloy, for following use in manufacture of cans and foil. In this case, the process must provide obtaining re-crystallization structure, monotonous surface at minimal strip thickness.

400-mm thick slabs, obtained by casting into electromagnetic crystallizer, are subjected to homogenizing heating at 560-580º C to provide maximal ductility and minimum yield strength. Required high temperature of rolling end is reached at the expense of increased thickness (70 mm) and temperature (470º C) of semis before 5-stand group. This is typical process for rolling large-scale coils of aluminium and low-alloyed aluminium alloys.

Rolling of high-alloyed alloys is characterized by the same regularities. The only difference is requiring minimizing temperature and deformation-speed intervals.

An example of the process optimization by reaching required preset properties at minimum anisotrophy is large-scale plate (up to 2500 mm wide and 30000 mm long) production process. Basic rolling parameter is here ratio of working roll to rolled plate thickness. The required quality is achieved at the parameter value of 6-8, and deformation change within 5-25% doesn't effect on the ratio.

Hot-rolled plates from precipitation-hardening alloys are subjected to hardening and stretch straightening at deformation degree of 1.5-3% for eliminating residual stress and contraction in the course of following mechanical treatment.

Cold-rolling process

Cold rolling is applied for obtaining sheets and bands with high surface quality and preset mechanical properties and structure, which can not be reached by hot rolling. Cold rolling produces sheets 0.5-4.5 mm thick, 1000-2000 mm wide and 2000-15000 mm long.

At a cold mill, aluminum strips are reduced to tight mechanical tolerances, and cold worked to impart a hardness to the metal. If the metal or the roll is allowed to heat, then the thermal expansion can threaten the mechanical dimensions of the strip, and the heat buildup can soften the metal. Likewise, a strip that is well below the optimal temperature can be run faster without concern for a loss of properties**.**

A criterion for choosing reduction regimes is deformation, which at cold rolling can reach 60-90% for hard alloys and above 95% for soft ones.

Very strict requirements are imposed on CR sheets and bands from aluminium and its alloys in surface quality, thickness uniformity, geometry, surface flatness.

Governing parameters in systems of rolled stock thickness control are rolling force, speed and tension.

Cold rolling of sheets from aluminium and its alloys is carried out at one-stand or continuous multi-stand mills (Table 27).

Obe-stand mills are used for rolling of sheets and bands of wide mix and size range at relatively small volumes of production. They a also used as demis-producing mills for continuous mills or for foil semis manufacture. They are also applied for obtaining regulated deformation of material within 30-60%. These mills are non-reversing that allows to increase considerably productivity with simplifying design of the mills.

Table 27. Characteristics of typical cold-rolling mills of Russian manufacture

Mill Type	Working roll diameter, mm	Support roll diameter, mm	Roll body length, mm	N, kW	Roling speed, m/sec	Initial semis thickness, mm	Final sheet thickness, mm	Sheet width, mm
One-stand reversing	650	1400	2800	4000	4	4-6	0.5-3	1200-2500
One-stand reversing	500	1250	1700	2200	5	6-12	0.5-3	1000-1500
One-stand reversing for sheets of bariable cross-section	650	1400	2800	920	0.25-0.5	3-12	0.8-10	1200-2000
One-stand non-reversing	560	1550	2300	4 x 2100	25	0.3-0.8	0.2-4	800-2100
One-stand non-reversing (capable to work in reversing regime)	500	1400	1800	2 x 4500	14	5-10	0.3-3	800-1560
Continuous tandem	650	1400	2800	2 x 4000	4	4-10	0.5-3	1200-2500
Continuous 3-stand	550	1300	2040	3 x 4500	18	2-8	0.4-3.5	1000-1800
Continuous 5-stand	500	1525	1800	2 x 1830 each stand	20	1-3 3-6	0.15-1.8	800-1500

To achieve high productivity in large-scale production of thin bands (narrow strip), *multi-stand continuous mills* are used. They are more economizing compard with the same stand quantity one-stand mills.

Rolling speed upper limit is around 25-30 m/sec.

One of basic conditions of high grade of CR band is *quality of working and support rolls,* which must demonstrate high abradability, hardness. Proper exploitation of rolls provides their quality and prolongs their service life. Eroded rolls are subjected to repeated polishing.

In cold rolling of aluminium and its alloys, as lubricants, light mineral oils with surfactants are used. The lubricant must have shielding ability and low kinematic viscosity that is achieved by addition of special additives with surfactants.

Applying the lubricans andhigh speeds of cold rolling require equipping CR mills with powerful automatic fire-fighting systems and plenum ventilation (with capture and condensation of oil vapor, for which volume folters are used).

Finishing of flam-rolled aluminium

Finishing is designated for obtaining flat-rolled semis of pricise geometry with improved surface quality. The rolled to final thicknes sheets, plates and bands are subjected to the following operations: straightening, flattening (restriking), cutting to final size, coating, control, labeling, conservation and packing.

Flat semis from heat-strengthened alloys are subjected to heat treatment (hardening and tempering), and non-heat-strengthened alloy semis are subjected to mechanical hardening or annealing. Commonly thin sheets below 3 mm thick are treated in coils at continuous heat-treatment and stretch straightening lines, and thick sheets 4-10.5 mm and plates piece by piece at special lines.

Stretch straightening is traditionally conducted at roll straihtening machines. Later facilities for continuous stretch straightening thin strip were created, providing, compard with the common design, higher productivity, lesser waste origination and straightening “in stream”.

Thick hardened sheets from alloys AV, D16, V95, AK4-1, 1201 4-10.5 mm thick are cut and subjected to stretch straightening at multi-roll straightening machine are hardened and then treated at special finishing line.

The line treats hardened sheets 1200, 1500, 2000, 2500 mm wide and 4-10 m long, including the following operations: preliminary straightening, straightening at 4-roll mill 2800 at 3-5 passes at toytal reduction up to 2%, flattening at stretching machine at reduction 2-3%, side shearing (trimming) with cut to lengths, final straightening, evenness control, sheet labeling, oiling and packing.

The line is compose of the following devices: vacuum stacker, 13-roll sheet-strightening machine, 4-roll mill 650/1300x2800 for straightening and mechanical working; stretch straightening machine; Tandem guillotine shears with bottom cut, 13-roll straightening machine for straightening sheets 4-10.5 mm thick; control plate, sheet-labelling machine; manipulator mechanism, sheet oiler, packing facility (vacuum stacker).

Thin sheets are obtained by cutting coils in annealed or CR state.

The finishing line for thin hardend sheets (from alloys AV, D1, D16, V92, V95, AK4-1 and other) treats sheets of sizes 0.5-4x1200-2000x1500-7000 mm. The line compositionis as follows: vacuum stacker, belt transporter, straightening machine, 17-roll sheet-strightening machine, 2- roll mill 900x2800, transfer device, stretch straightening machine, tandem shears, feed table, first control plate, manipulator mechanism, second control plate, sheet-labelling machine sheet oiler, packing facility.

Mechnical working is conducted at 2-roll mills in 10-20 passes at total reduction of 5%.

Continuous strip stretch straightening line is designated for stretch straightening and trimming. At the line, CR and annealed coils are treated. The line includes: conveyer accumulating mechanism for 3 coils, de-coiler, wedge drum, drive roll, shears for cutting tie band, undender unit, straightening device on 3 rolls, flying shears, inclined table, pulling rolls, circular shears, scrap ballr, hydraulic type stitcher, stretch device with 4 working rolls and 2 pressure rolls, straightening machine with group of straightening rolls, stretch device, drive of stretch devices, inspection table for visual control of flatteness, guillotine shears with top cut for cross cutting, console winder, belt wrapper, conveyor for finished coils, strapping device.

Slitting line is designated for trimming and sliting strip. The line is composed of the same facilities as the straightening line, excluding disk shears, stitcher and guillotine shears (the latter are replaced with multi-disk slitting shears.

Continuous heat treatment line is designated for continuous hardening and annealing, as well as straightening strip, plus cutting to sheets is possible. The line receives CR strip withvarious degree of mechanical working.

Proces of treatment at technological lines consists in annealing and hardening in throough-type furnace at controlled stretch.