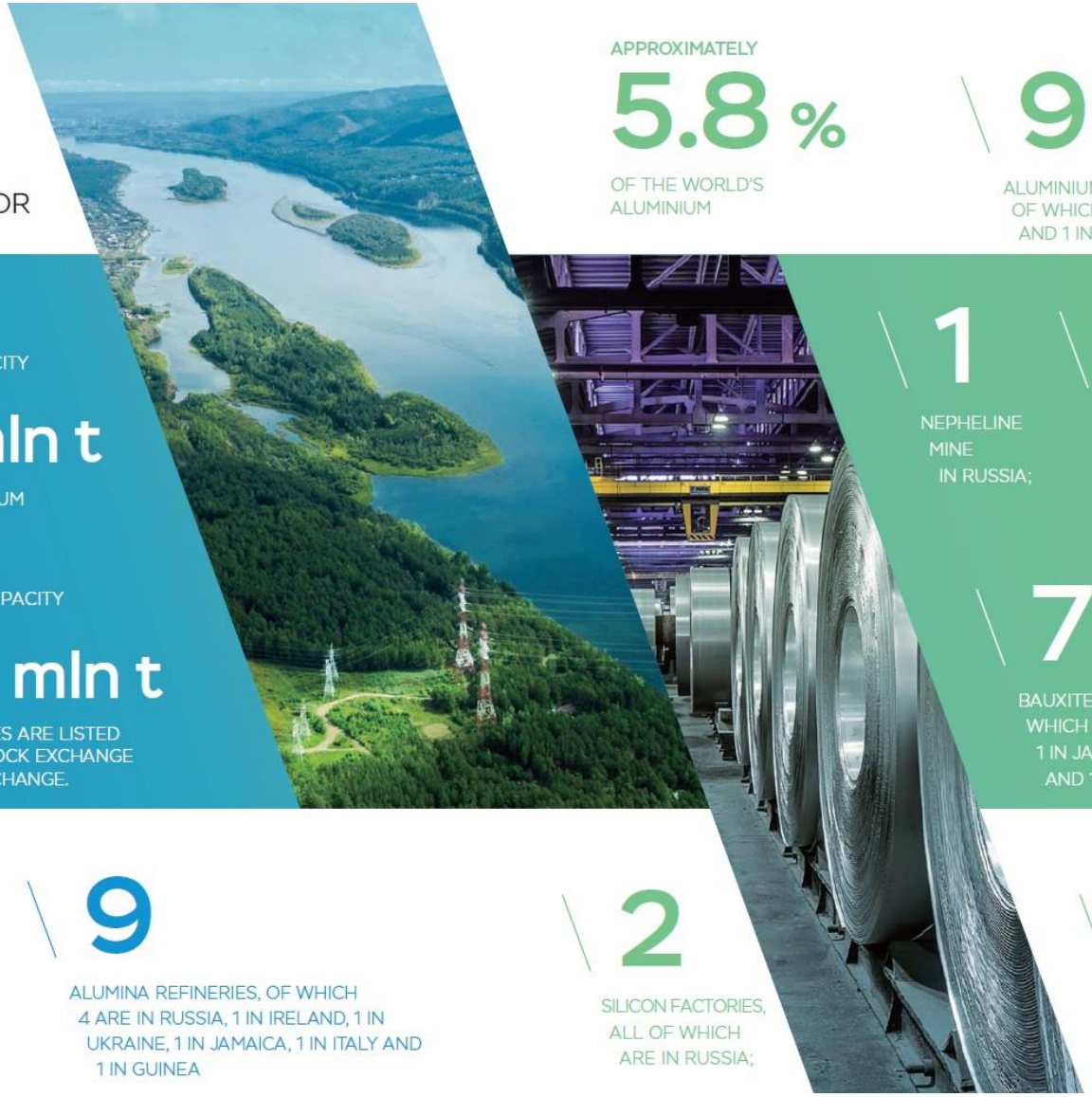
ADVANCED ALUMINIUM PRODUCTS FOR HIGH-TECH INDUSTRIES

KEY FACTS IN 2020

RUSAL ACCOUNTED FOR

APPROXIMATELY
5.8 %
OF THE WORLD'S ALUMINIUM

9
ALUMINIUM SMELTERS, OF WHICH 8 ARE IN RUSSIA AND 1 IN SWEDEN



ALUMINIUM PRODUCTION CAPACITY
3.76 mln t
RUSAL IS No.1 LARGEST ALUMINIUM PRODUCER OUTSIDE CHINA

ALUMINA PRODUCTION CAPACITY
8.18 mln t
RUSAL'S ORDINARY SHARES ARE LISTED ON THE HONG KONG STOCK EXCHANGE AND THE MOSCOW EXCHANGE.

1
NEPHELINE MINE IN RUSSIA;

4
FOIL MILLS, OF WHICH 3 ARE IN RUSSIA AND 1 IN ARMENIA;

7
BAUXITE MINES OF WHICH 2 ARE IN RUSSIA, 1 IN JAMAICA, 3 IN GUINEA AND 1 IN GUYANA;

ABOUT
6.5 %
OF THE WORLD'S ALUMINA PRODUCTION

9
ALUMINA REFINERIES, OF WHICH 4 ARE IN RUSSIA, 1 IN IRELAND, 1 IN UKRAINE, 1 IN JAMAICA, 1 IN ITALY AND 1 IN GUINEA

2
SILICON FACTORIES, ALL OF WHICH ARE IN RUSSIA;

2
WHEELS FACTORIES SITUATED IN RUSSIA.

In 2017 RUSAL set up new R&D center – Institute of light materials and technologies (LMTI)

Strategic goals

- Development of the new high VAP, technologies of their production and application (alloys, composite materials, ceramic and reinforcement materials)
- Scientific and technological support of production and implementation of the new products and solutions into industry
- Forming of the industrial scientific cluster of consumers and developers for the expanding aluminium products to the new markets

LMTI Staff

42 employees 15 of whom has PhD degree

Location: Russia, Moscow, Leninsky av. 6-21

LMTI competencies

Department of casting alloys
- Advanced alloys
- Casting technologies
- Combined technologies for the production

Department of additive technologies
- Materials for 3D printing
- Technologies for printing parts
- Production of powders

Department of wrought alloys and composite materials
- Alloys and MMCs
- Extrusion, drawing, rolling, forging processes

Department of chemical technologies
- New non metallic products
- Alloying and reinforcement materials
- Technologies for fluorides and rare-earth materials

More than **12** current R&D projects

More than **20** partners within Russian and foreign universities and companies

More than **20** в types of new products under development

LMTI Testing center (ISO 17025:2017 certified)

- Casting and heat treatment site
- Machining, sawing and drilling site
- Laboratory of simulation and modelling
- Laboratory of physical investigations
- Laboratory for mechanical testing
- Laboratory of corrosion
- Metallography and chemical analysis

Laboratory of mechanical testing

Metallography

Chemical analysis

Laboratory of corrosion

Physical properties determination

Wrought alloys

Low cost Sc containing alloys

21 Sc Scandium

RUSAL ensures a reliable supply of the rare earth Scandium

Own advanced technology for Scandia leaching from red mud

Scandia further processed to AlSc2 master alloy by original energy efficient process

RUSAL developed low Sc aluminium alloys to meet market needs and make Sc market attractive

5081 alloy (Al-Mg-0,1Sc)

- Can compete with 6XXX and 2XXX alloys;
- Internal project with Russian space agency;

5181 alloy (Al-Mg-0,03Sc)

- Developed for marine application;
- Cost effective with cross section reduction;

CO_2

RUSAL enhances its own environmental credentials and ones of customers

All alloys are implemented and tested within real metallurgical production in Russia and Europe

Wrought alloys

Low cost Sc containing alloys

5081 (0,1 Sc) alloy is implemented into production and will be used for the space application as the substitution of Al-Cu and Al-Mg alloys

Even with just 0,03% Sc you can get:

>10%

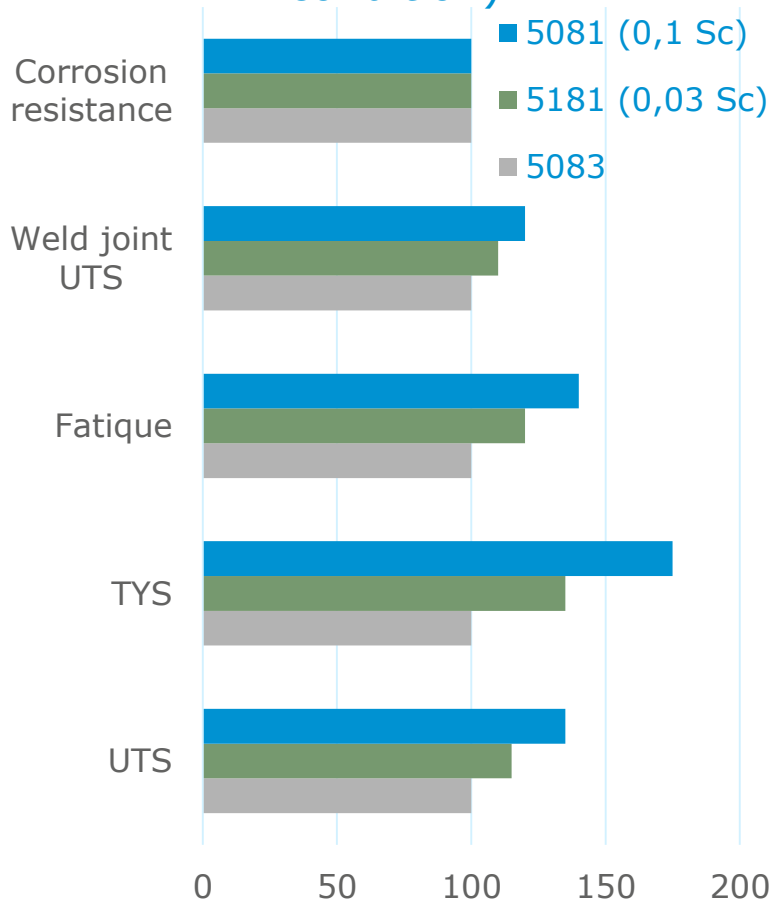
minimum operational cost reduction due to lighter weight and longer lifespan

>25%

higher yield & fatigue strengths

Potential application: automotive, marine

Sc vs 5083 alloy (in annealed condition)



Wrought alloys

Alloys for building constructions

Designed for extrusion performance with improve corrosion properties

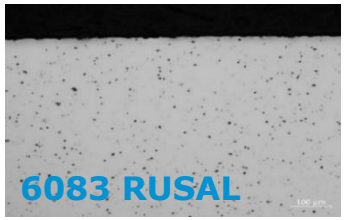
RUSAL 6083 alloy compare to 6082 alloy

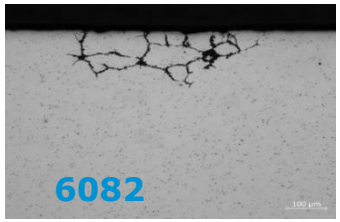
+ 7 % Average increase endurance limit
σ-1 (2*10⁷ cycles) = 95 MPa

NO Tendency to intergranular corrosion

+20% Average increase *strength of welded joint*

Alloy	Tensile strength, MPa		
	UTS, MPa	YTS, MPa	σ, %
6083 RUSAL	320	290	12
6082	314	245	8





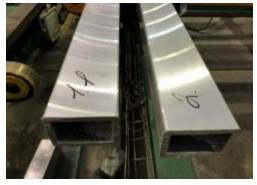
RUSAL 1939 alloy compare to 7005 type alloy

+ 10 % Average increase endurance limit
σ-1 (2*10⁷ cycles) = 110 MPa

+23 % Average increase yield strength

+17% Average increase stress corrosion cracking
290 MPa

Alloy	Tensile strength, MPa		
	UTS, MPa	YTS, MPa	σ, %
1939 RUSAL	400	320	14
1915	373	245	8



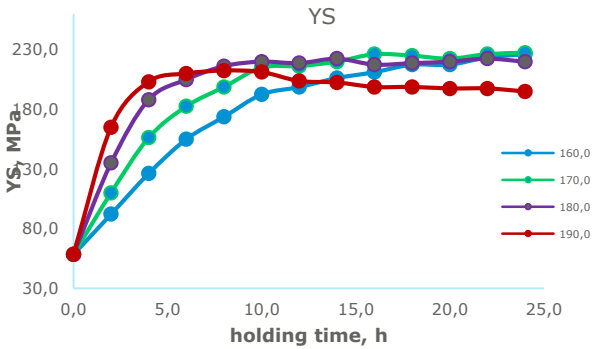
An increase in corrosion resistance leads to an increase in the structure service life by 10–15%

Wrought alloys

MaxiFlow family

This is special brand of RUSAL 6XXX billets which were designed for better extrusion performance while its chemical composition and strength performance are in fully accordance with specifications.

Geography of successful trials



Each alloy has own aging curve in order to adjust aging treatment

9 alloys of 6XXX series (both hard and soft) are developed under MaxiFlow brand

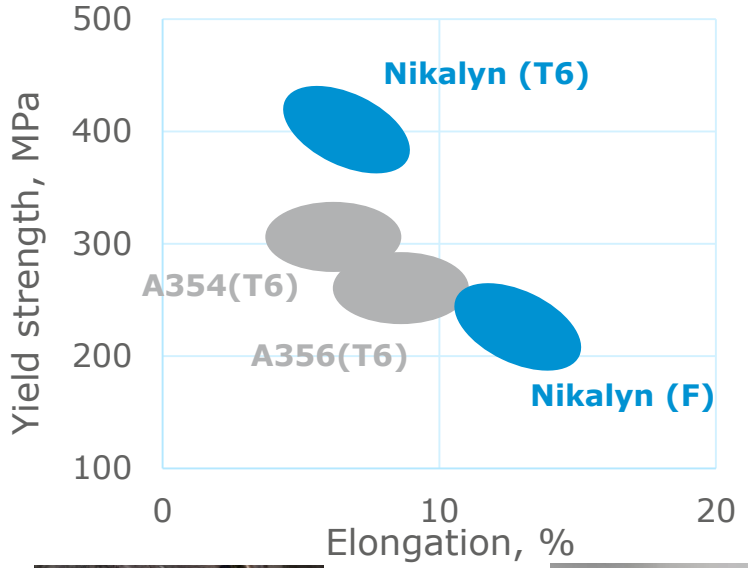
20% Average increase in extrusion speed for soft alloys (6063, 6060)

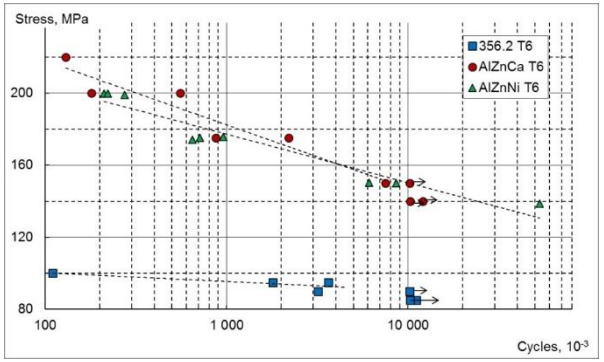
10% Average increase in extrusion speed for hard alloys (6061, 6005, etc.)

Casting alloys

High strength alloys for lightweight applications

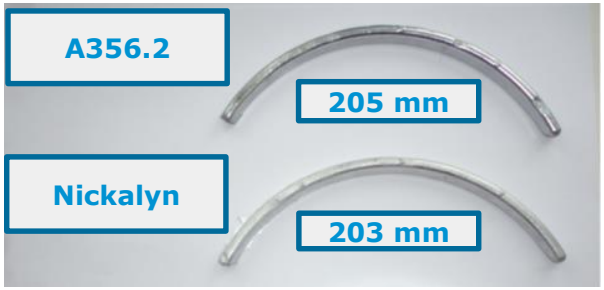
Designed for Low-pressure and gravity casting with improved performance





>30%

higher yield & fatigue strengths

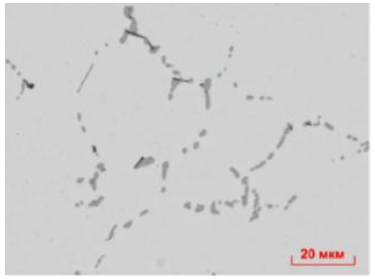


Same

Castability due do eutectic design

Automotive wheels

Steering knuckle



Al-Fe-Ni eutectic

Casting alloys

Heat treatment free alloys for price efficient applications

New line of alloys adapted for use without quenching after casting

Alloy	UTS, MPa	TYS, MPa	El, %
Al-Ca	250	130	8
Al-Mn	190	90	15
Al-Zn-Mg	275	170	7

No

Distortion of parts due to absence of quenching

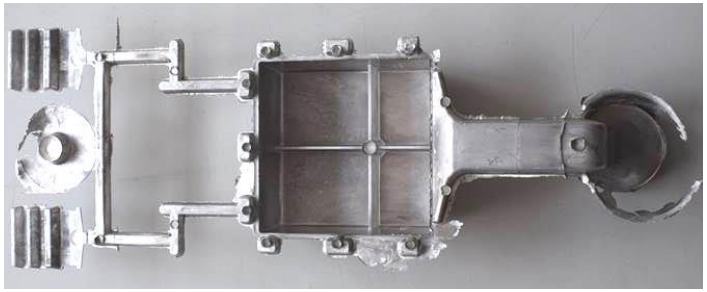
HPDC

Adapted (proved during casting at various sites)

Up to 20%

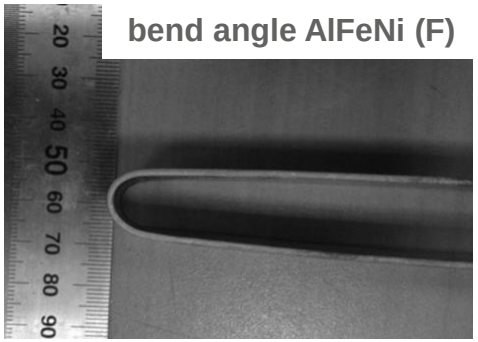
Decrease in cost due to strength, elimination of heat treatment

Supports from Al-Ca alloy



Housing from Al-Zn-Mg alloy

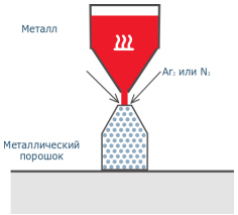
bend angle AlFeNi (F)



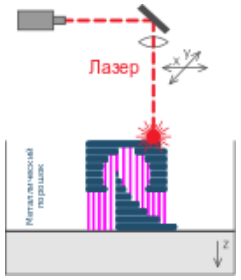
casting properties

Suitable for riveting

Additive technologies center of RUSAL



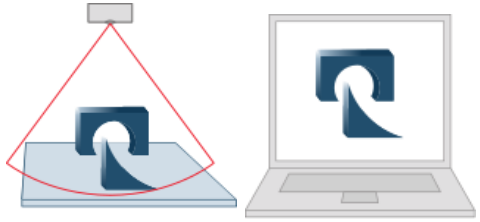
Powder production



3D-printing

Post-treatment

+



Reverse-engineering

Simulation of printing process

Material properties

Engineering

Full cycle for creation of final products

Atomizer BluePower AU12000

3D-printer EOS M290

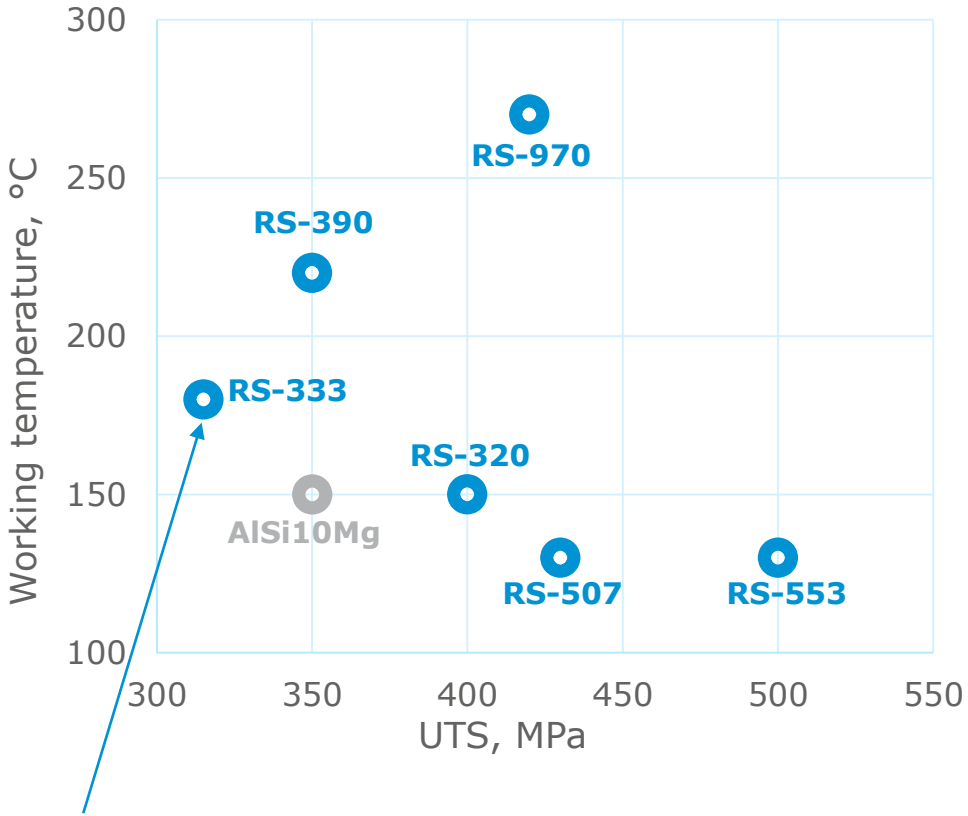
3D-scanner Kreon Ace Skyline

3DExperience Software

Additive manufacturing

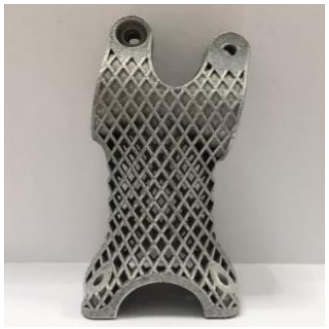
Aluminium alloys of new generation

Designed for additive with better strength and heat stability

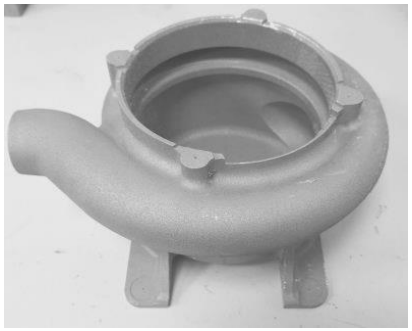


RS-333 – alloy with increase heat conductivity by 30%

Successfully tested for

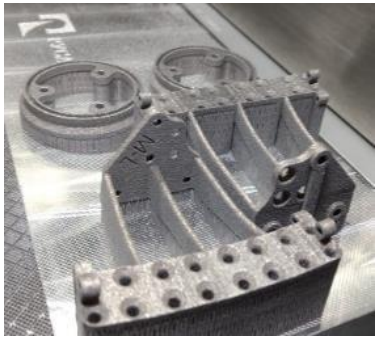


Sport goods RS-553



Air conditioning element RS-300

Heat exchanger for space RS-333



Elements for exoprosthesis RS-333

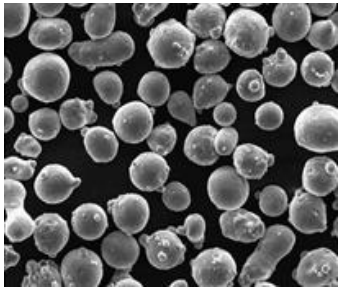
High-strength low-Sc RS-553. Mechanical Properties

RS-553 is a corrosion resistant Al-Mg-Sc alloy with improved performance in heat treated state. The parts or samples do not require solution treatment followed by quenching. Sc concentration was adjusted so as to provide an optimal high tensile characteristics to price ratio.

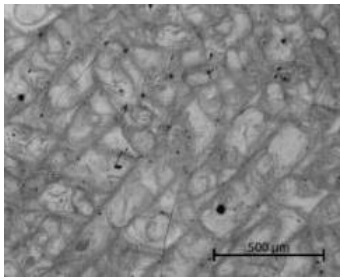
Mechanical properties in annealed state		RS-553 (0,3 % Sc)	AlMg0,8Sc*	2024-T3*
Modulus of elasticity, GPa	XY	**72**	72	73
	Z			
UTS, MPa	XY	**495**	520	440
	Z	**490**		
TYS, MPa	XY	**440**	470	290
	Z	**435**		
El., %	XY	**14.5**	13.0	10.0
	Z	**12.7**		

Other tests' results	
Modulus of compression elasticity , GPa	71.9
Compression YS, MPa	474
Hardness, HV	150
Fatigue crack growth rate, 10^{-4} mm/cycle XY Z	 3.58 5.02

Physical Properties	
Density, g/cm^3	2.64
CTE, 1/K · 10^{-6}	23.2
Thermal conductivity, W/m·K	126.8
Heat capacity, J/kg · K	928
Electrical resistivity, Ohm · mm^2/m	0.062



Spherical powder
O_2 content ≤ 0.08 %
H_2O ≤ 0.03 %



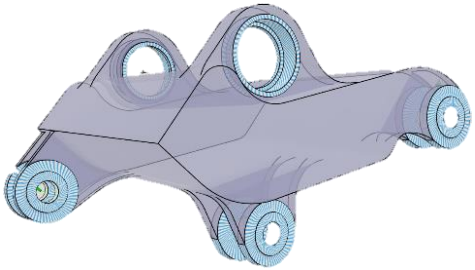
Porosity of the printed material
< 0.5 % vol.

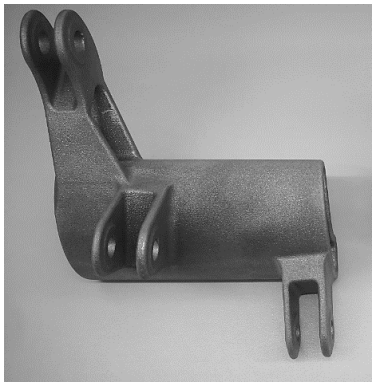
Properties are approved for 2 commercial batches in certified laboratory

*** Matweb, Airbus (datasheet)**

Additive manufacturing

Original part

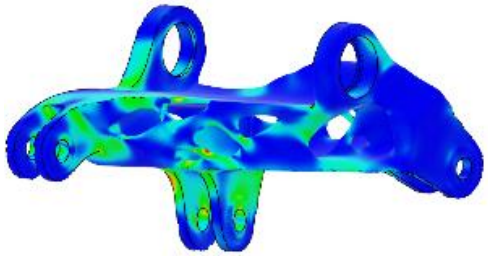




AlSi7Mg (die casting)

Weight - 641 g

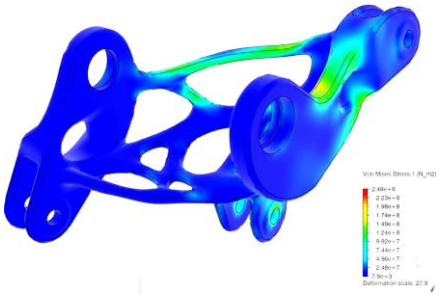
Concept 1



RS-320 (3D printing)

Weight - 544 g (-15%)

Concept 2



RS-553 (3D printing)

Weight - 370 g (-33%)

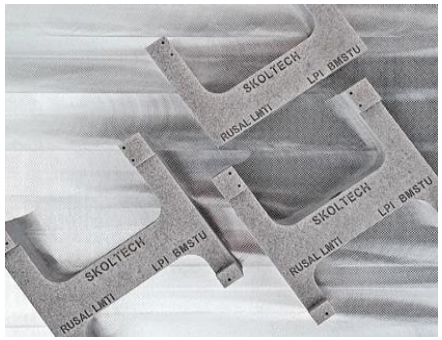
New materials together with new approaches for part design allow to achieve significant weight reduction

High thermal conductive RS-333 alloy

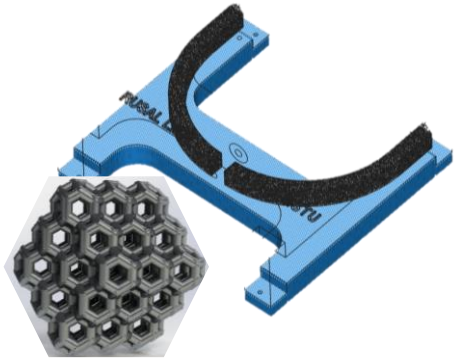
RS-333 is a novel high thermal conductive alloy with medium strength. High thermal conductivity is achieved after low temperature aging. No solution treatment followed by quenching are required for the parts.

Typical mechanical properties			
Material	**RS-333 annealing**	6061* T6	6063* T6
UTS, MPa	**315**	310	241
TYS, MPa	**235**	276	214
Elongation, %	**16**	17	15
Thermal conductivity, W/m · K	**185**	167	200

Other properties	
Density, g/cm^3	2,66
Porosity, vol. %	≤ 0,20
Corrosion rate, g/cm^2·24 h	0,26



Thermal management unit for gamma-detector in the satellite "Yarilo"



Internal cell structure with the size 0,3 microns

Weight reduction:
25%

Increase of heat flow
20%

Production time
40 hours

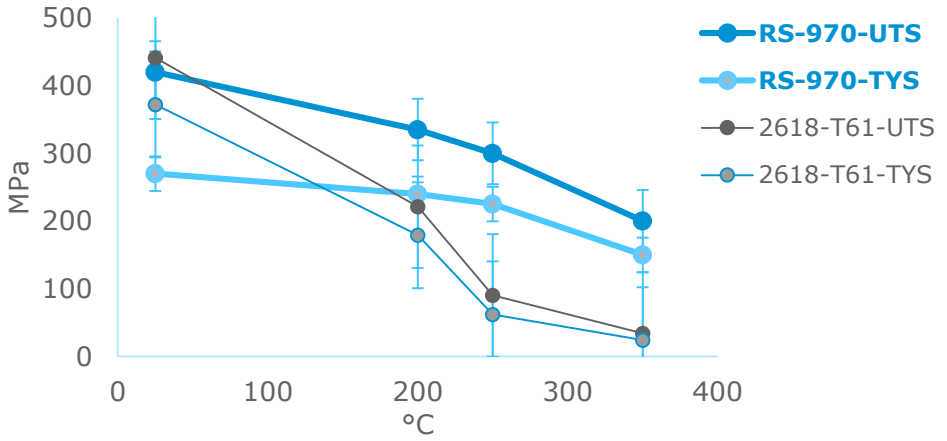
*Matweb Database

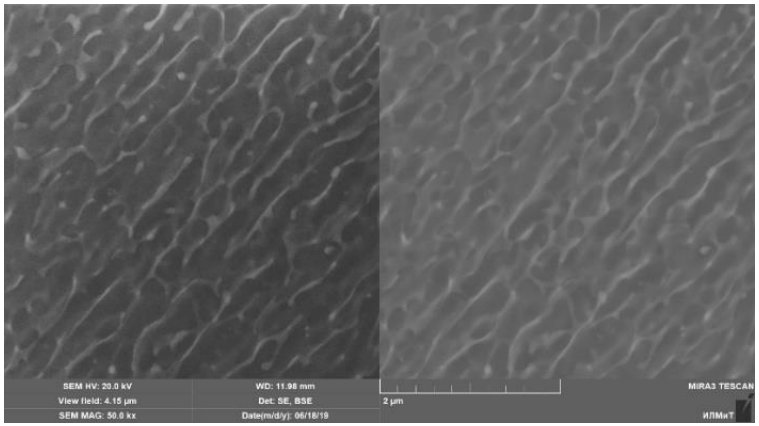
Heat resistant RS-970 alloy

RS-970 is a novel heat-resistant alloy with medium strength characteristics stabilized by transition metals additives. This alloy shows good processability via PBF and good as sintered properties without dramatic reduction during stress relief treatment. No solution treatment followed by quenching are required for the parts.

Typical mechanical properties			
Material	**RS-970 annealing**	2219-T851* plate	2618-T61* forgings
UTS, MPa	**420**	400	430
TYS, MPa	**270**	290	380
Elongation, %	**6.0**	6.0	7.2

The alloy demonstrates thermal stability up to 350 °C





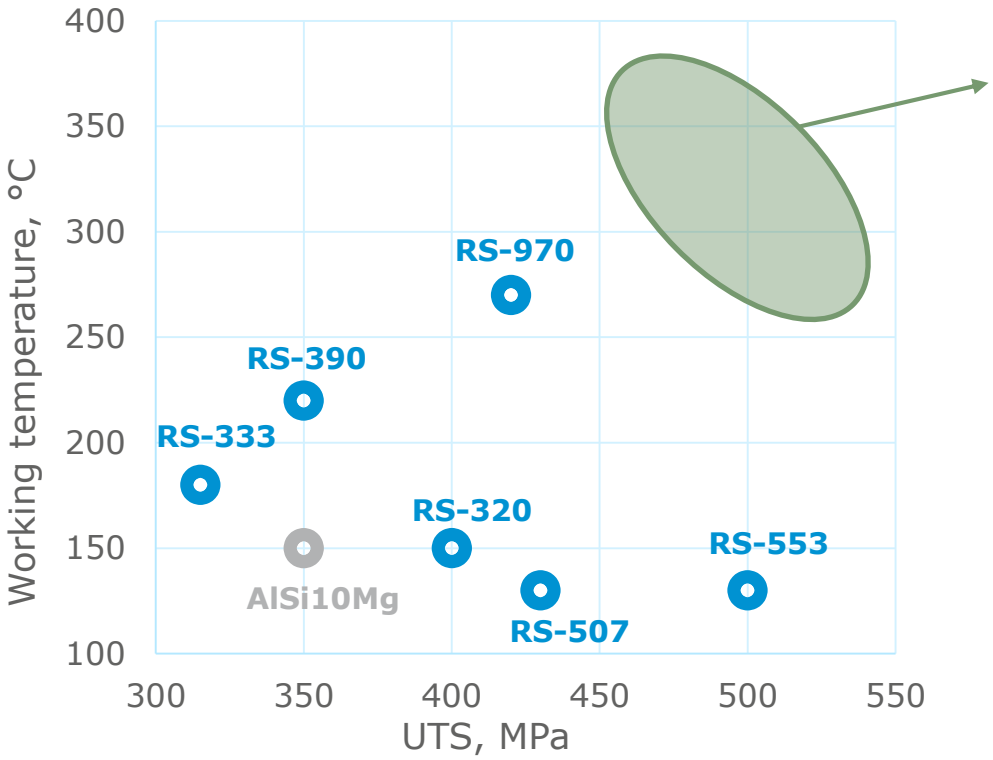
SEM image of the RS-970 as-printed structure

Physical properties	
Density, g/cm^3	2,9
Porosity, vol. %	≤ 0,20

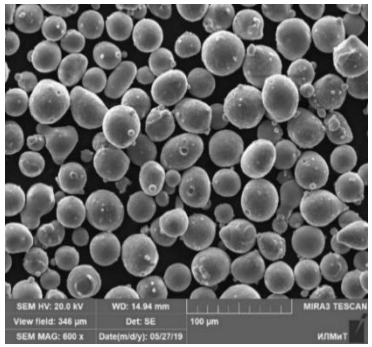
*John Sessler «Materials Data Handbook», Matweb Database

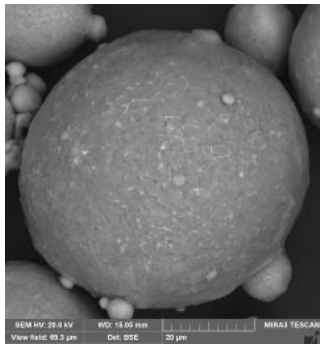
Additive manufacturing

Aluminium alloys of new generation



Potential area of the new material with advanced properties





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