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New cast alloy on basis of quasibinary section of the ternary system Al-Mg-Si (X)

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Production of Al ingots and rods, metallic glasses (ribbons and bulk), powders of aluminum alloys, ingots of different transition metals and alloys.

Materials in investigation:

Al and aluminum alloys (wrought, cast, PM and aluminum foams), metallic glasses, quasicrystals, intermetallics, covalent crystals, ceramics, refractory metals and alloys (Cr, Mo, W) and coatings.

Methods of investigations:

1. Mechanical test (tension, compression and bending) in vacuum and the temperature interval (-196 - +1400 ^{o}C).

2. Indentation testing (-196 - +1000 ^{o}C), determination of complex mechanical properties, including plasticity.

3. TEM, SEM, Auger spectroscopy, light microscopy.

4. Hardware-software complex for automatic registration and processing of acoustic emission (AE) signals while indentation.

5. High-temperature (up to 2200 ^{o}C) DTA unit.

6. Units for investigation of tribological characteristics.

Hardware-software complex for automatic registration AE signals

Unit for investigation of tribological characteristics

Melting of aluminum alloys

Production of melt-spun ribbons

- Cast aluminum alloys
- Cast aluminum alloys on the base of intermetallic Al_3Ti
- High-strength aluminum alloys
- Heat resistant aluminum alloys strengthened by quasicrystalline particles
- Metallic glasses
- Aluminum foams

High-strength wrought Al-alloys containing Sc

High-strength Al-alloys containing Sc were elaborated. These alloys may be produced by casting and by PM.

Mechanical properties of standard Al-alloys and Al-Sc alloys

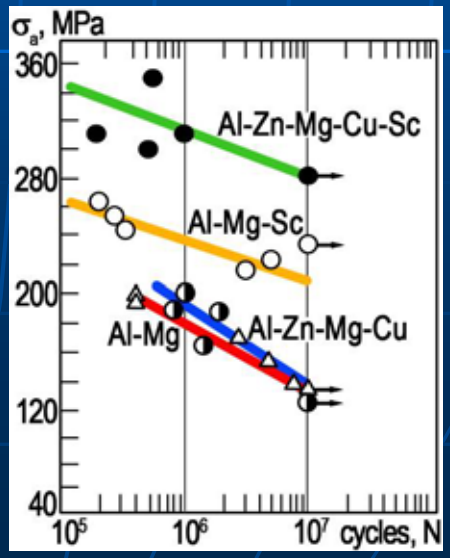
Desig-nation of alloy	Standard alloys			New alloys, alloyed by Sc in additions Cast technology / PM techology		
	YS, MPa	UTS, MPa	El, %	YS, MPa	UTS, MPa	El, %
	Al – Mg					
1570(Russia)	300	400	15			
AMr(Russia) 5056(USA)	180	300	20	480 / 510	520 / 570	10 / 8
	Al – Mg – Li					
1420(Russia)	290	440	11	540	590	6
	Al – Zn – Mg					
7046(USA)	420	470	12	530 / 600	590 / 650	12 / 8
	Al – Zn – Mg – Cu					
B95(Russia) (7075 USA)	550	580	8	740 / 750	810 / 800	10 / 8

Further increase of the level of mechanical properties of aluminum alloys is possible with using additional alloying by Sc in combination with other transition or rare-earth metals.

It was shown that alloys with a record level of strength YS = 700-740 MPa, UTS = 770-820 MPa with a rather good plasticity of 9-14 % in T6 semi-products can be produced.

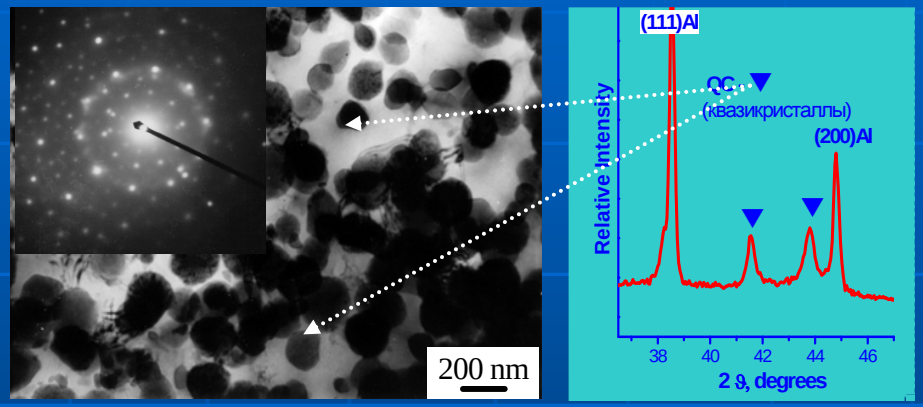
New alloys have good weldability. Sc-alloying of Al-alloys increases corrosion resistance in the sea-water, maybe possible to use the recycled aluminum with high concentration of Fe and Si [Yu.V.Milman et al, 2006].

The alloying of the system of Al-5Mg with Sc increases fatigue limit (σ_a) at 60 % and crack resistance in 2 times; for the system Al-Zn-Mg-Cu increasing of fatigue limit in 2 times.



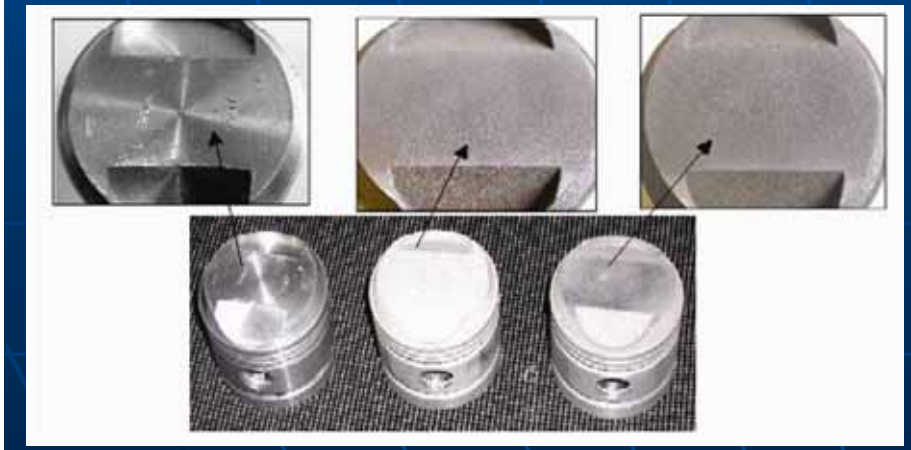
Elaboration of structural aluminum alloys with quasicrystalline reinforcement for temperature application

Quasicrystals combine high hardness (6-10 GPa), high elasticity modulus (to 140 GPa), high wear resistance, low friction coefficient (in certain conditions lower than 0.1), comparatively low density (about 4.7 g/cm^3), increased corrosion resistance and low thermal conductivity on the level of ceramic materials.



Chemical composition, at. %	20 °C			300 °C		
	YS, MPa	UTS, MPa	EL, %	YS, MPa	UTS, MPa	EL, %
AlFeCr	421	473	12.0	245	270	5.8
AlFeCrTi	470	534	8.0	286	312	5.4
AlFeCrZr	584	615	5.1	265	302	3.2
AlFeCrTiZr	588	620	5.4	307	332	3.0

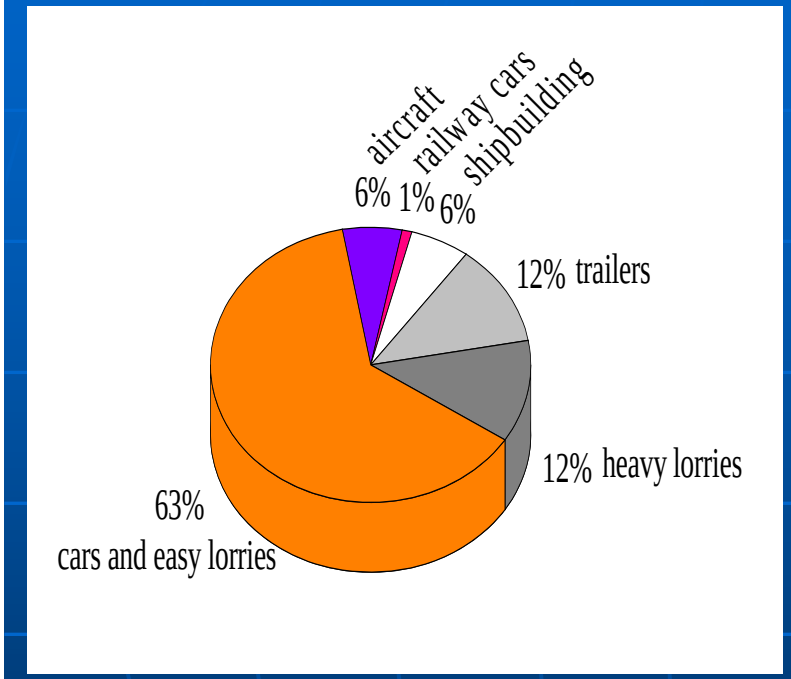
Production of quasycrystalline Al-Cu-Fe powder by water atomization technique for heat-protective coatings. Structure and mechanical properties of coatings



Composition	Density ρ, Kg\m^3	Thermal expansion coefficient αx10^{-6}, K^{-1}	Thermal conductivity coefficient λ, Wm^{-1}K^{-1}
Fe	7870	11. 39	73. 3
Al	2700	23.3	243
Al_2O_3	3080	8.7	3.4
$ZrO_2 - 8\%Y_2O_3$	5700	10.3	1.8
Q.C.standard	3770	14	2.3
Q.C. experimental (Al-Cu-Fe-Sc)	3800	14.6	1.66

Problem Description & Market Need

Use of aluminium alloys in the world market of transport



The forecast of consumption of aluminum alloys in transport, 2004.....2019 years

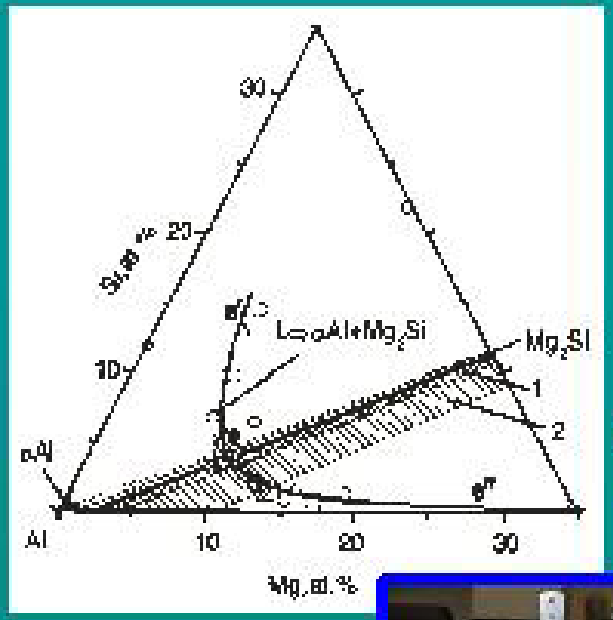
[Metallosnabzhenie & Sbut, 2004, No 1]

- casting	69 %
- sheet	17.8 %
- stamping	7.4 %
- forging	5.3 %

By forecasts, the share of Al-base alloys in cars will grow almost twice at the running decade. It is worth noting that the majority of them, namely almost 70%, is cast alloys

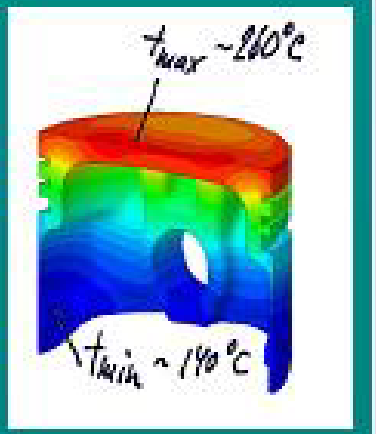
[First International Conference Aluminium in Transport, Moscow, 2005]

Development of new advanced cast eutectic alloys



Casting alloys for pistons based on ternary system Al-Mg-Si with increased level of physical&mechanical properties

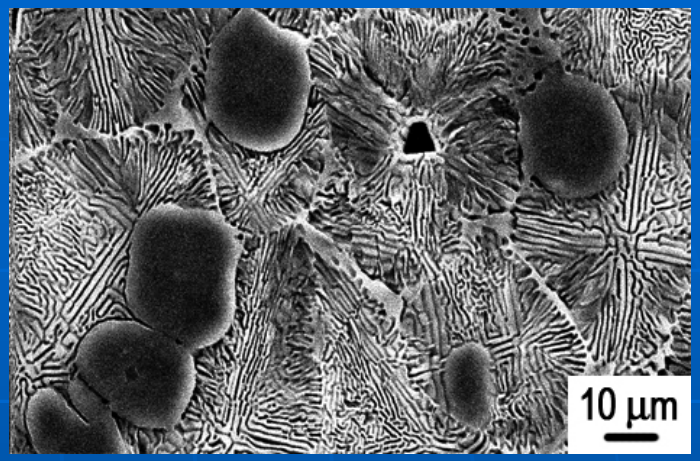
On the whole a technology of production of a large ingot with its weight of up to 20 kg was developed.



Novel high-strength cast eutectic aluminum alloys

The fundamental authors' works in the fields of phase transformations are the physical base for creation of the new cast aluminum alloys, which according to their physical and mechanical properties exceed modern cast high strength aluminum alloys.

New cast alloys are created on a basis of the quasibinary (α-Al+Mg_2X) section of the ternary system Al-Mg-X.



Microstructure of eutectic (α-Al+Mg_2X) alloy

Due to purposeful alloying the different systems of particles which should not interact with eutectic colonies and are stable in certain temperature intervals were created in the matrix of eutectic alloys. According to that, the two groups of alloys have been developed: for operating an ambient temperature (Type I or Type II) and for high-temperature application (Type III) as well.

Alloy	Testing temperature,°C	Mechanical properties			Temperature interval of melting, °C
		UTS, MPa	YS, MPa	δ, %	
Type I	20	540-660	490-620	1-2	590-620
Type II	20	310-501	300-460	< 1	575-590
Type III	20 260 315	240-330 180-203 102-130	225-275 146-164 91-115	< 1.5 5-10 13-15	595-599

Advantages

in accordance with GENERAL SPECIFICATION OF THE CAST ALLOYS the developed Al-Mg-Si eutectic alloys are 6XXX NOVELTY

1XXX – Aluminum, ≥ 99.00% min aluminum

2XXX – Aluminium - Copper (Cu) alloys

3XXX – Aluminium – Si+Mg, Si+Cu, Si+Cu+Mg

4XXX – Aluminium - Silicon (Si)

5XXX – Aluminium - Magnesium (Mg)

6XXX - Aluminium (**Al**) **+** Magnesium (**Mg**) **+** Silicon (**Si**)

UKRAINIAN TEAM PIONEERED IN FILLING 6XXX ROW

7XXX – Aluminium – Zinc (Zn) + Magnesium (Mg)

8XXX – Aluminium - Tin (Sn)

Novel high-strength cast eutectic aluminum alloys

The essential advantage of new alloys is the combination of high mechanical, tribology, corrosive properties and excellent castability. The yield strength of new cast eutectic alloys by prior estimate exceeds this characteristic for available cast eutectic aluminum alloy 356.0 (USA) in all temperature intervals of test, and the specific strength of these alloys exceeds 4135 steel (USA) in 1.5 times.

The certain alloy compositions were patented

The new (α-Al+Mg_2X) alloys could be the potential candidate for replacing of the some of commercial alloys. The high mechanical and technological properties of the new alloys will enhance their service life and durability, and thereby ensure an increment of the performance attributes.

Ukrainian research team can make the whole research cycles from target setting up to marketable product due to the most modern ideas and available technology

www.cast-alum.org.ua

Competitive Matrix

Important product or technology characteristics	Ukrainian product	MSFC-388 NASA	Aluminium Rheinfelden Magsimal-33^{TM}
Mechanical properties in tensile test *at room temperature* ■ UTS [MPa] ■ δ [%]	 290-285 1.0-1.5	 277 0.5	 200-220 3-5
at 315 °C (a) UTS [MPa] (b) δ [%]	 195 1.8	 187 2.5	 N/A
Solidification temperature range [°C]	610-590	619-486	N/A
Cost [$ / kg]	5.2 - 6.2	N/A	7.5-10.5
Density [10^3 kg/m^3]	2.59 – 2.61	2.76	2.61 – 2.65

Stage of development

- Bench tests completed
- Ukrainian and Russian patents on basic technology
- Next step to do suitability and shop tests
- Need to apply for International application (PCT)

Competition

- New aluminium cast alloys on the basis of Al-Mg-Si system have some preferences over *SILUMINS* (Al-Si systems) :
- High strength, heat resistance and wear resistance;
- Excellent casting characteristics;
- Lessening of weight due to high magnesium content which is very essential for modern engines. It leads to drop of a fuel consumption and
- improvement of ecological conditions in cities and on the highways.
- *Suitable for low cost mass production* using conventional casting methods, such as permanent mold casting, die casting, and sand casting

We had cooperation with AFORCE Dayton USA, EARD Germany and keep on project with Boeing USA.
We look forward to participate in Aero-Ukrainian Consortium.