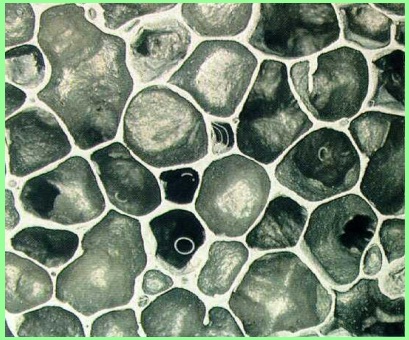
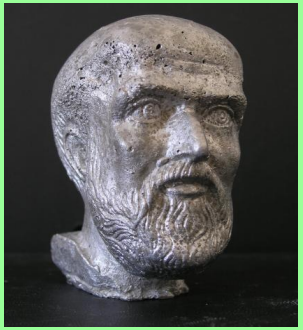
Lighweight materials for future cars





Fero Simančík

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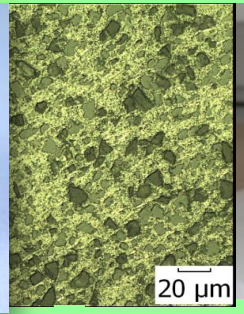
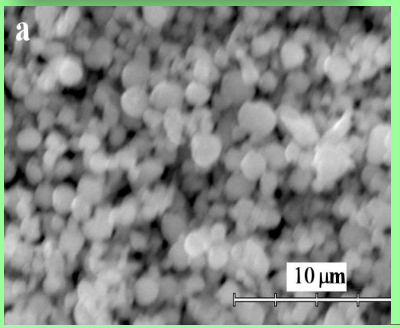
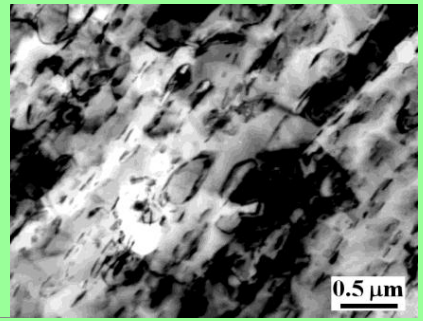
Ján Spišak

Technical University Košice

TECHNICKÁ UNIVERZITA V KOŠICIACH

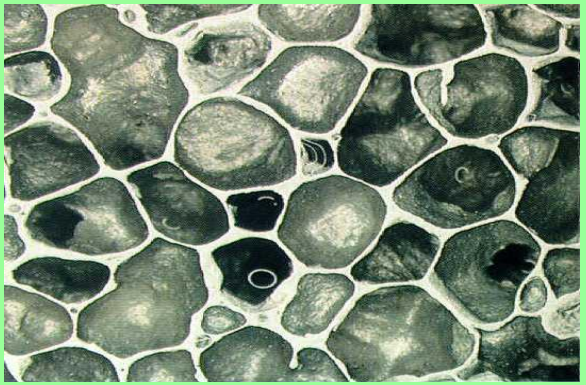



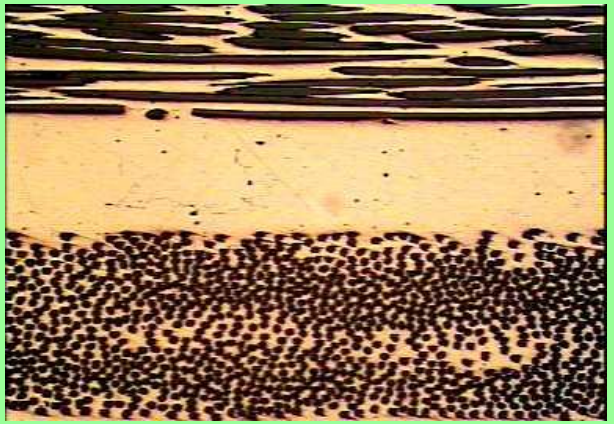


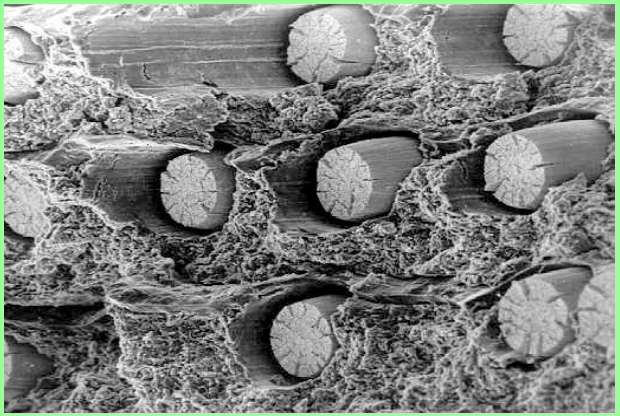
2nd Symposium on Innovation, cooperation in technology and international transfer of technology
China + 16 CEEC Format, Slovak Republic, September 21. – 23. 2015

Development of advanced materials

- Metal matrix composites
- FGM
- Metallic foams
- Intermetallics
- Nanostructured bulk metals
- Ultrahard coatings







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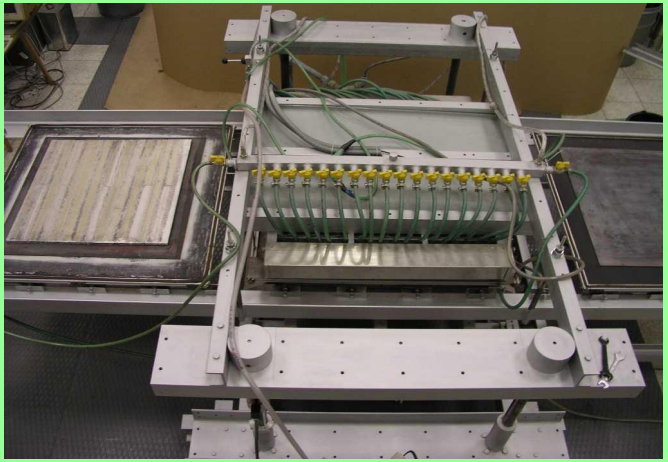
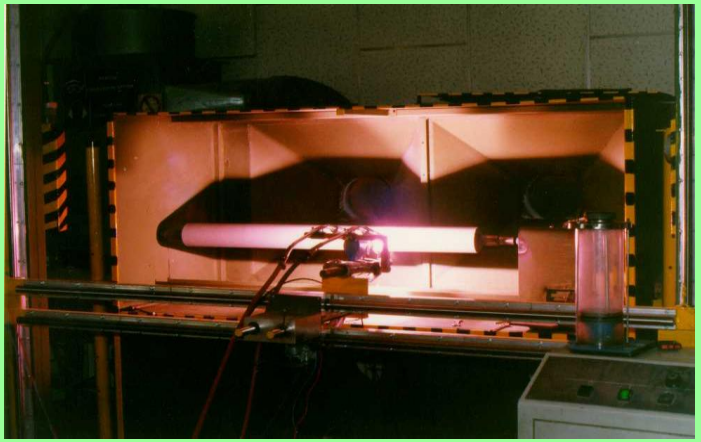
Development of modern technologies

- Gas pressure infiltration
- Plasma spraying
- Foaming of metals
- Advanced solidification processes
- Rapid prototyping
- Powder metallurgy
- PVD, CVD





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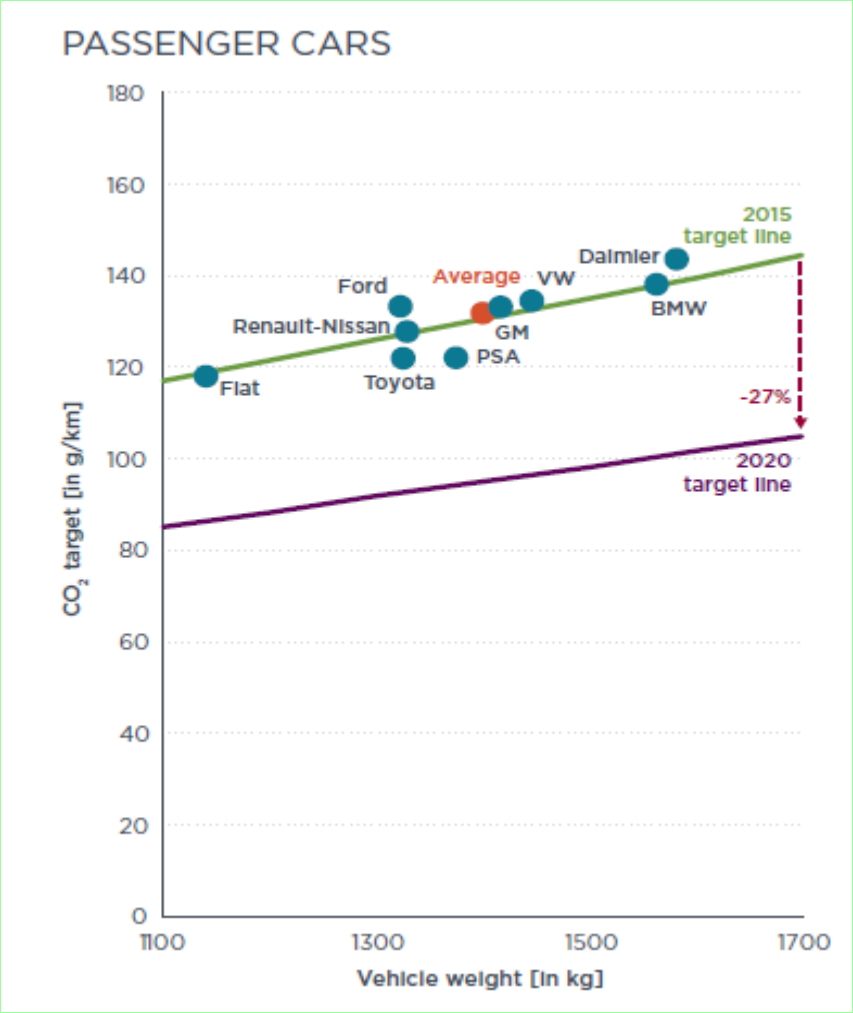
CO2 limits for cars – strong motivation for lightweight construction

EC directive: *2015 - 130 g CO2 / km* *2020 - 95 g CO2 / km*



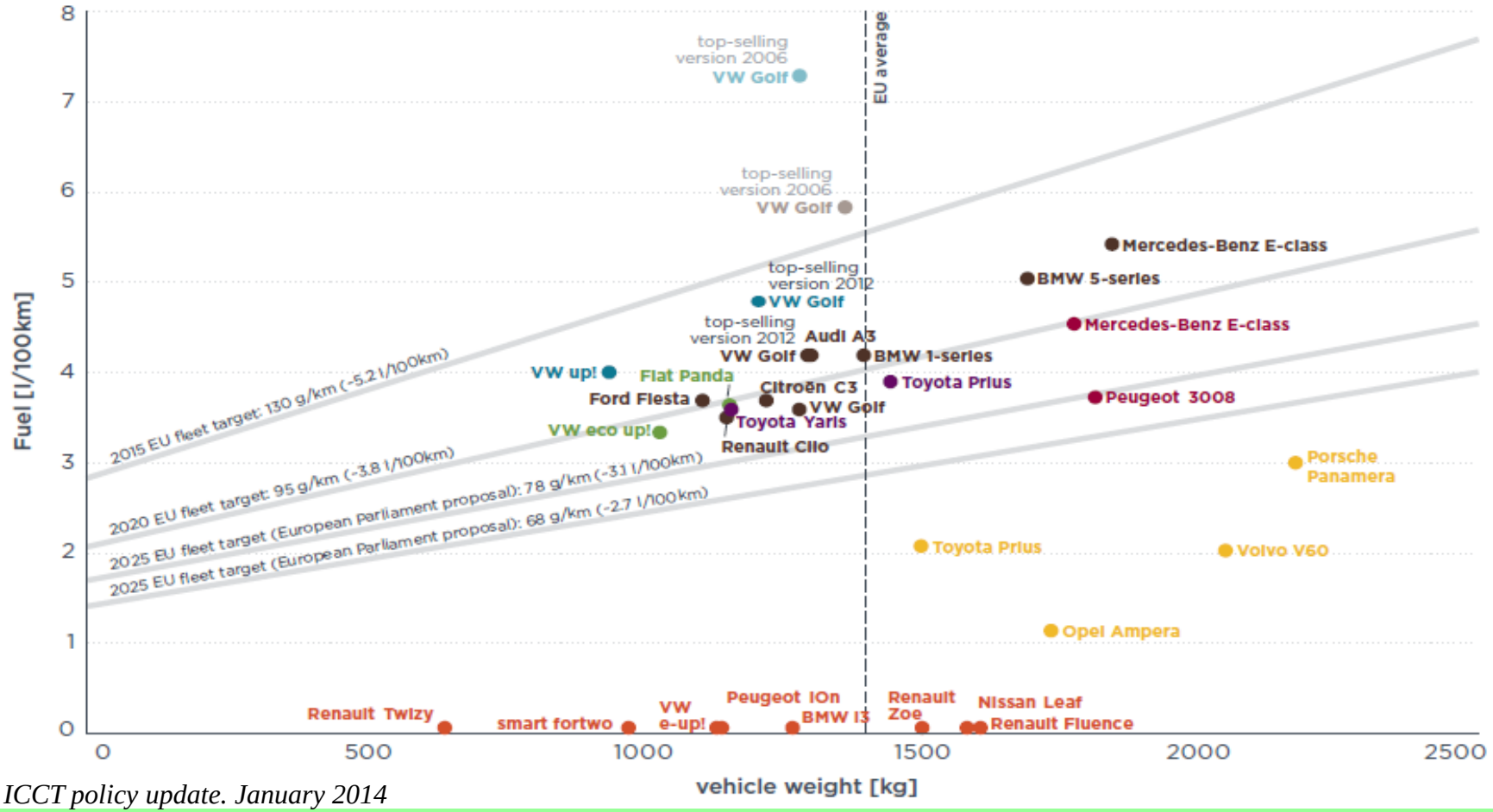
ICCT policy update. January 2014

Ranking by average C02/km emissions 2020				
Rank	**OEM**	**2010**	**2015**	**2020**
1	Toyota	130	113	97
2	Fiat	126	117	99
3	PSA	132	119	100
4	Ford	137	121	100
5	GM	140	125	100
6	Renault	136	118	100
7	VW	143	125	101
8	Suzuki	137	118	103
9	Honda	147	127	104
10	Hyundai	139	125	105
11	Mazda	150	130	105
12	BMW	148	129	107
13	Nissan	148	126	107
14	Daimler	163	131	108

Tim Lawrence Developing vehicles to meet carbon emissions reduction targets - PA Knowledge Limited 2015

Penalty for exceeding limit 2020: 95 eur/ per 1 g CO2 per sold car

Possibilities for car manufacturers to reduce CO2



ICCT policy update. January 2014

- Change car fleet portfolio towards smaller cars
- Increase powertrain efficiency
- **Reduce car weight (reduction of 100kg ~ 0.3 l fuel reduction /100 km & 7g CO2/km)**

100 kg weight reduction ~ 665 euro penalty savings

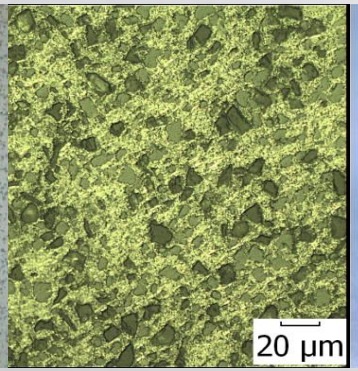
Materials for lightweight construction

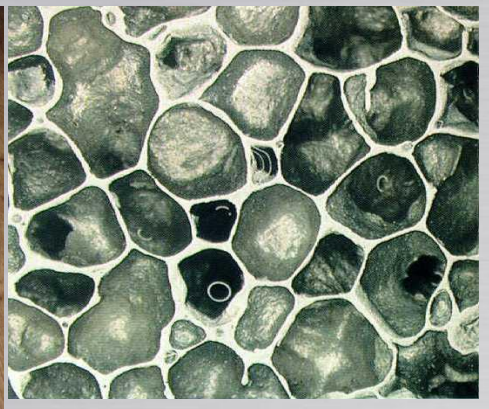
Material	Weight	Costs	Specific costs
Steel	400 kg	1.600 €	3 – 5 € /kg
Aluminium	260 kg	5.000 €	15 – 25 € / kg
CFRP	160 kg	15.000€	80 – 120 € / kg

Courtesy Prof. Dr. Robert Bjekovic

Aluminium development for future lightweight construction

Composites:
net shape processes
wear resistance, high stiffness,
structural and dimensional stability



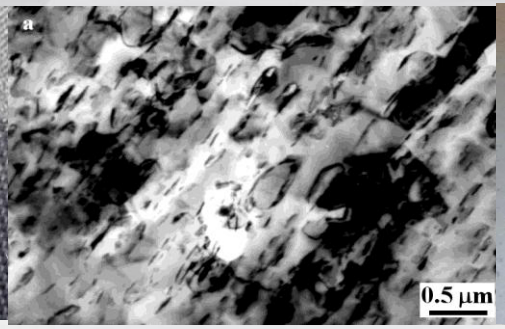


Novel structures:
(foams, hybride parts)

Lightweight, stiffness crash performance, NHV performance

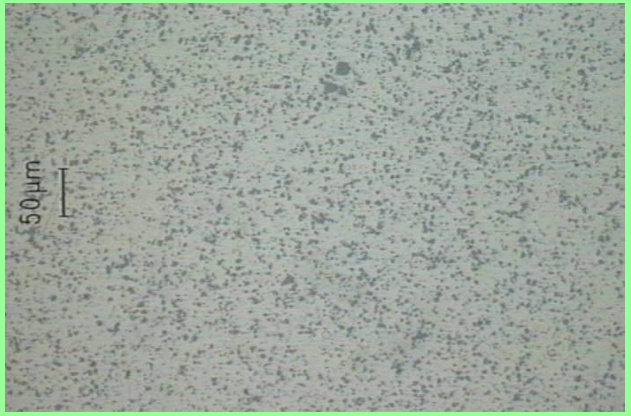
Nanostructured complex alloys,

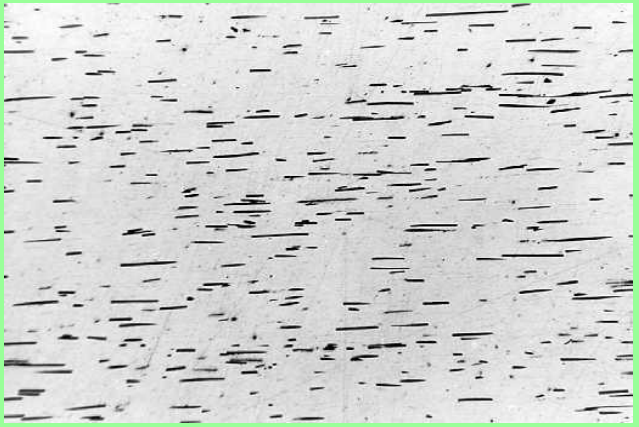
High strength and thermal stability at HT

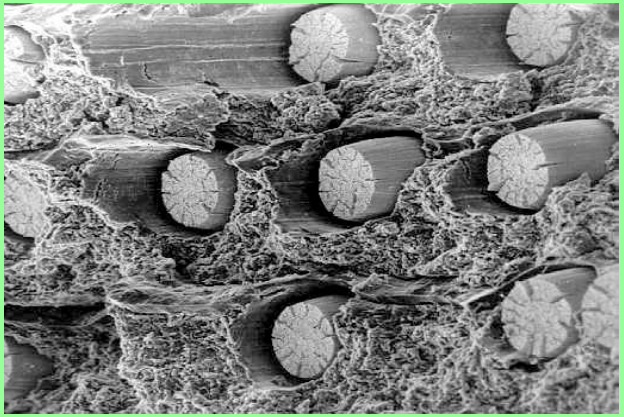


Advantages of composites:

- ✓ new classes of materials with unique combination of properties
- ✓ increased stiffness for given weight
- ✓ Control of physical properties possible (thermal conductivity, thermal expansion, magnetic properties)
- ✓ higher reliability (toughness) if compare to structural ceramics
- ✓ Better temperature resistance and stiffness if compared to metals
- ✓ improved damping, EMS, etc.







Powder techniques – aluminium composites

Technology developed at industrial scale

sapa: Shaping the future

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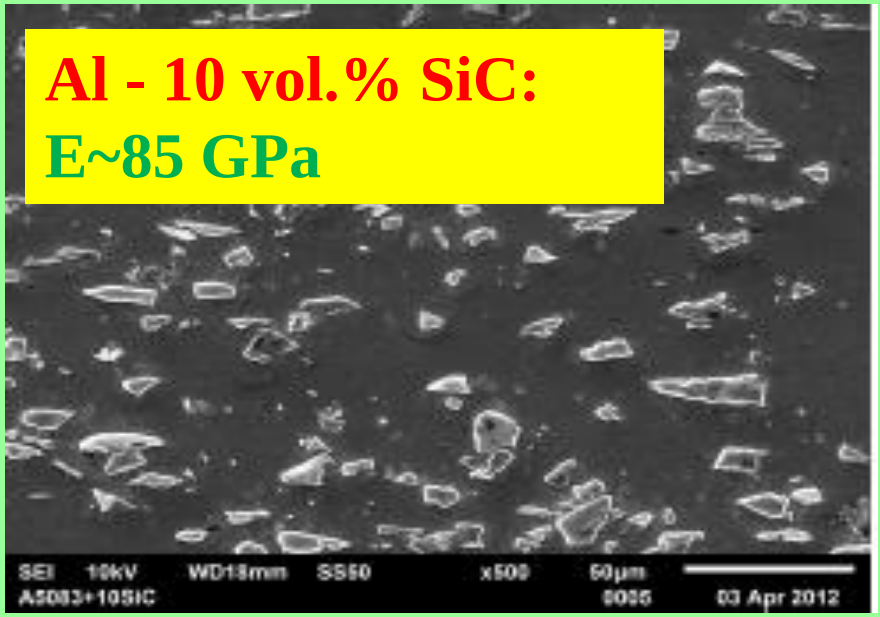
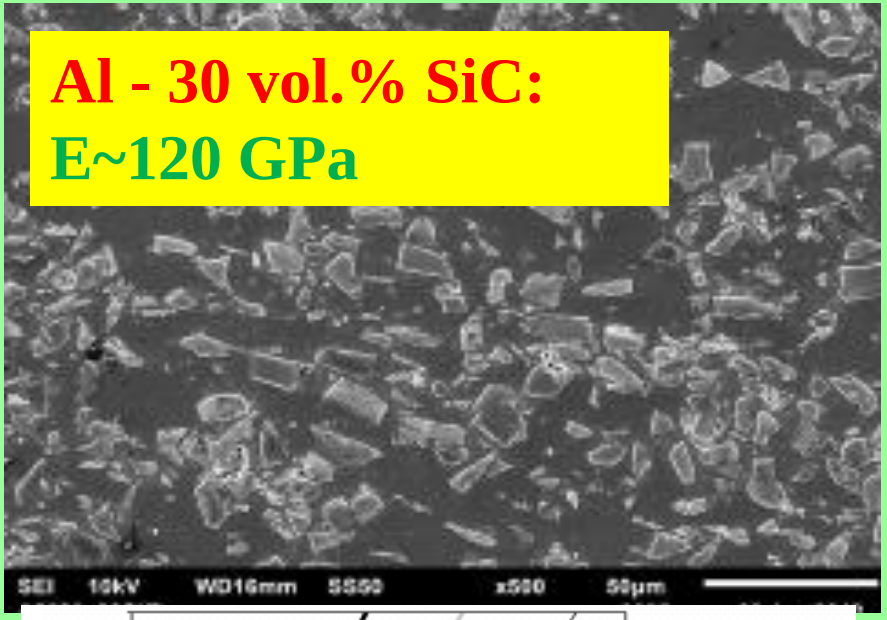
Young's modulus of extruded MMCs [GPa]

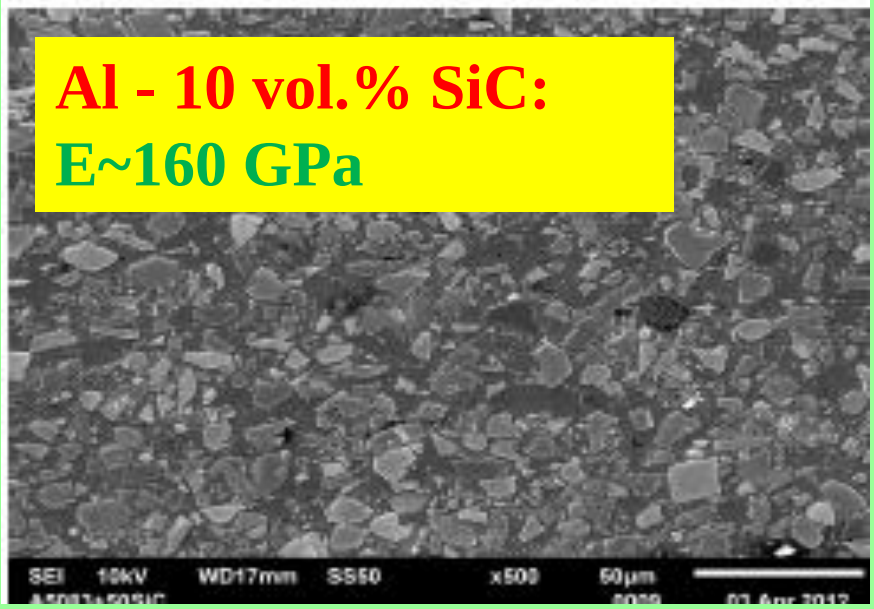
Al - 10 vol.% SiC:
E~85 GPa



Al - 30 vol.% SiC:
E~120 GPa



Al - 10 vol.% SiC:
E~160 GPa



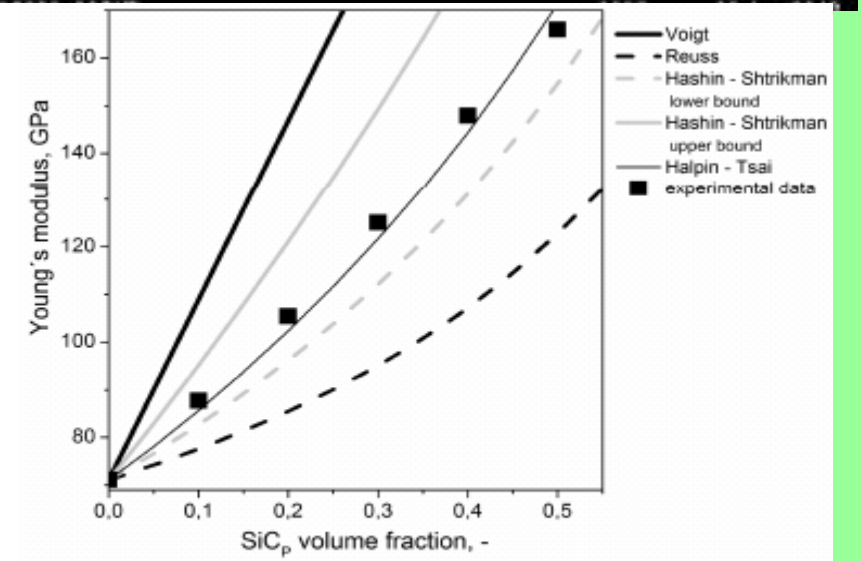
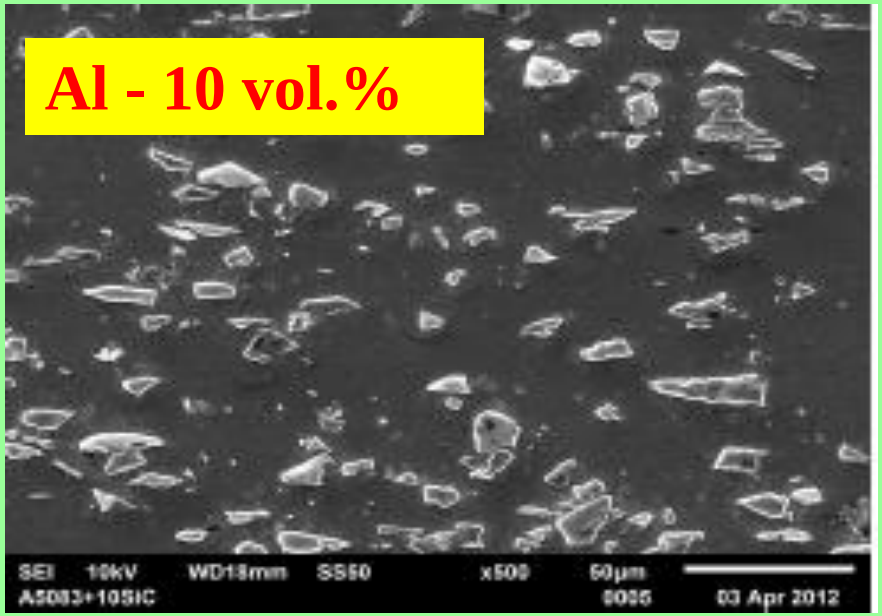


Fig. 2. Theoretical models for prediction of Young´s modulus for particulate Al/SiC composites and experimental data.

Mechanical properties of extruded MMCs



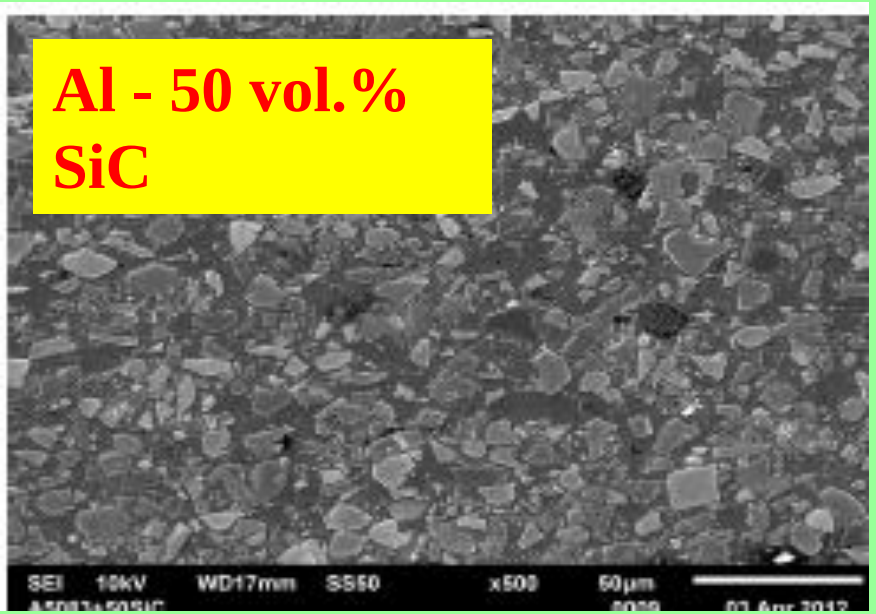
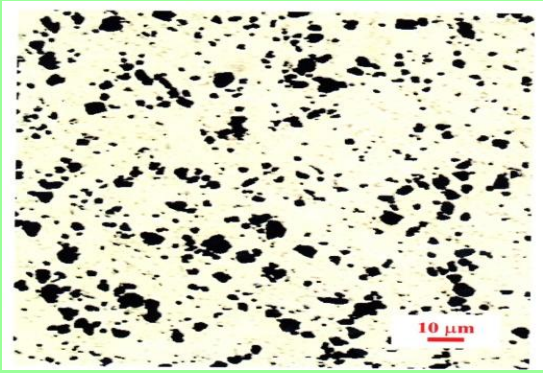


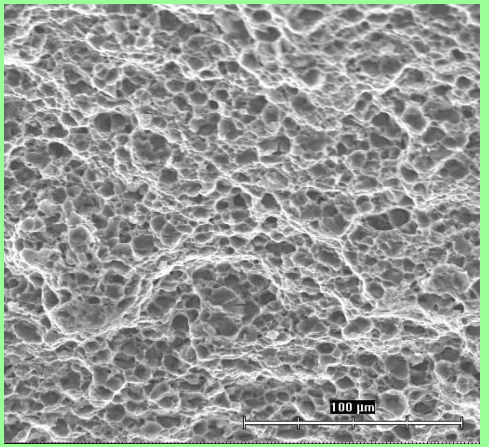
Table 1 The porosity and ultimate tensile strength (UTS), yield strength (YS) and elongation (A) of A5083/SiC_p composites.

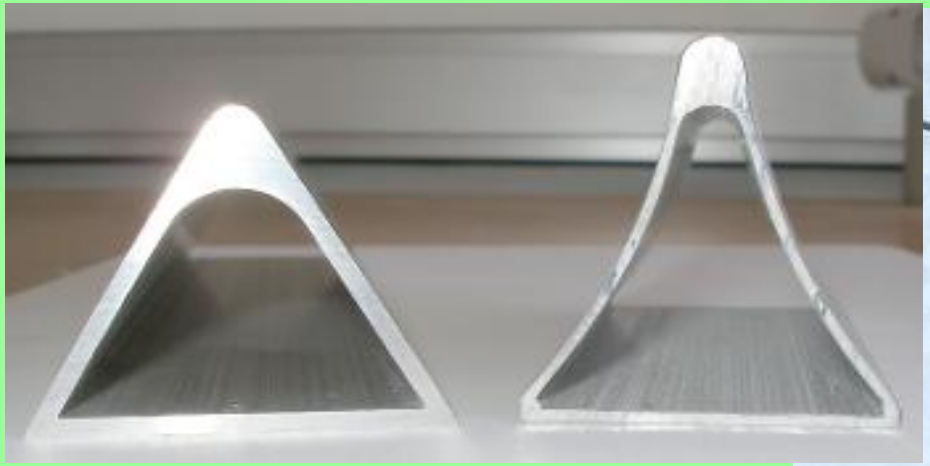
	Volume fraction of SiC particles					
	0	0.1	0.2	0.3	0.4	0.5
Porosity (%)	0.14±0.02	0.03±0.01	0.24±0.03	0.16±0.02	0.44±0.03	0.49±0.04
UTS (MPa)	399±3.4	400±2.8	404±4.1	438±4.7	446±5.8	–
YS (MPa)	258±5.8	294±21	332±11	340±15.3	371±7.6	–
A (%)	15±4.9	6±0.2	3±0.9	2±0.3	1±0.1	–

Materials developed at industrial scale
Al 6061 alloy- 20vol.% SiC_p composites

- Young's modulus: ~100 GPa
- Strength comparable to 6061 alloy
- Density 2,6 g/ccm
- excellent wear resistance
- controllable CTE ~16-18 ppm/K
- Good dimensional stability

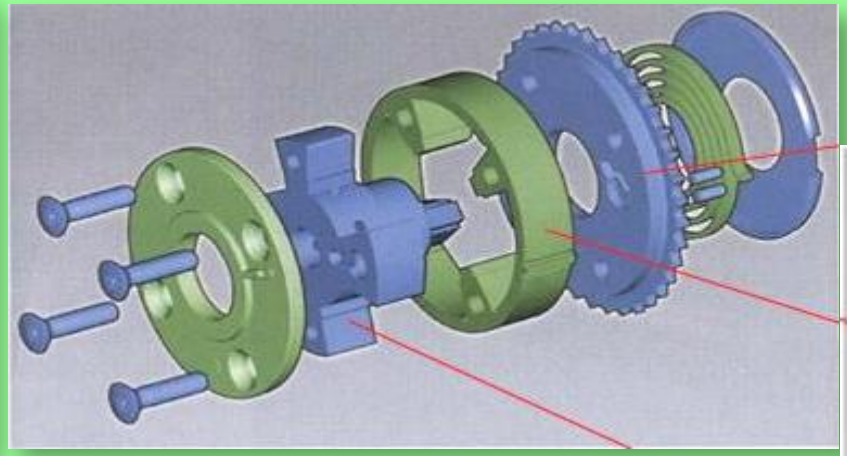


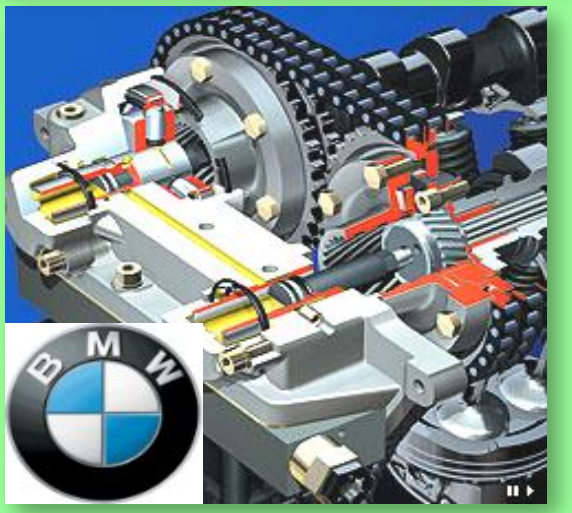


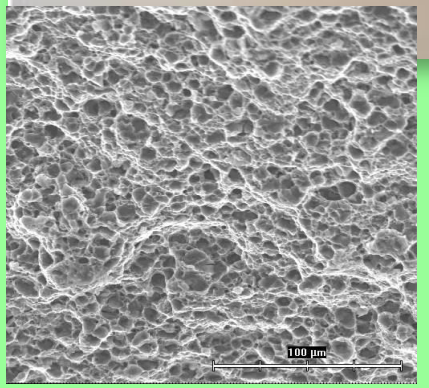


potential for radical weight reduction

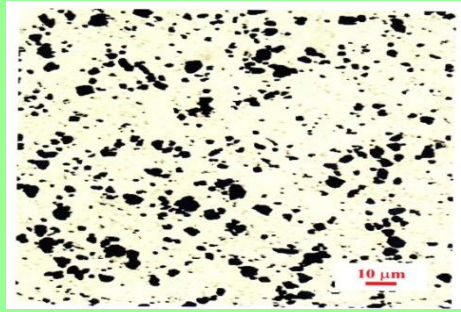
Powder techniques – aluminium composites







Joint development of:
Slovak Academy of sciences,
SAPA Profily, Žiar nad Hronom (SK)
Alulight GmbH, Ranshofen (A)
SHW GmbH, Wasseralfingen (D)

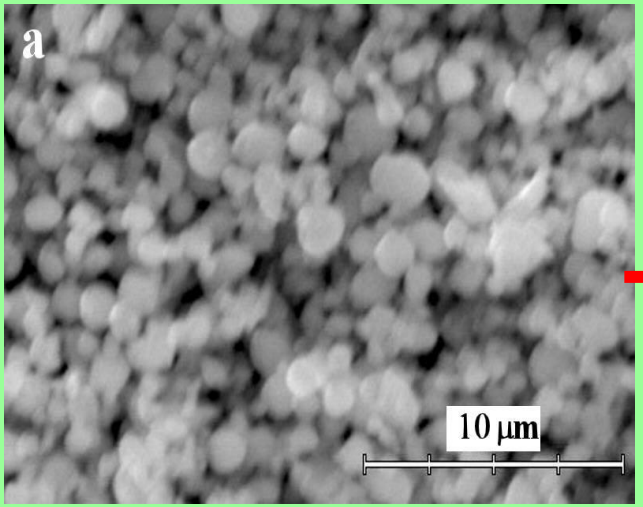


Camshaft phaser stator ring

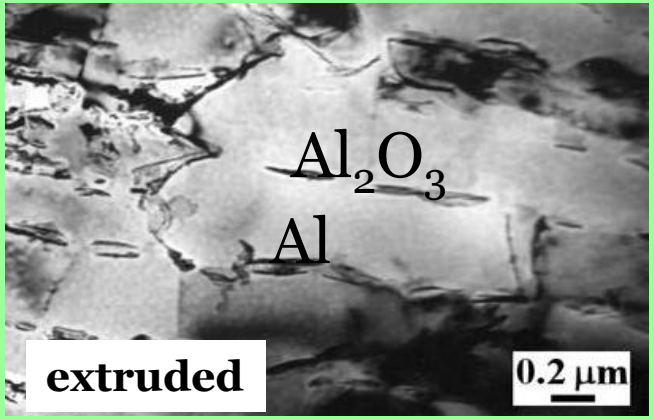
- **engine BMW, 900.000 pcs/year**

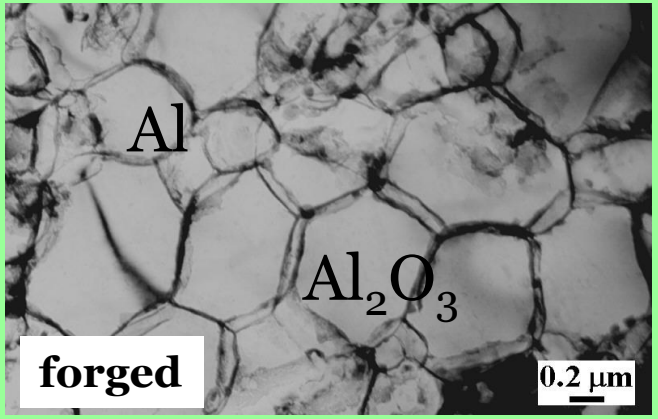
Research on bulk Al nanomaterials

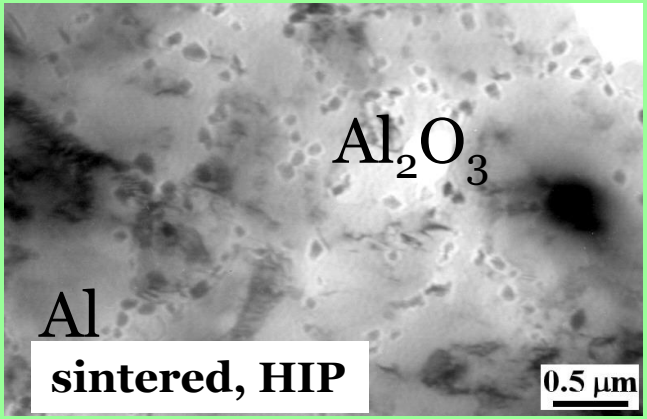
- lightweight structural applications (Al based)
- enhanced strength at ↑T (up to 400°C)
- without ductility, toughness, creep and fatigue deterioration
- technologically feasible
- production expenses

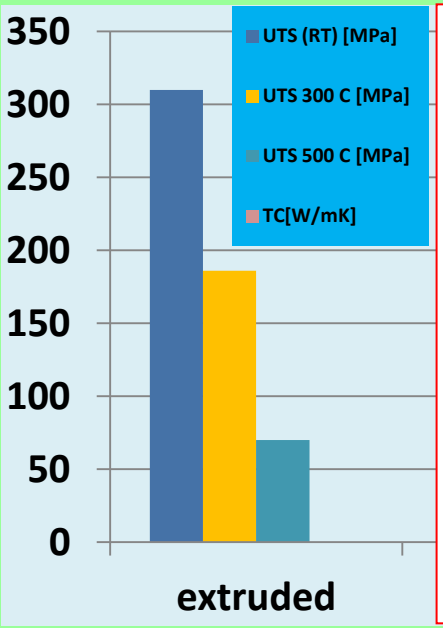


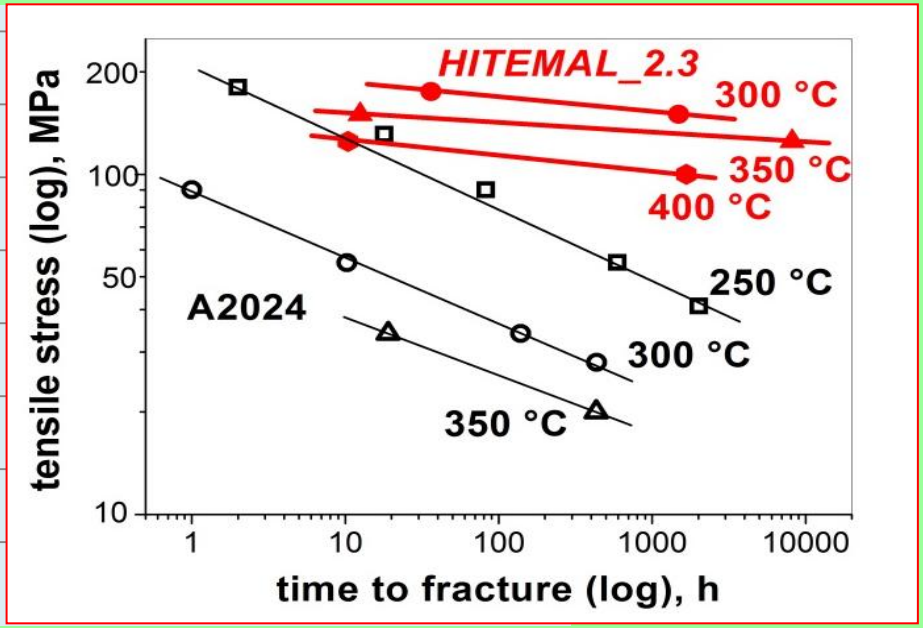
HITEMAL high temperature aluminium stabilized with nano Al_2O_3











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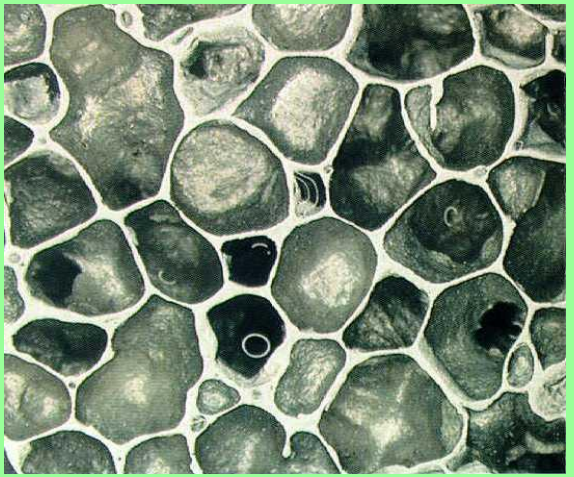
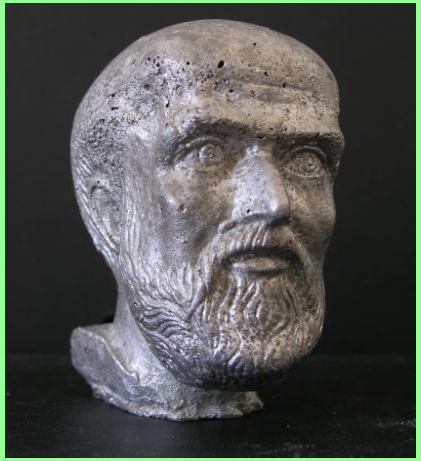
Balog M., Simancik F., Walcher M., Rajner W., Poletti C.
Mater. Sci. Eng. A 529 (2011) 131– 137.

Car body as cast Al monocoque
fiction or realistic dream?

Aluminium foam



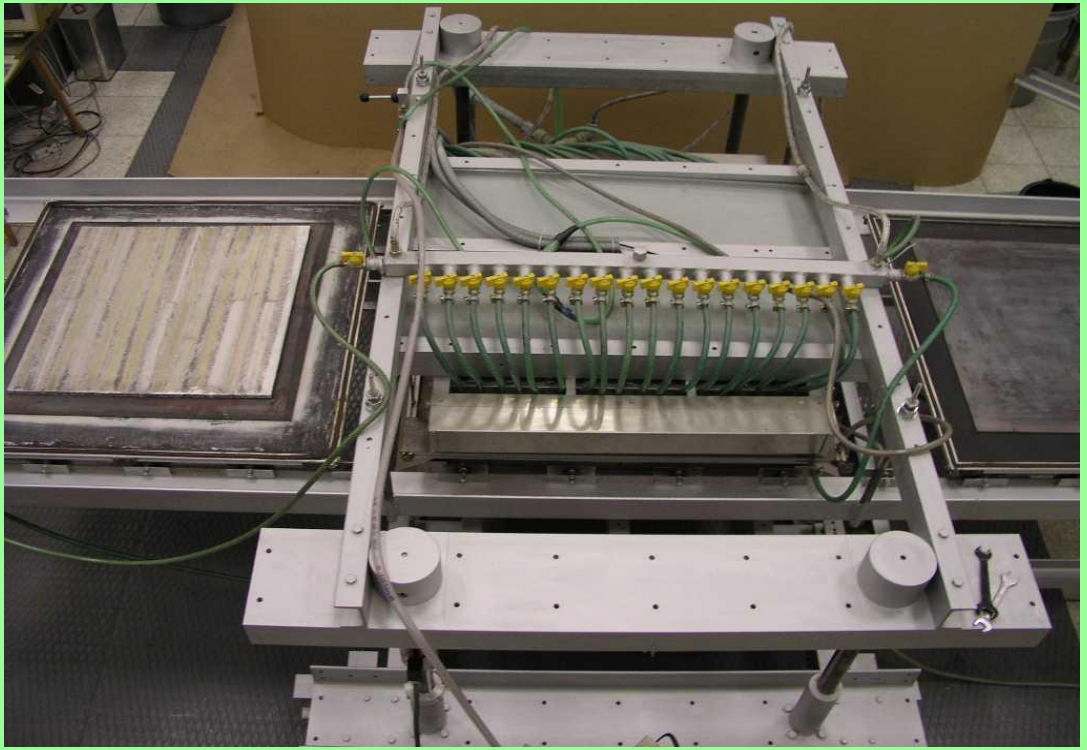


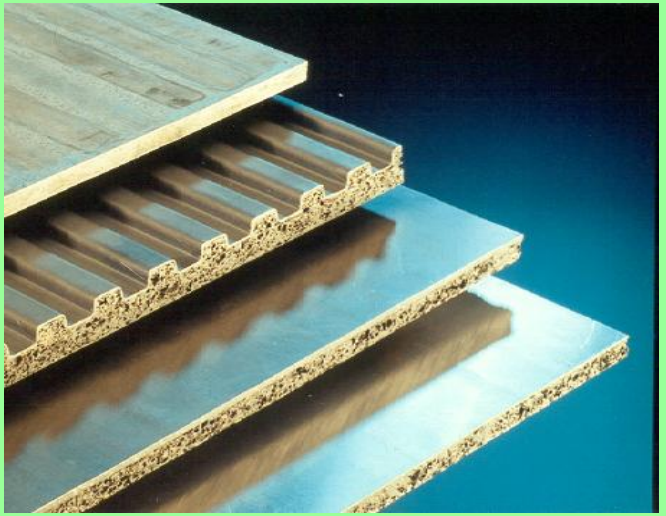
- ✓ Low weight (0.3 – 0.9 g.cm^{-3})
- ✓ High stiffness
- ✓ Crash absorption capability
- ✓ sound absorption
- ✓ Low heat capacity
- ✓ Excelent thermal & electric conductivity
- ✓ Vibration damping
- ✓ Electromagnetic shielding

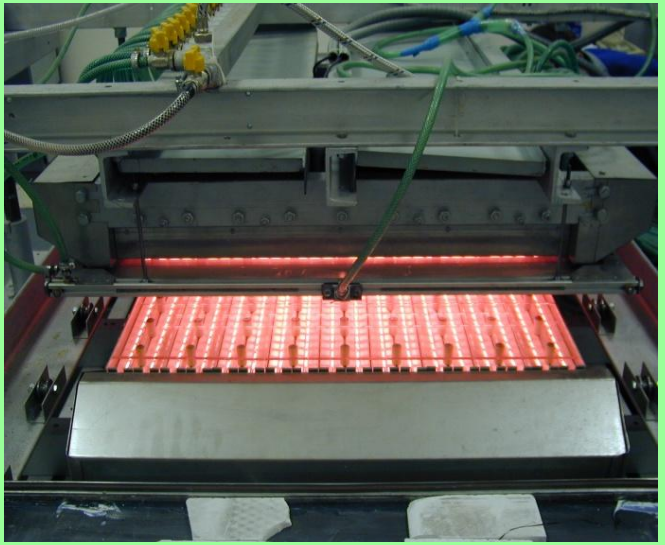
Joint development of Slovak Academy of Sciences and Alulight GmbH, Ranshofen (A)

PM manufacturing of aluminium foam

Manufacturing of panels and sandwiches from aluminium foam







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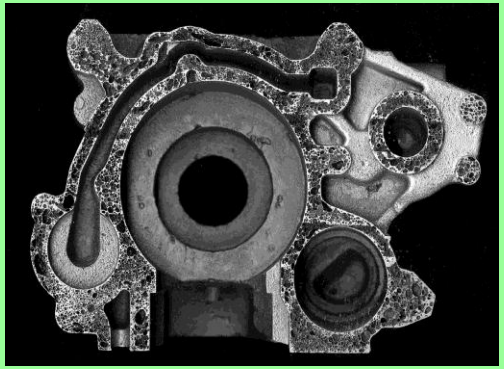
Manufacturing of complex shape parts from Al foam



low pressure injection

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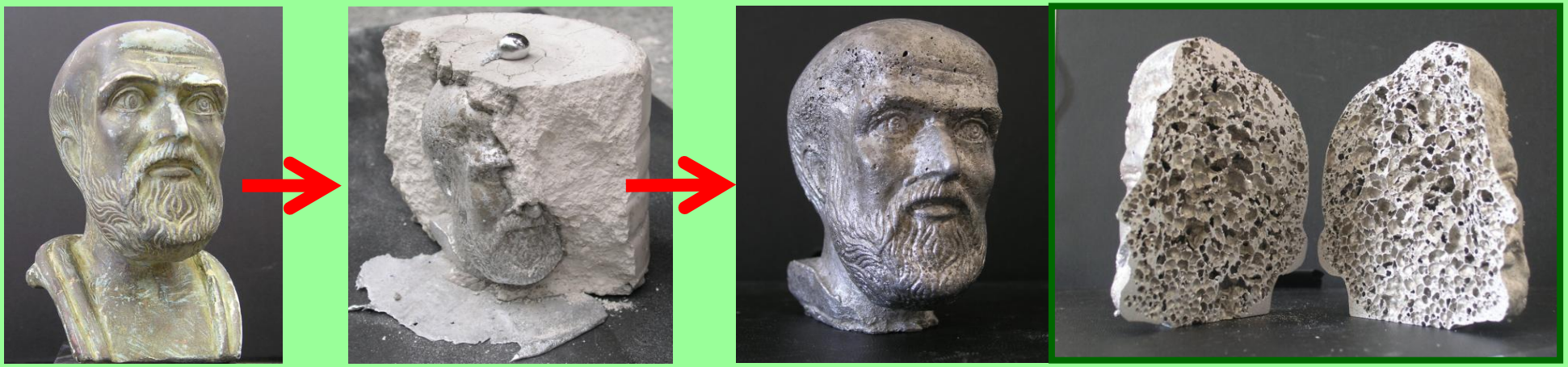
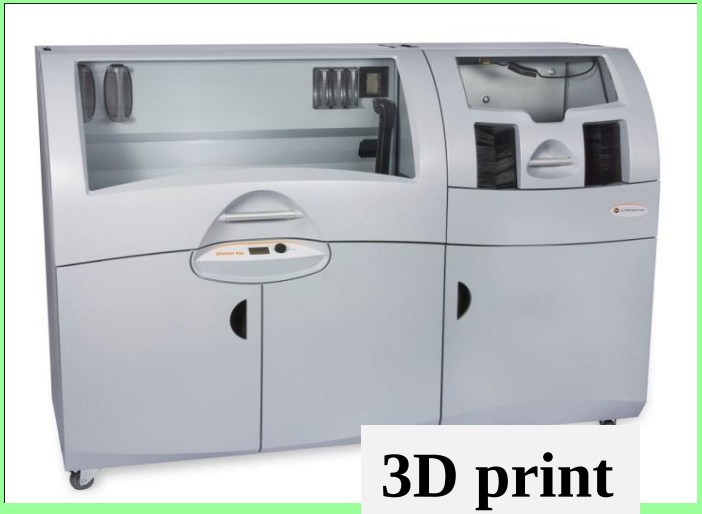
Rapid prototyping, 3D printing technology



Aristoteles

3D scan



3D print

Vacuum casting wax

Vacuum / pressure casting - metal

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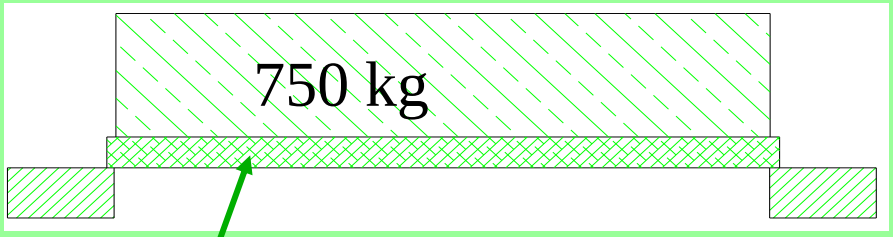
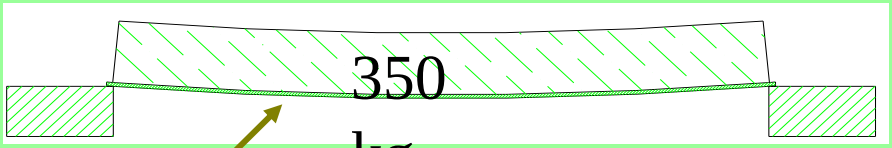
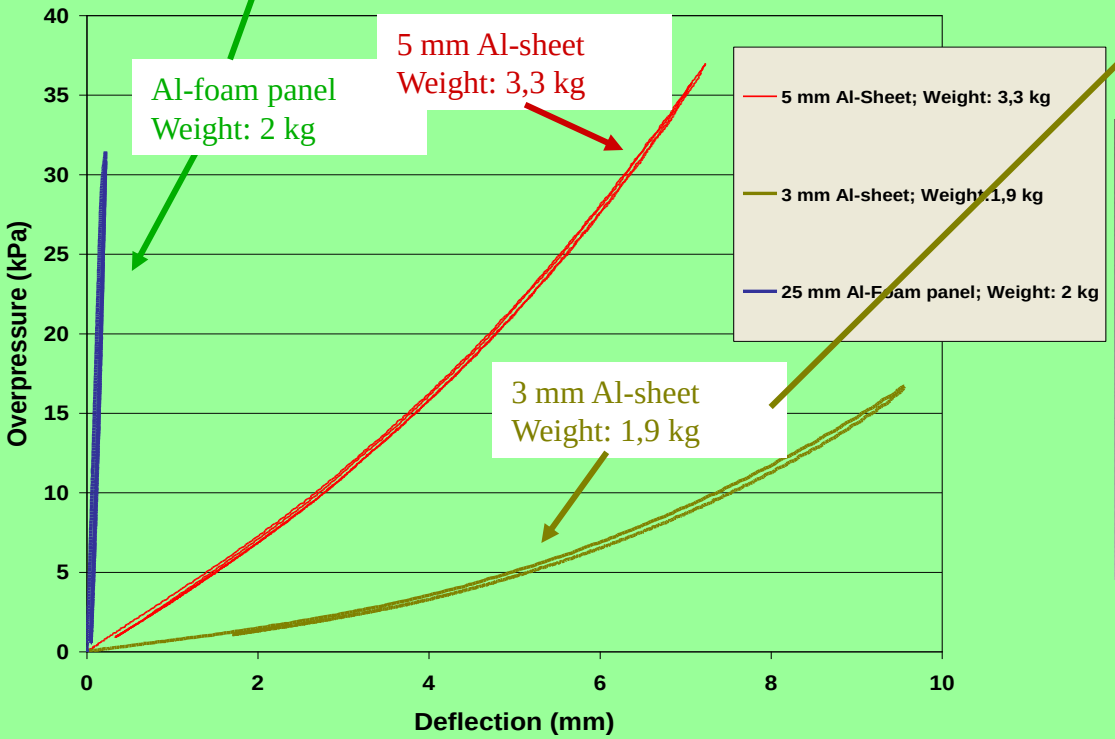
Al foam: high stiffness at low weight



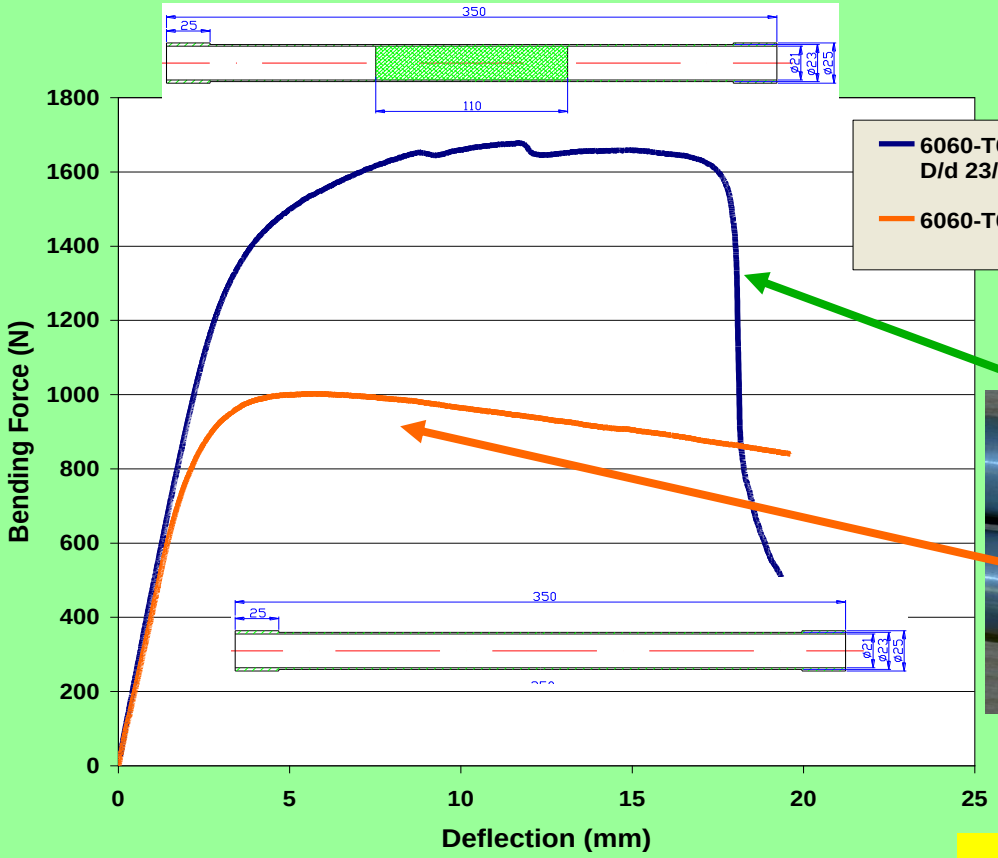


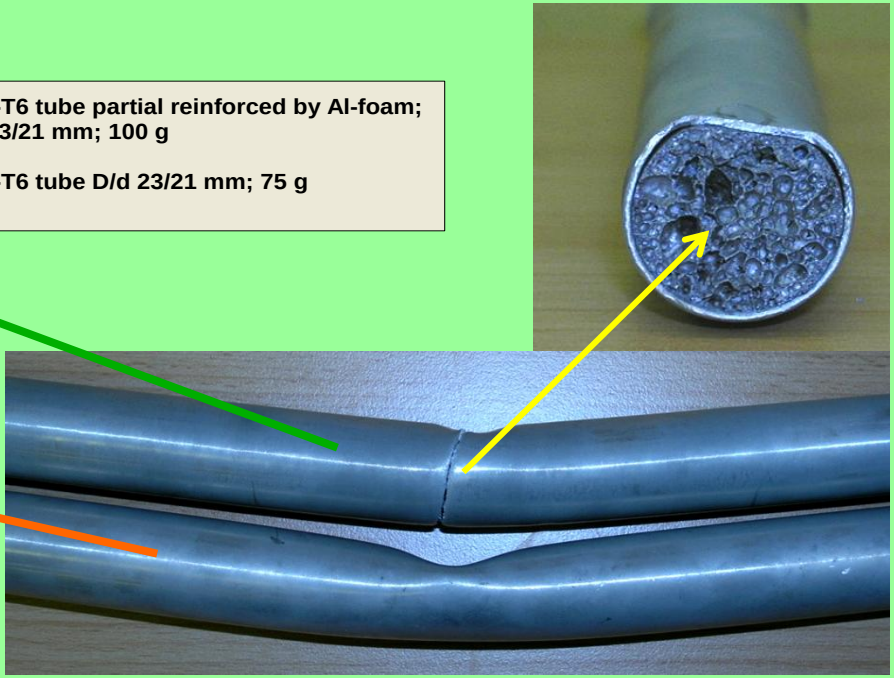


Better stiffness – similar weight

Reinforcing of hollow profiles

Heat treatment after foaming process will restore mechanical properties





weight increase - 25%
bending strength increase - 60%

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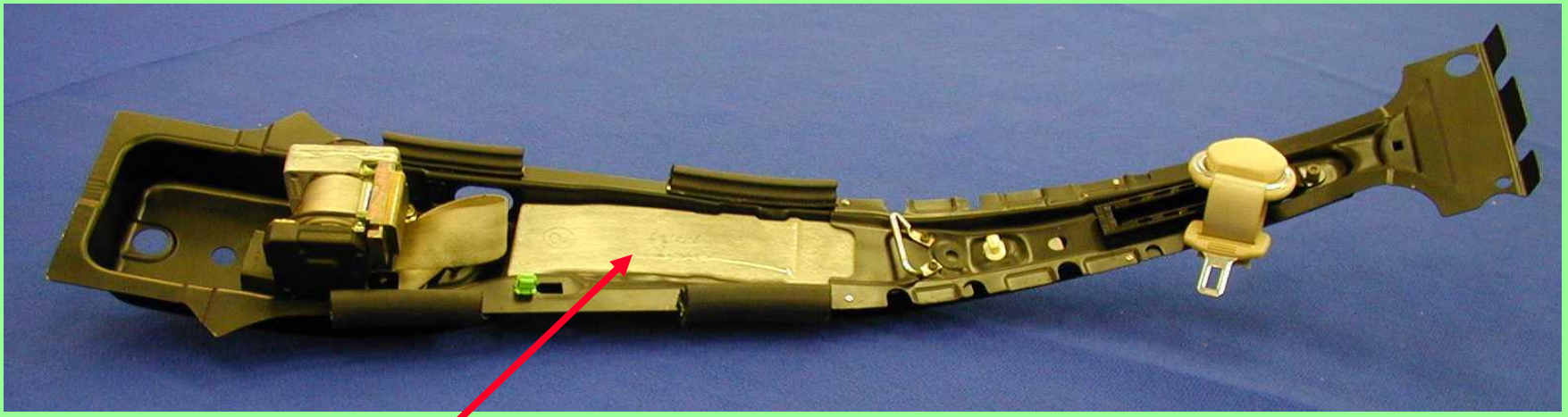
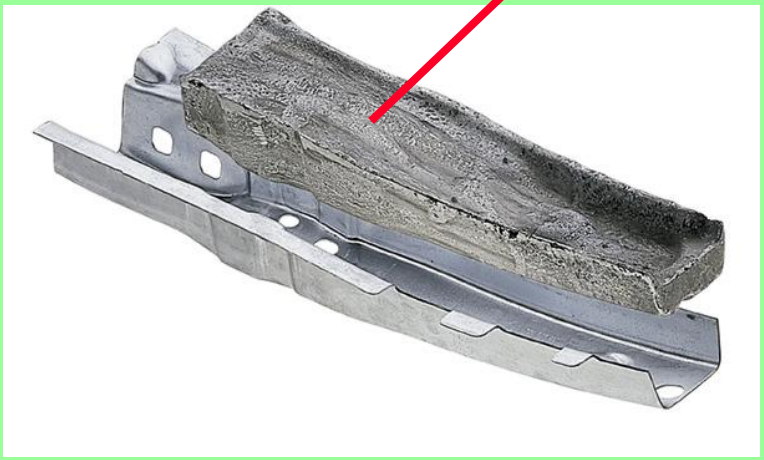
Typical Al foam prototypes

stiffener in welded component





Foam insert in car body B-column

Improved stiffness & crash performance

Courtesy of Alulight

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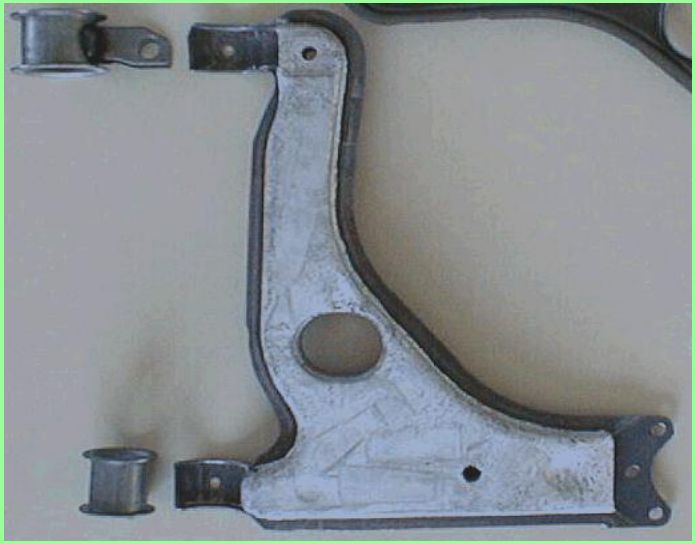
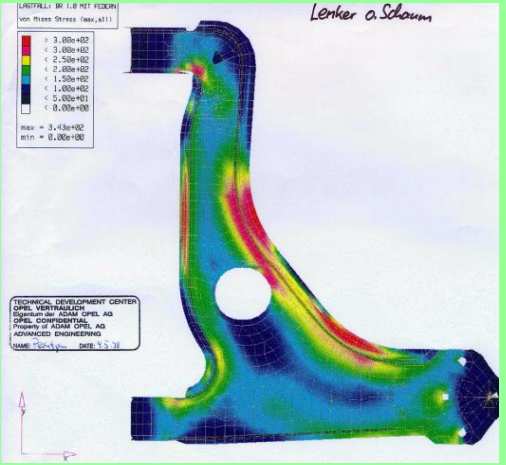
Typical Al foam prototypes

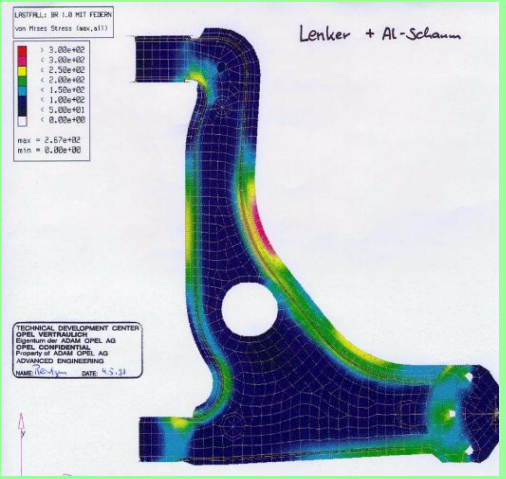
stiffener in welded suspension part



without foam stiffener



with foam stiffener



Results:

almost 5 times higher endurance limit

no need to change standard welding and forming technology

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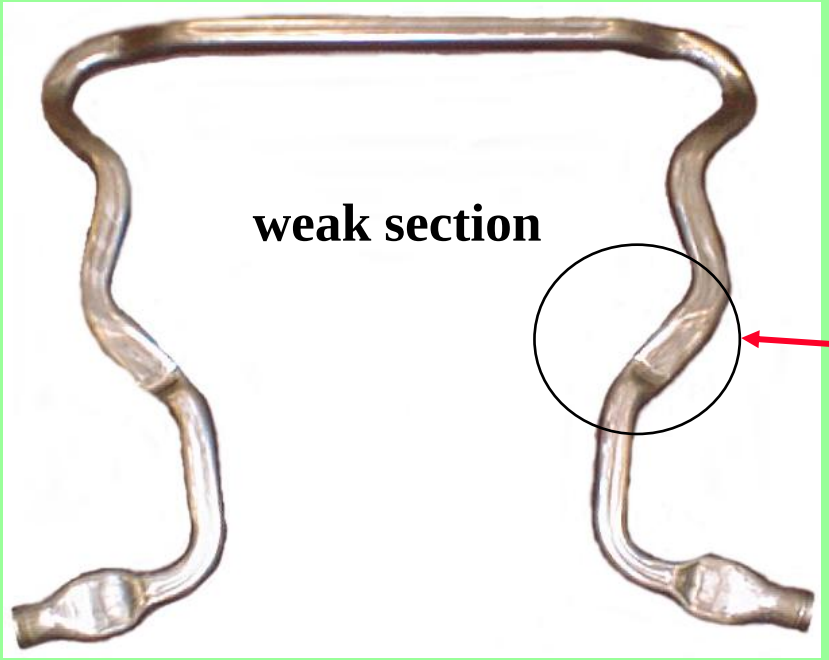
Courtesy of Alulight

Typical Al foam prototypes

stiffening of hydroformed motor carrier



increased stiffness
capability to absorb deformation energy
damping properties

Courtesy of Alulight

possible **reduction** of the thickness of profile wall & pressing forces

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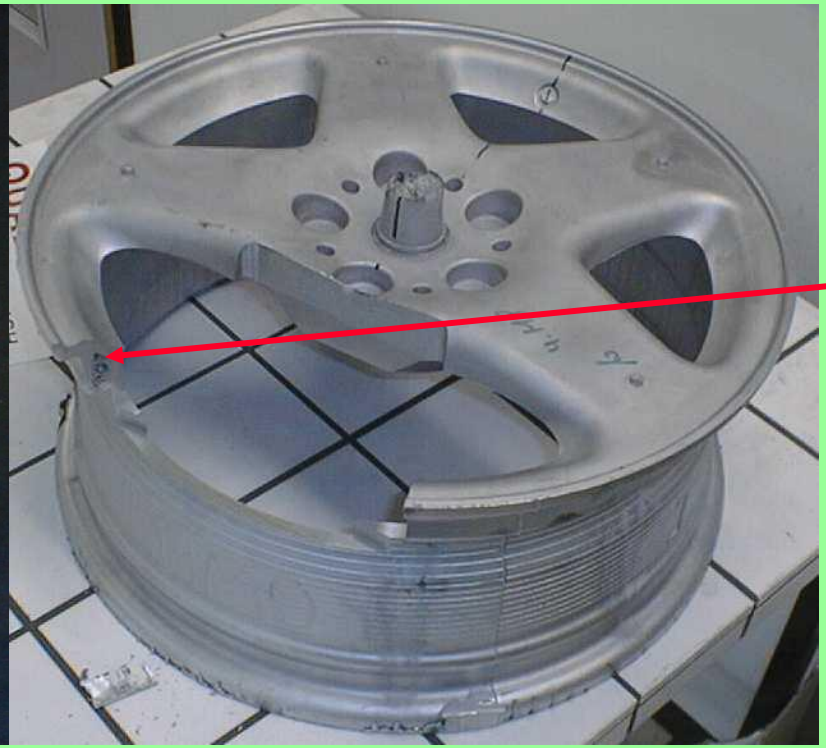
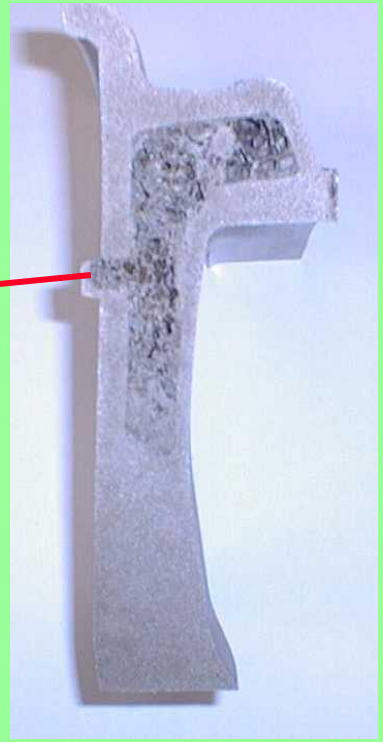
Typical Al foam prototypes

foam cored castings

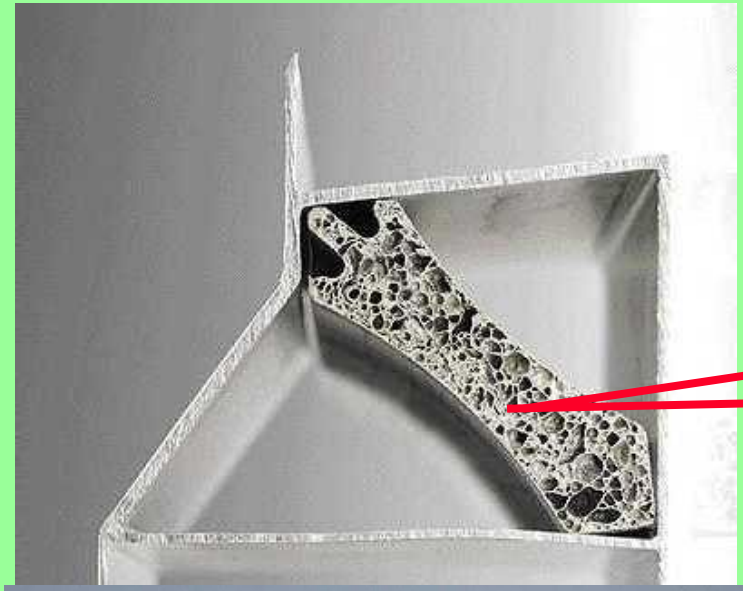


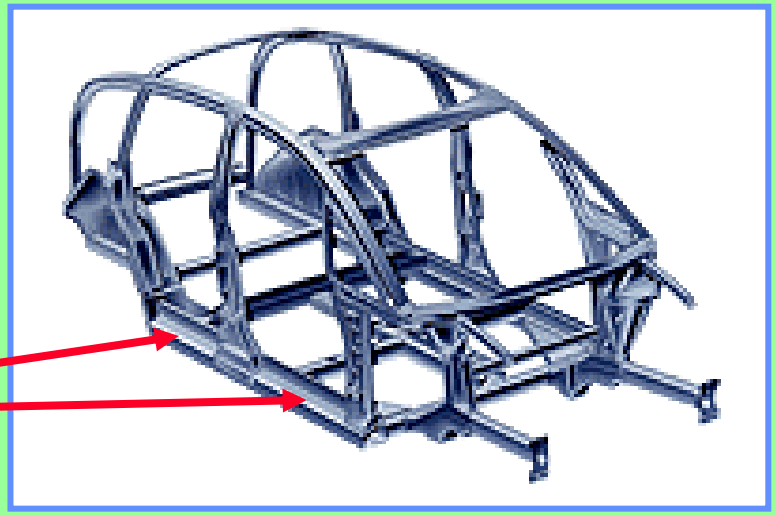


✓ saving of ca. 2 kg weight per wheel

Courtesy of Alulight

Success cases



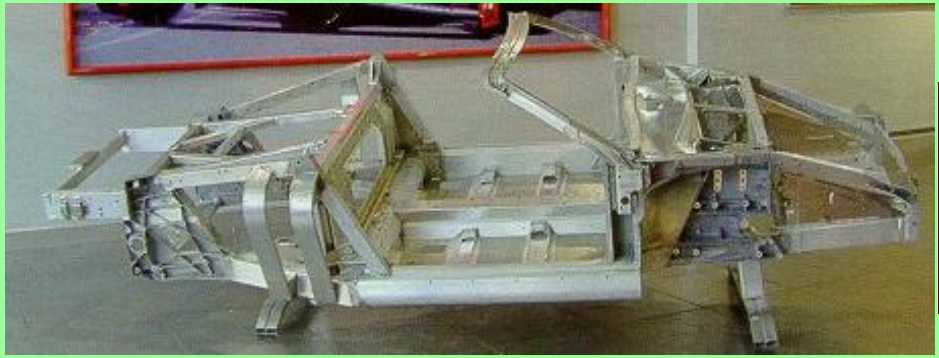


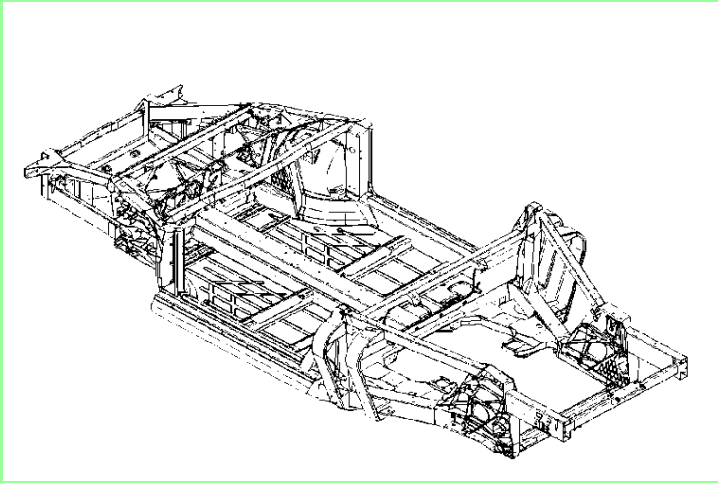
Stiffener of side rail Audi Al2:

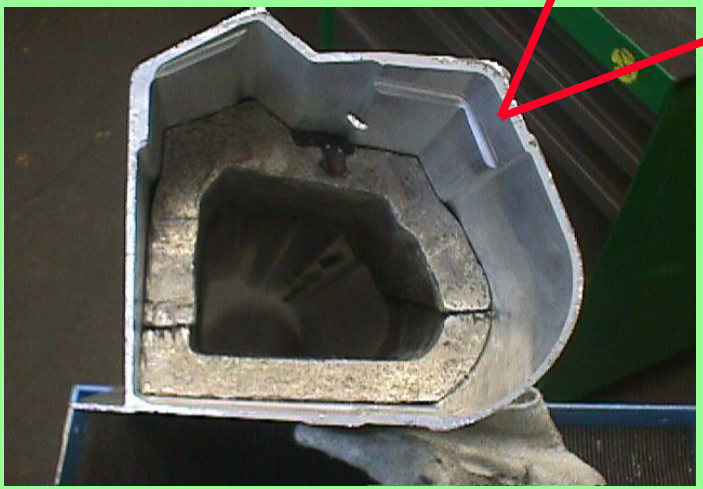
- ✓ **start of serial production 2001 at Neuman Alufoam GmbH, Marktl (A)**
- ✓ **developed by Slovak Academy of Sciences**

firts attempt for serial application of Al foam in automotive

Success cases







Stiffener of side rail Ferrari Modena 360:

- ✓ **6.000 pcs/year**
- ✓ **developed by Slovak Academy of Sciences**
- ✓ **Produced by Alulight GmbH, Ranshofen (A)**

worldwide first serial application of Al foam in automotive

Success cases – aluminium foam

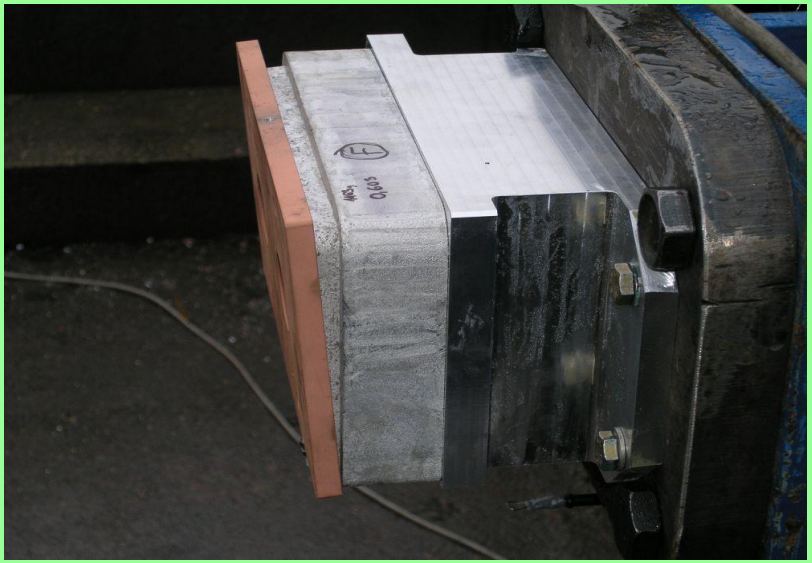
Crash box Audi Q7:

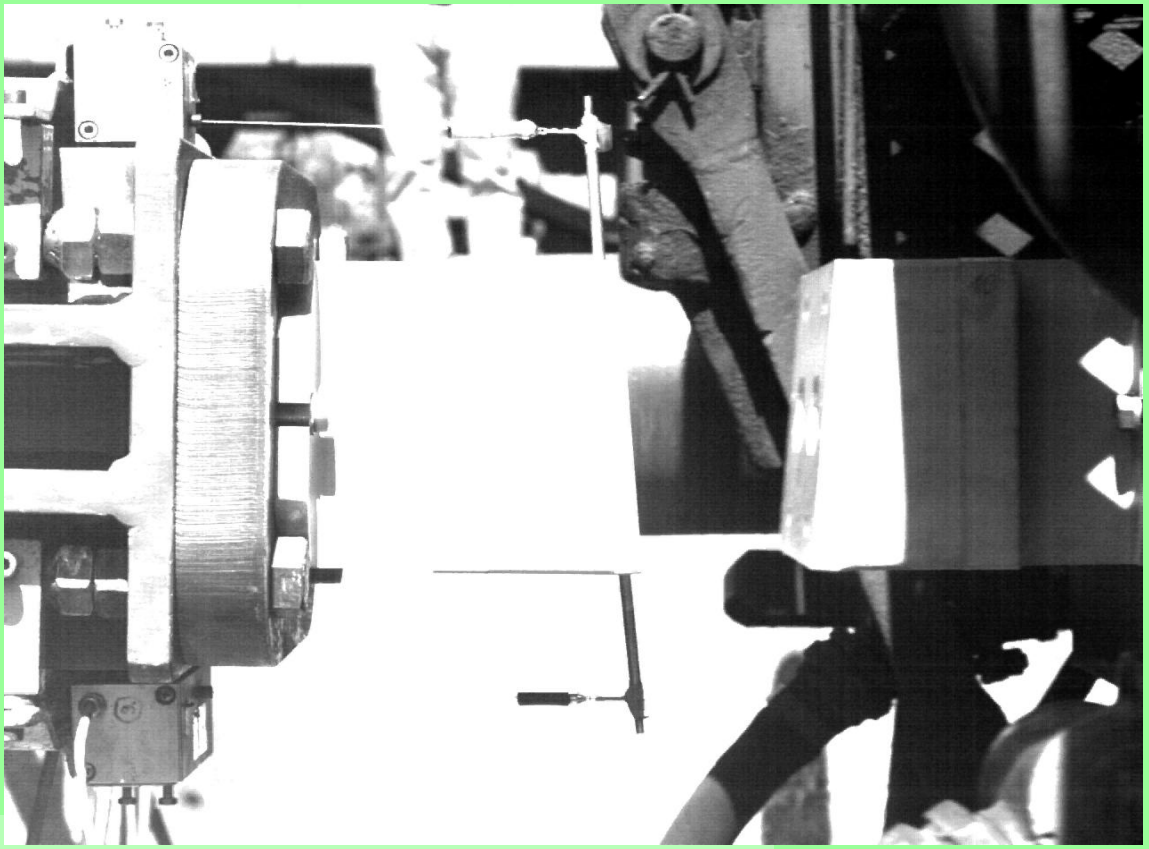
- ✓ **120.000 pcs/year**
- ✓ **developed by Slovak Academy of Sciences**
- ✓ **produced by Alulight GmbH, Ranshofen (A)**

worldwide largest serial application of Al foam in automotive

Success cases

Crash box for railway carriage

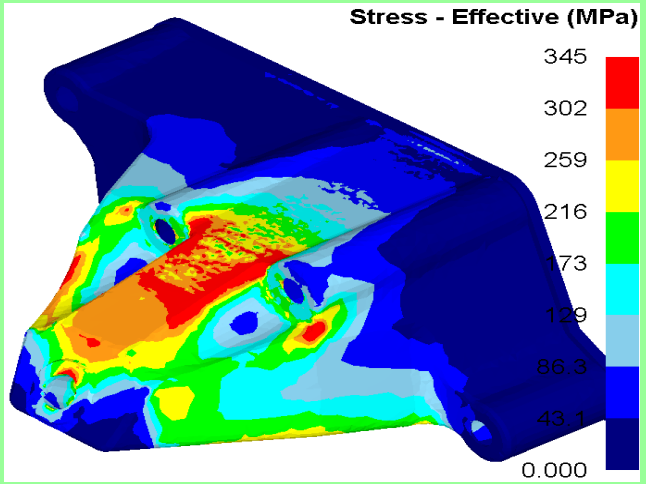




- ✓ 1000 pcs/year
- ✓ developed and produced by Slovak Academy of Sciences
- ✓ Assembled by Gleich GmbH (D)

Case of study - engine carrier

Al foam redesign

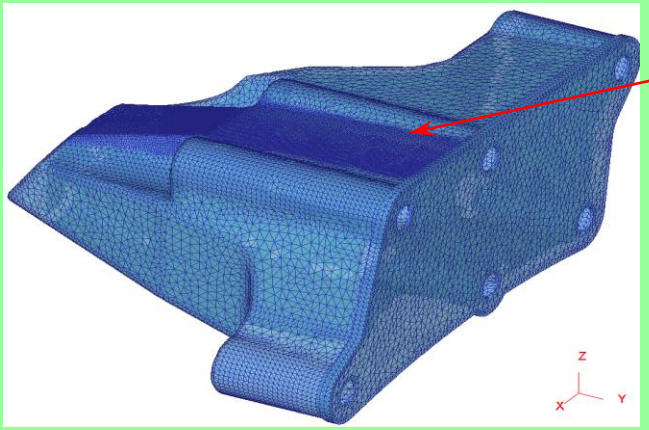


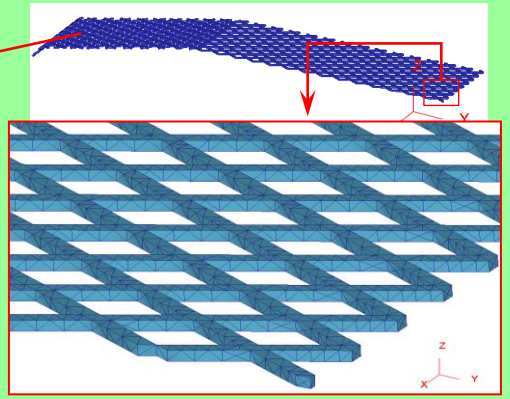
Requirements:

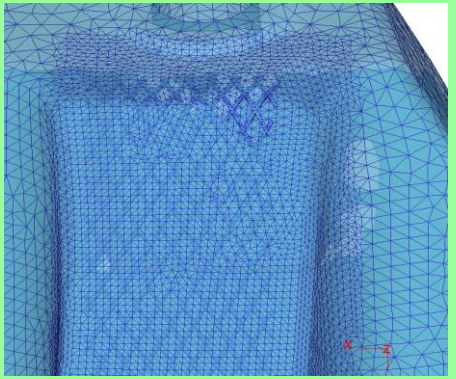
- Same density as original HPDC part
- Better NHV performance
- Fulfill loading requirements incl. fatigue
- Same or lower manufacturing costs
- No changes in outer shape

Suggestions:

- Monolytic full foam solution
- Bulk aluminium parts needs to be integrated
- Stress concentrators need to be reinforced
- Continuous surface skin ~1 mm

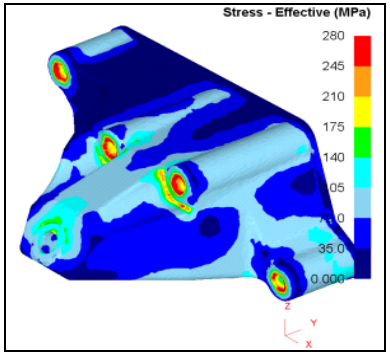
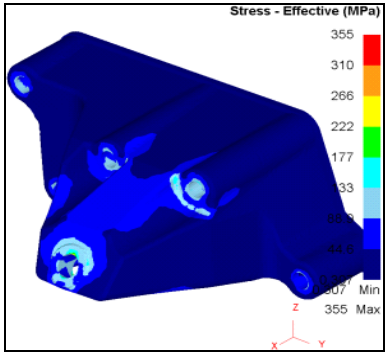
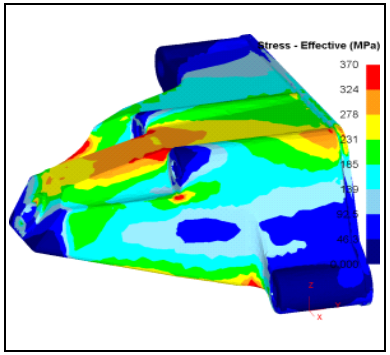
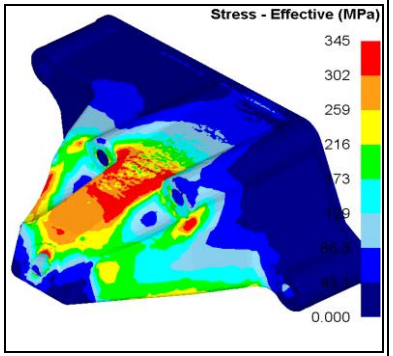
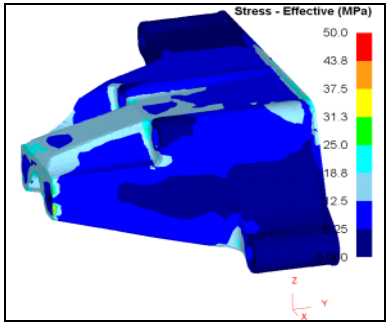
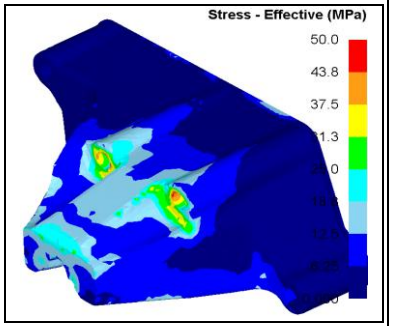






Case of study - engine carrier

Al foam redesign

Bracket LH 3M300	*Current design*	*Full foam porosity 81,2 %*	*Bulk Al shell 1 mm + foam porosity 81,2 %*	*Bulk Al shell 1 mm + foam porosity 81,2 % + reinforcing mesh*
Weight	***1050 g***	***595 g***	***788g*** *(shell 243 g + foam 545g)*	***803 g*** *(foam 547g + shell 256g + perforated sheet 5g)*
Max. Stress distribution (outside view) [MPa]				
	Max = 291 MPa	Max = 355 MPa	Max = 400 MPa	Max = 345 MPa
Max stress in the foam				
			Max = 50 MPa	Max = 50 MPa

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Case of study - engine carrier

Al foam redesign

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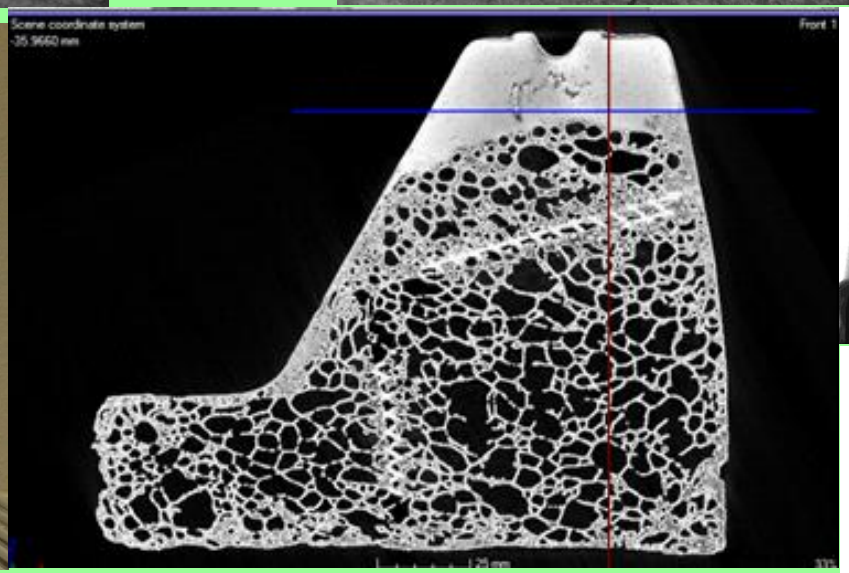
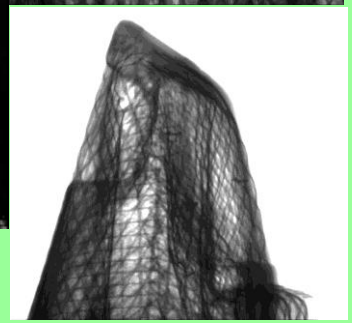
Case of study - engine carrier

Al foam redesign





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Case of study - engine carrier

Al foam redesign

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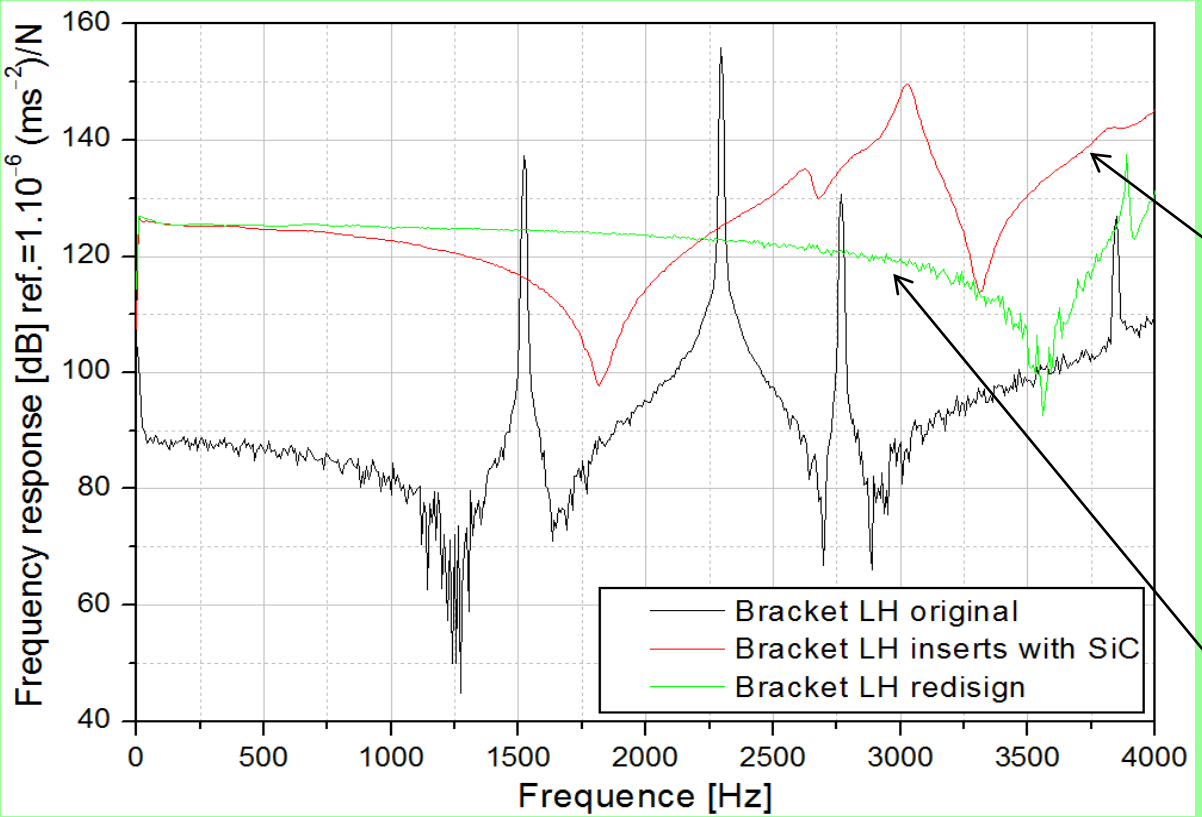

Bracket type	Figure	Weight [kg]	Δ NVH [dB]	Δ NVH [%]
Current		1,072	Ref.	Ref.
IMSAS		1,404	13	30%↑
IMSAS Redesign		1,040	16	37%↑

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Competence Center for Light Metals and Composites

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INOVAL

Žiar nad Hronom

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EUROPEAN REGIONAL DEVELOPMENT FUND

Support implementation of R&D activities in the industry:

- solution of daily problems with quality, scrap, pollution
- accessible R&D infrastructure for industry
- mutual R&D labs between academia and industry
- knowledge transfer, workshops, education

Operačný program VÝSKUM a VÝVOJ

ASFEU

Infrastructural projects funded from ERDF (app. 14 MEURO)

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iNOVAL

Žiar nad Hronom

- Lightweight construction using modern materials and technologies developed for light metals (Al, Mg)
- Design of structural parts incl. rapid prototyping
- Modelling and simulation of properties
- Stress analysis, incl. thermal stresses
- Design and optimization of process parameters for forming, casting and surface treatment processes
- Structure analysis
- Testing of properties
- Evaluation of shape and dimensional accuracy
- Optimization of heat treatment

- Consultancy and expertise on the transfer of scientific knowledge into industrial practice
- Presentation of results, education of students

EUROPEAN UNION
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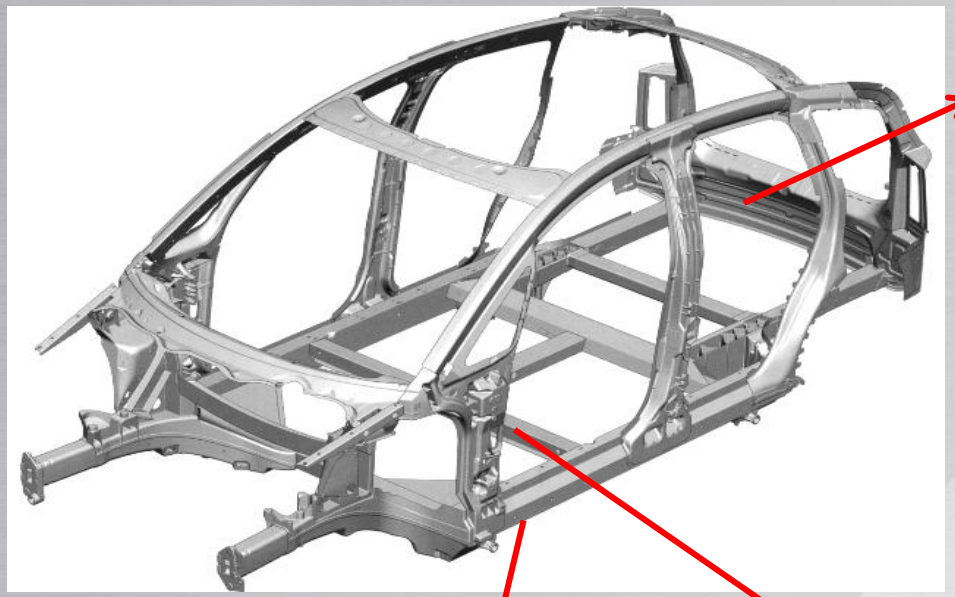
Potential developing suppliers for lightweight construction in automotive



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Stamping parts
Assembly
Welding
Machinery

FAGOR
Fagor Ederlan Slovensko

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Powertrain, chassis, body
Al, composites, hybrid castings

sapa:

extruded profiles
Al, Mg, composites

Thank you for your attention

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