The SALEMA Project Journey: main outcomes, challenges and possibilities

Manel da Silva (EURECAT) Tutku Özen (ASAS)
and Andrea Bongiovanni (Stellantis)

21st March 2024 – SALEMA FINAL EVENT

Summary

- Project introduction and video
- Scrap sorting system
- Development of HPDC SALEMA alloys
- Validation of HPDC SALEMA alloys in Shock Tower
- Alloy development and industrial validation in Hot Stamping
- Alloy development and industrial validation in extrusion
- Validation procedure of new alloys by an OEM

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

PROJECT GOAL

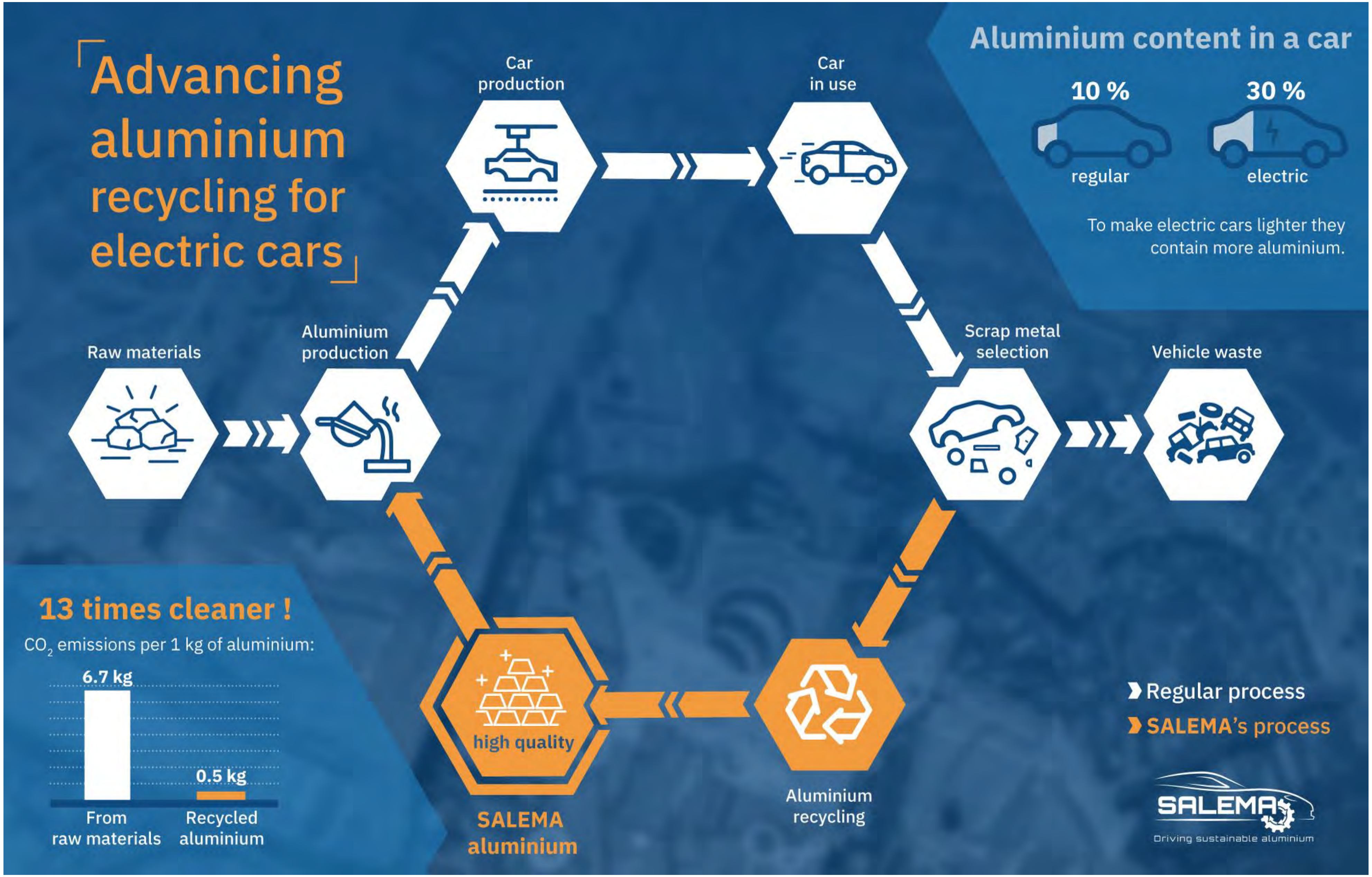
European Green Deal poses multiple challenges for the automotive industry:

- Need for new, high-performance but lightweight materials
- Decrease the dependencies on imported raw materials while creating a sustainable economy for the future

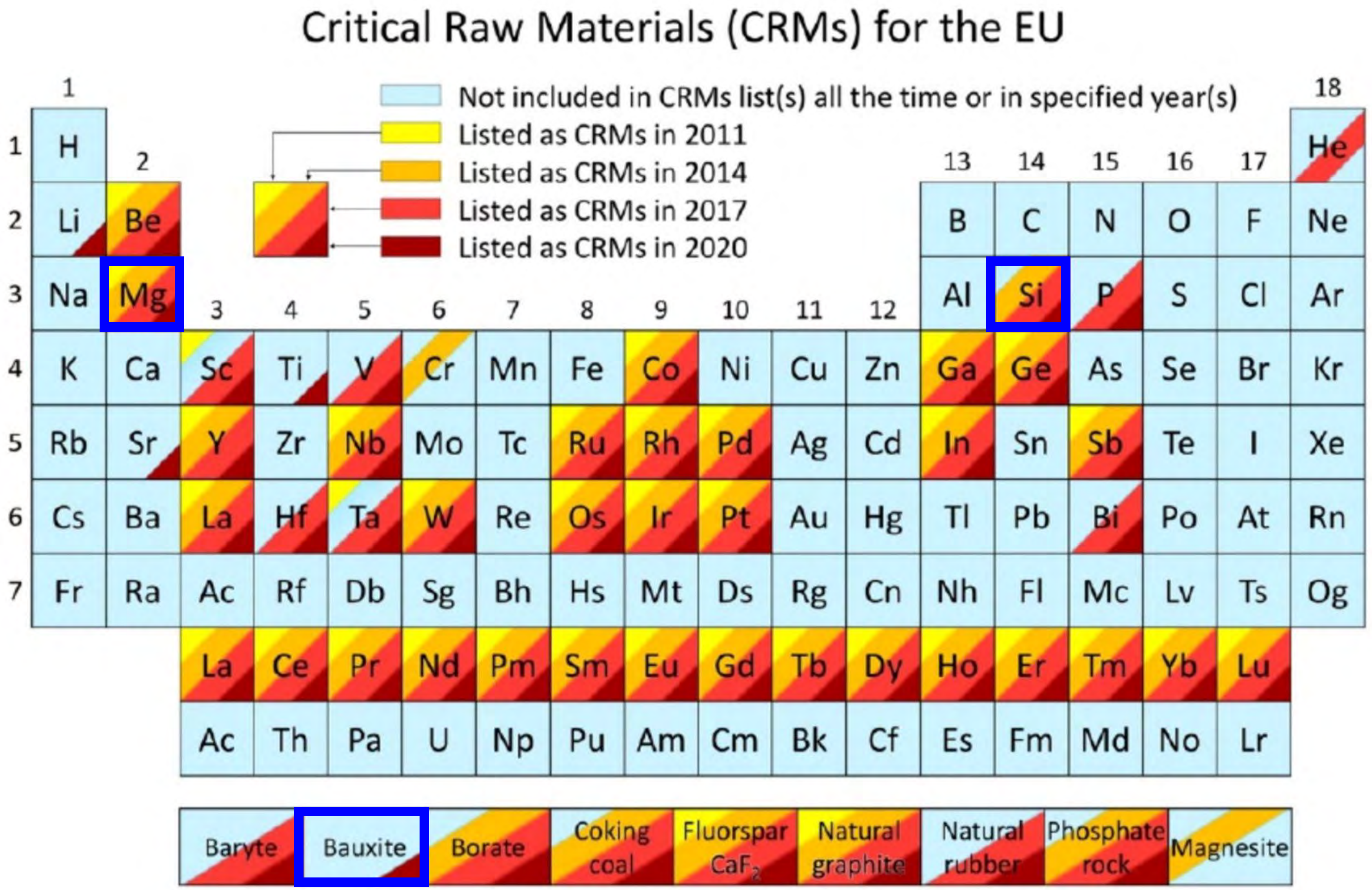
SALEMA Main objectives:

- To develop a non-CRM dependent aluminium ecosystem, by exploring 2 different approaches:
  - By **substituting primary CRMs with alternative** and commonly available elements
  - By obtaining the **CRMs elements from domestic scrap**, significantly increasing the amount of recycled material

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

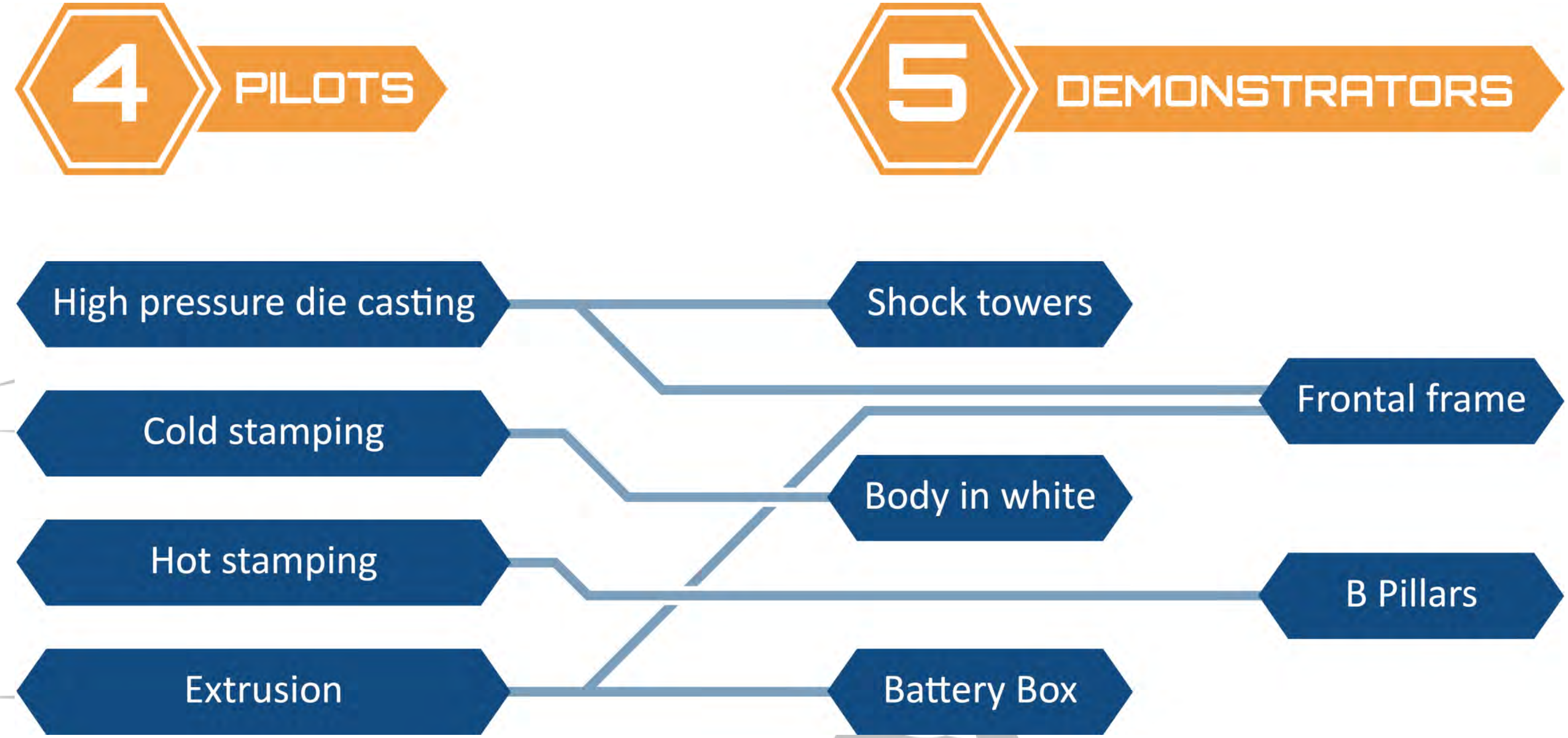


The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

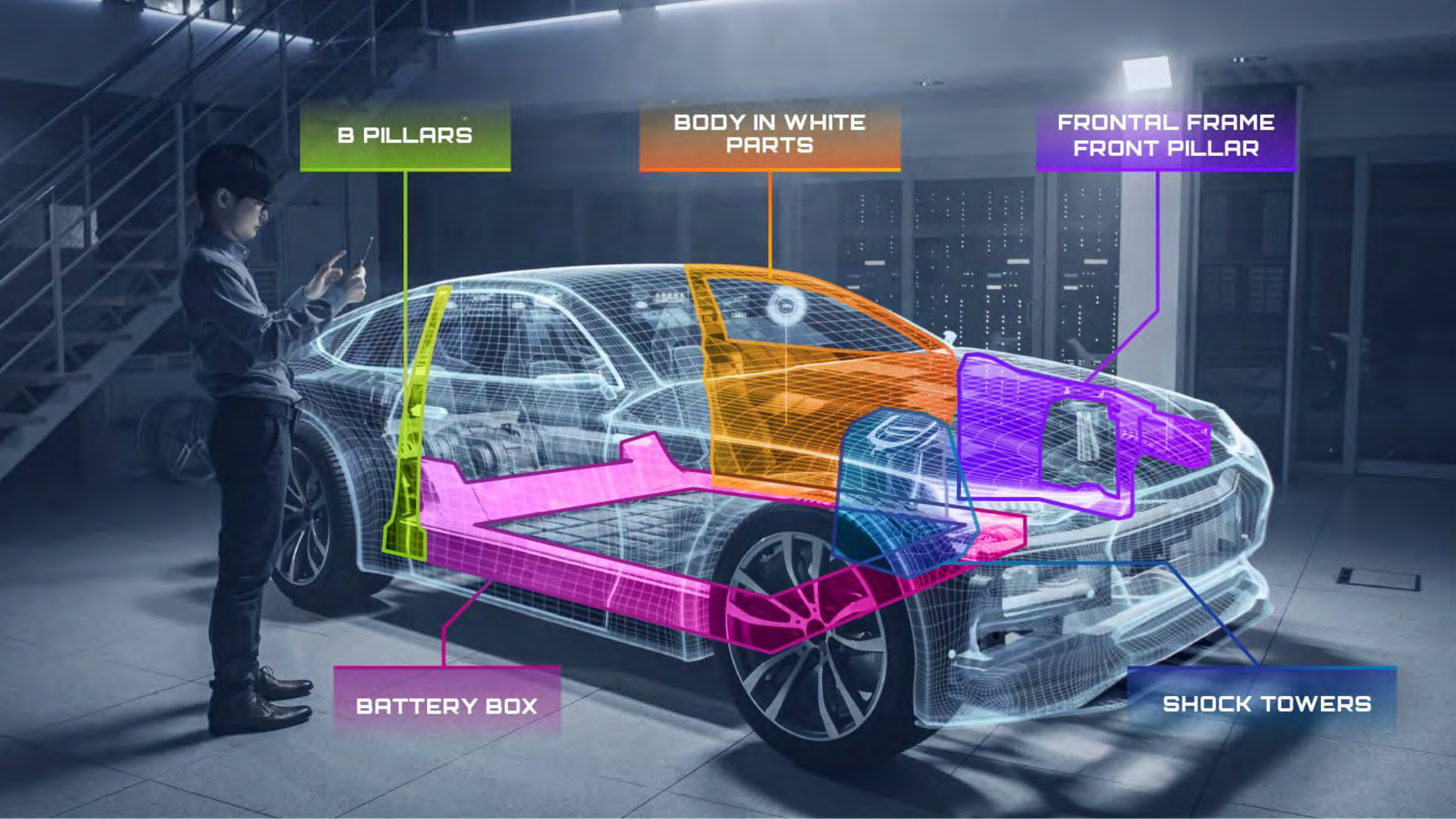


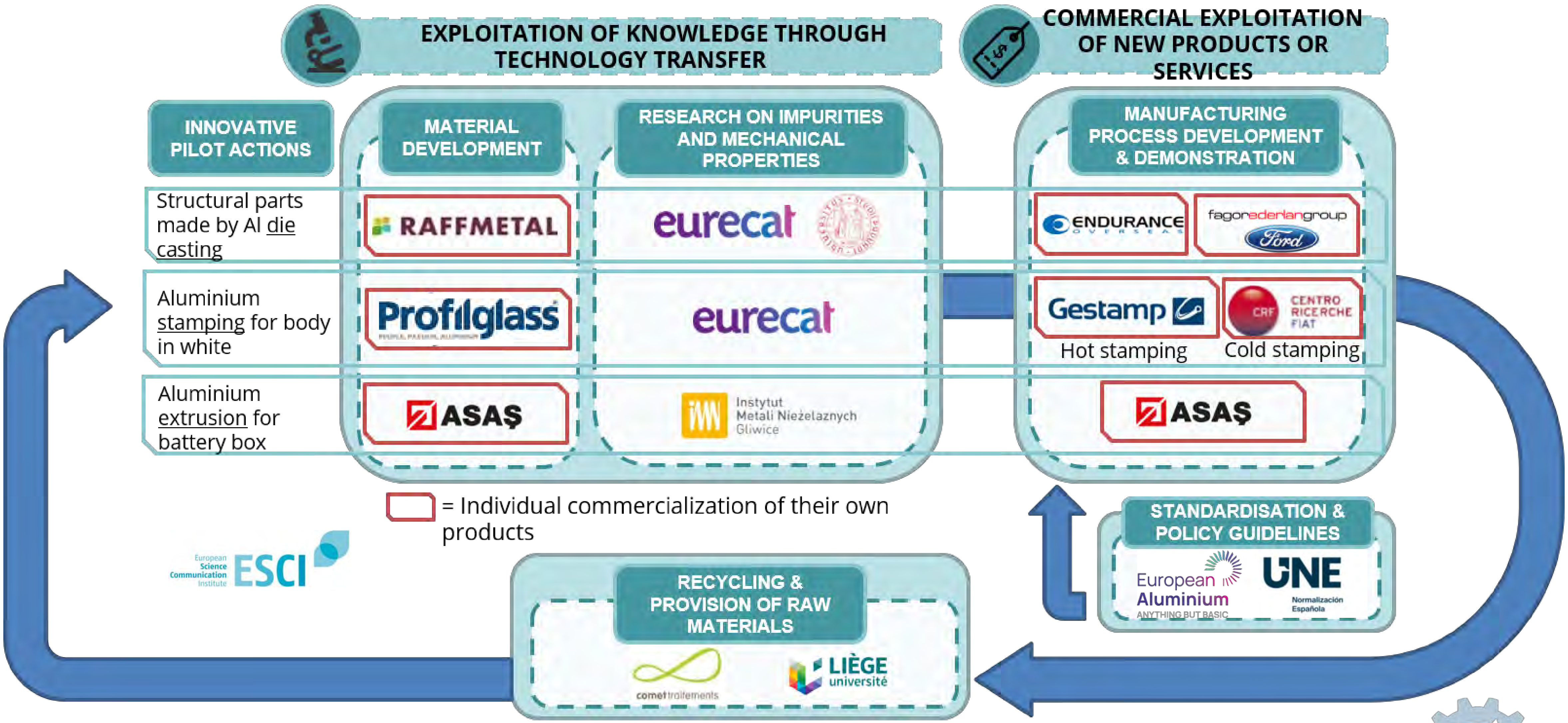
- Aluminium is a lightweight and cost-effective material
- Production of Aluminium and its alloys requires bauxite and other Critical Raw Materials (CRM), such as Si and Mg

The project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101003785.



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.


B PILLARS
BODY IN WHITE PARTS
FRONTAL FRAME FRONT PILLAR
BATTERY BOX
SHOCK TOWERS



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

- FINAL VIDEO

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

Summary

- Project introduction and video
- Scrap sorting system
- Development of HPDC SALEMA alloys
- Validation of HPDC SALEMA alloys in Shock Tower
- Alloy development and industrial validation in Hot Stamping
- Alloy development and industrial validation in extrusion
- Validation procedure of new alloys by an OEM

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

SCRAP SORTING SYSTEM

Objectives

- Adapt PICKIT sorting prototype to **separate post-consumer scraps** based on their alloying elements with LIBS.

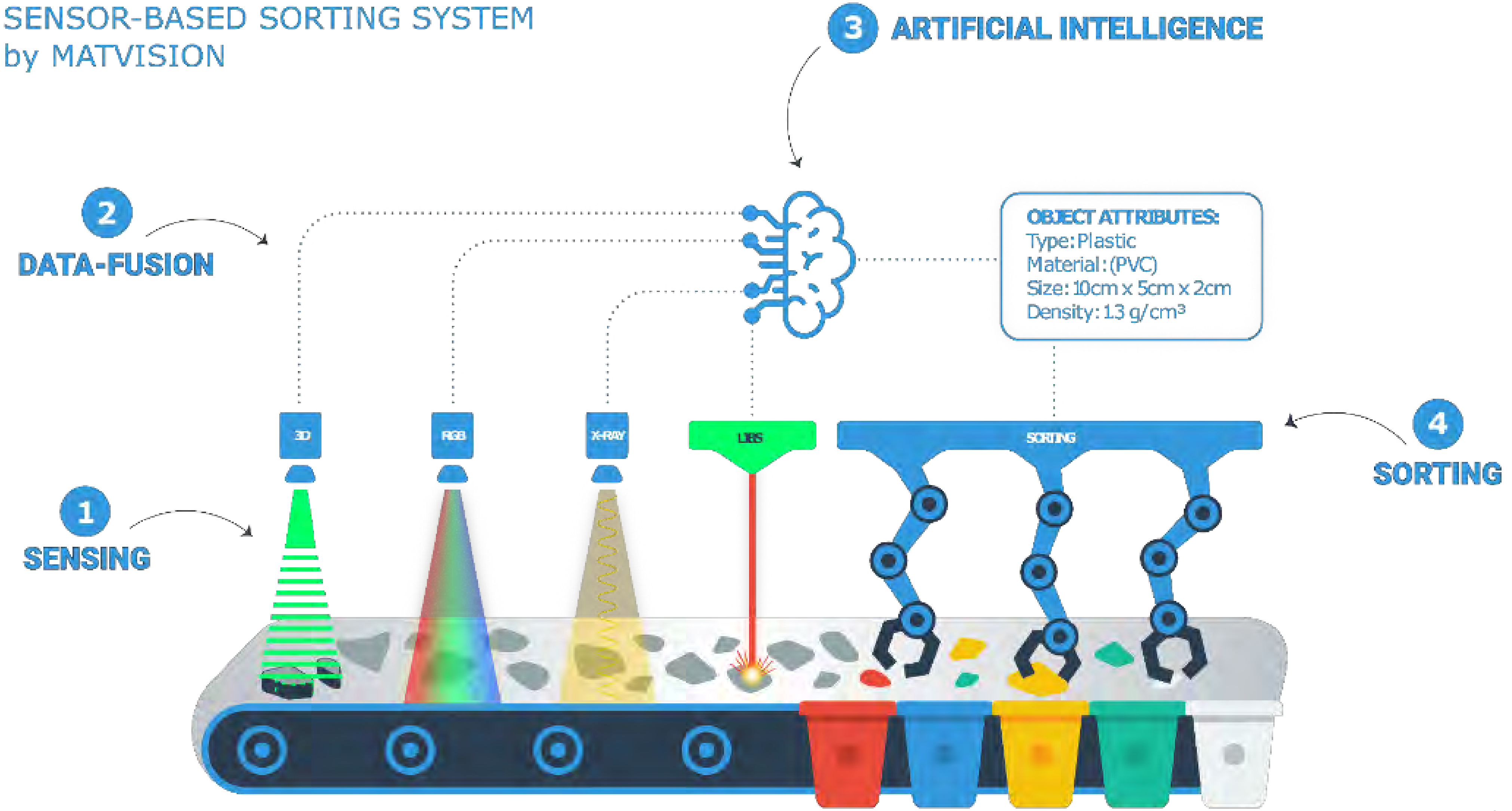
Results

- Successfully produced **high-quality lots of 1xxx, 2xxx,3xxx, 5xxx & 6xxx** for industrial validation with SALEMA's partners

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

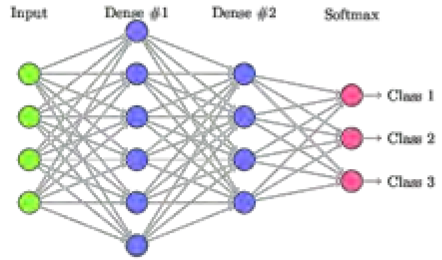
SCRAP SORTING SYSTEM

SENSOR-BASED SORTING SYSTEM
by MATVISION



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

SCRAP SORTING SYSTEM

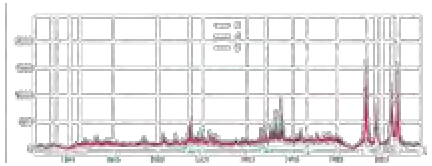


Two complementary approaches:

- Multi-output regression models:

=> Chemical content estimation

INPUT



OUTPUT

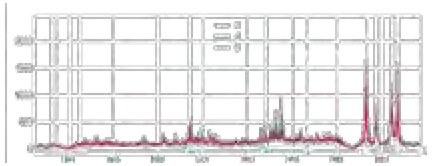
Elemental content:

Si	Fe	Cu	Mn	Mg	Zn	Al
7.1%	0.3%	0.1%	0.1%	0.3%	0.1%	92.0%

- Classification models:

=> Decision for sorting

INPUT



OUTPUT

Posterior probabilities:

2xxx	5xxx	6xxx	7xxx	AlSi10Mg	AlSi10M...	AlSi5Cu2	AlSi7Mg
0.00010	0.00000	0.82794	0.00003	0.00017	0.01977	0.00691	0.14509

Decision: « 6xxx »

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

Summary

- Project introduction and video
- Scrap sorting system
- Development of HPDC SALEMA alloys
- Validation of HPDC SALEMA alloys in Shock Tower
- Alloy development and industrial validation in Hot Stamping
- Alloy development and industrial validation in extrusion
- Validation procedure of new alloys by an OEM

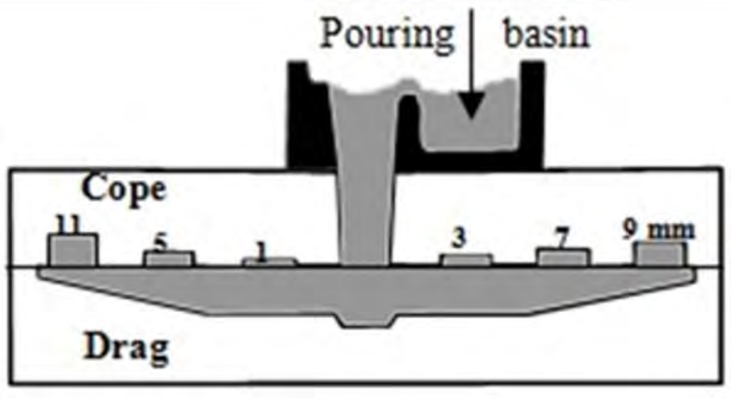
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

HPDC ALLOY DEVELOPMENT

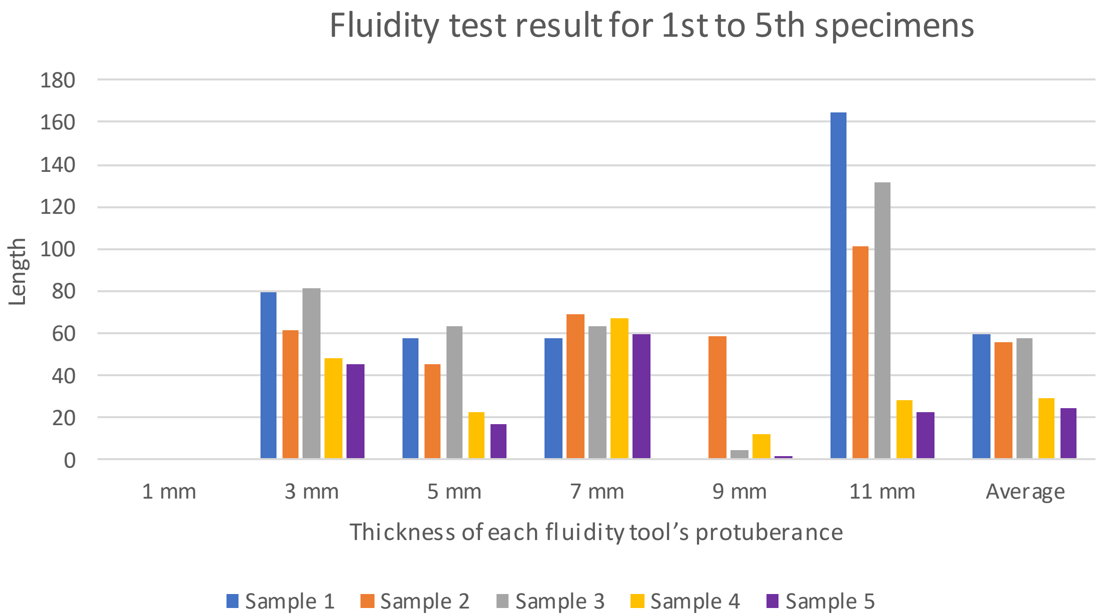
n=5	%Si	% Fe	%Mn	%Cu	%Zn	%Ti	%Mg
EN AB-43500	9.0-11.5	<0.2	0.4-0.8	<0.03	<0.07	<0.15	0.15-0.6
1	9.89	0.16	0.5	<0.03	<0.03	0.03	0.29
2	9.9	0.16	0.5	0.07	<0.03	0.03	0.29
3	9.81	0.17	0.5	0.13	<0.03	0.03	0.29
4	9.9	0.17	0.5	0.13	0.11	0.03	0.29
5	9.78	0.19	0.51	0.14	0.2	0.03	0.3
6	10.28	0.14	0.58	0.03	<0.03	0.06	0.16
7	10.4	0.21	0.58	0.03	<0.03	0.06	0.16
8	10.39	0.25	0.58	0.03	<0.03	0.06	0.16
9	10.3	0.26	0.61	0.03	<0.03	0.06	0.16
10	10.37	0.26	0.63	0.03	<0.03	0.06	0.16
11	10.32	0.14	0.56	0.03	<0.03	0.06	0.17
12	10.26	0.18	0.62	0.07	<0.03	0.07	0.17
13	10.27	0.21	0.6	0.06	<0.03	0.06	0.16
14	10.31	0.25	0.59	0.11	<0.03	0.06	0.16
15	10.42	0.29	0.6	0.12	<0.03	0.06	0.16

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

HPDC ALLOY DEVELOPMENT



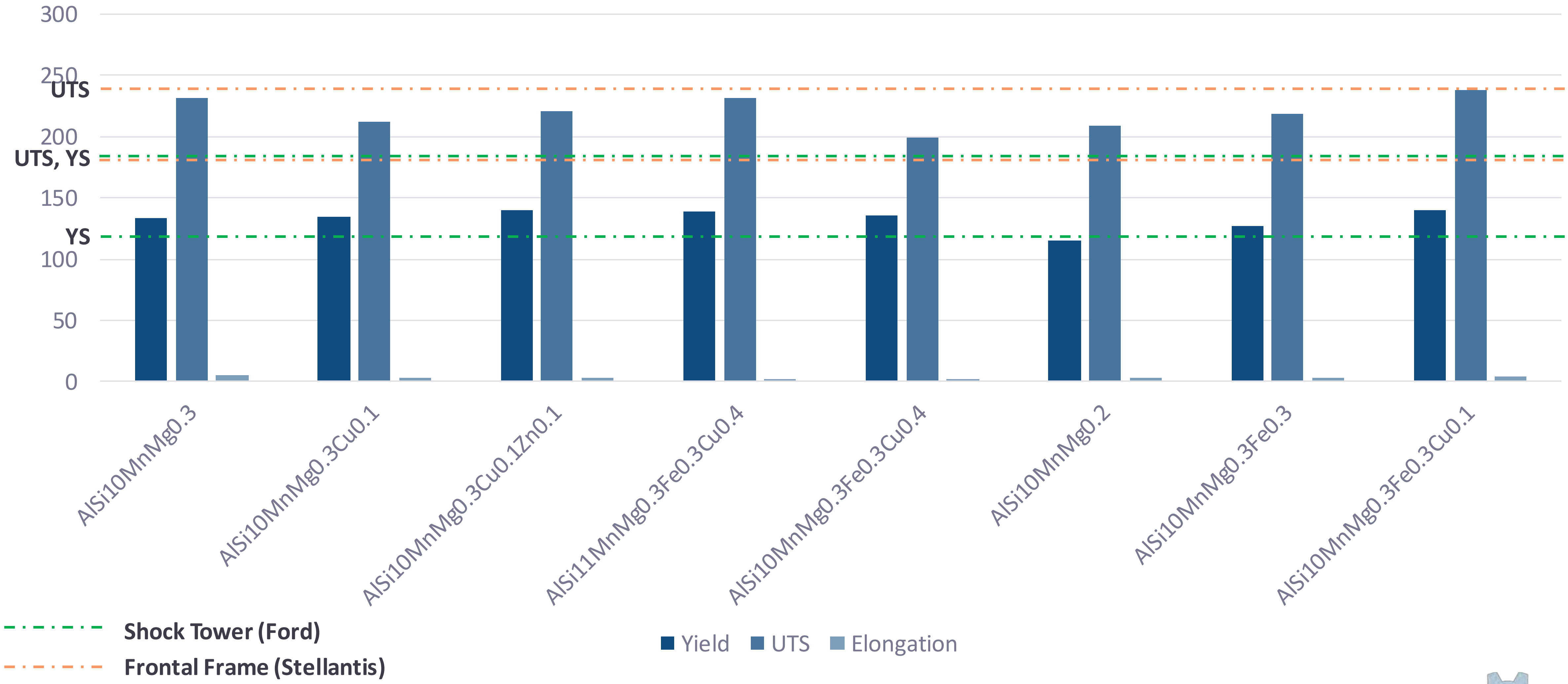
n=5	%Si	% Fe	%Mn	%Cu	%Zn	%Ti	%Mg
EN AB-43500	9.0-11.5	<0.2	0.4-0.8	<0.03	<0.07	<0.15	0.15-0.6
1	9.89	0.16	0.5	<0.03	<0.03	0.03	0.29
2	9.9	0.16	0.5	0.07	<0.03	0.03	0.29
3	9.81	0.17	0.5	0.13	<0.03	0.03	0.29
4	9.9	0.17	0.5	0.13	0.11	0.03	0.29
5	9.78	0.19	0.51	0.14	0.2	0.03	0.3



Alloy variant number	R_p [Mpa]	R_m [Mpa]	A_{25} [%]
1	92 ± 6	169 ± 4	5.9 ± 0.4
2	101 ± 7	177 ± 5	5.9 ± 1
3	98 ± 4	165 ± 16	3.8 ± 2.1
4	91 ± 2	173 ± 9	5.2 ± 1.3
5	105 ± 4	161 ± 27	3 ± 2.1

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

HPDC ALLOY DEVELOPMENT



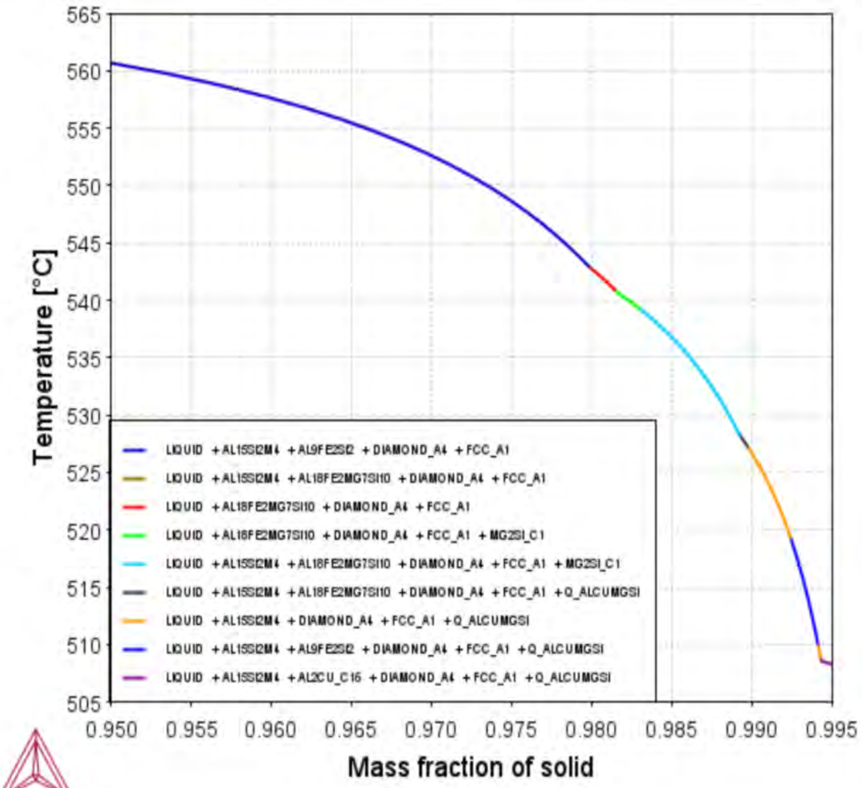
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

HPDC ALLOYS WITH REDUCED CRM CONTENT

Conceptual area	Characteristic of phenomenon to be modelled	Category of model
CRM content	Criticality Index	Properly developed
Castability	Fluidity (as the inverse of viscosity)	Thermo-Calc Software
	Solidification shrinkage	+ elaboration
	Slag/dross formation tendency	+ elaboration
	Die soldering tendency	+ elaboration
	Hot tearing tendency	+ elaboration

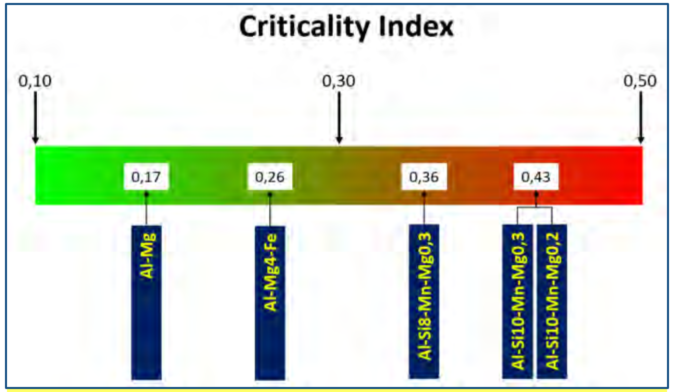
Hot Tearing

➔ TFR (Terminal Freezing Range): 95 to 100% of solidification



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

HPDC ALLOYS WITH REDUCED CRM CONTENT



Ranking for Criticality

➔ Criticality Index

Ranking for Processability

Attribution of weight to
- ➔ Viscosity/Fluidity
- ➔ Volume Shrinkage
- ➔ Sludge Factor
- ➔ Die soldering
- ➔ Hot Tearing

System	Set	RANKING	BALANCED SCORE	Suggested variants
AlSi8MnMg0.3	9	1	3,8	3, 6, 9, 21, 24, 27
AlSi10MnMg0.3	3	2	3,7	3, 6, 9, 21, 27
AlSi8MnMg0.3	10	2	3,7	3, 6, 9, 21, 24, 27
AlSi10MnMg0.2	6	4	3,6	3, 6, 9, 21, 24, 27
AlSi10MnMg0.2	7	4	3,6	3, 6, 9, 21, 24, 27
AlSi8MnMg0.3	11	4	3,6	3, 6, 9, 21, 24, 27
AlSi10MnMg0.3	4	6	3,5	3, 6, 9, 21, 27
AlSi10MnMg0.3	5	6	3,5	3, 6, 9, 21, 27
AlSi10MnMg0.2	8	8	3,4	3, 6, 9, 21, 24, 27
AlSi10MnMg0.2	8.1	8	3,4	3, 6, 9, 21, 24, 27
Al-Mg	1	10	3,3	22, 23, 27, 28,
Al4MgFe	2	10	3,3	28, 30

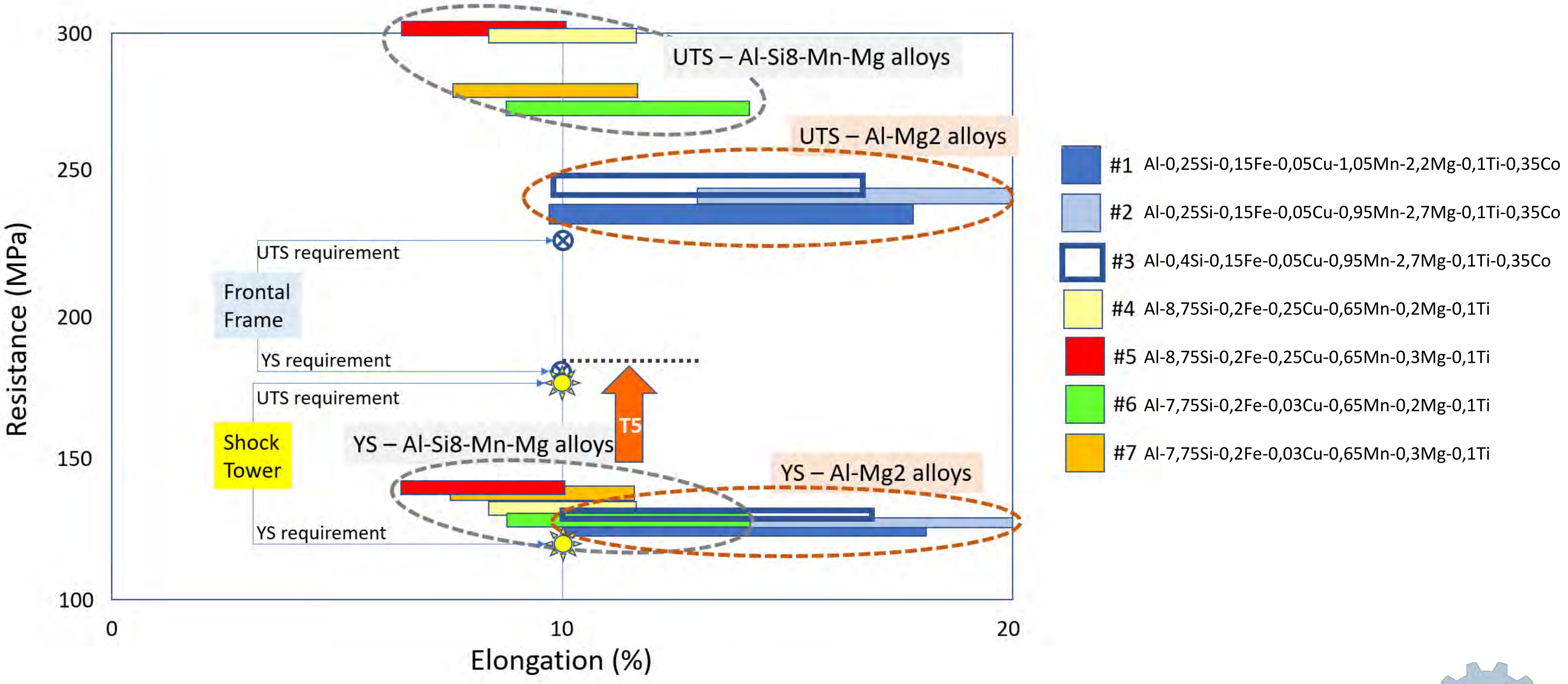
Weighting

Balanced Score

Final selection of variants for experimental tests

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

HPDC ALLOYS WITH REDUCED CRM CONTENT



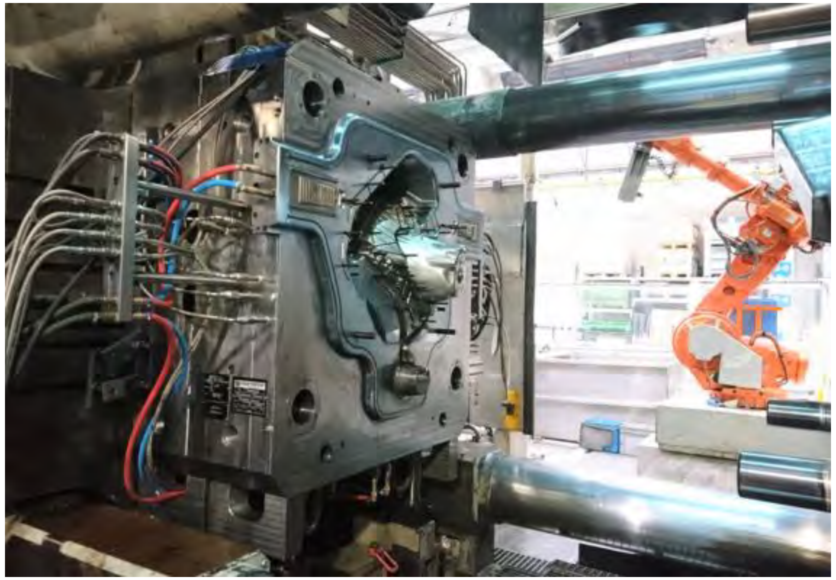
The project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101003785.

Summary

- Project introduction and video
- Scrap sorting system
- Development of HPDC SALEMA alloys
- Validation of HPDC SALEMA alloys in Shock Tower
- Alloy development and industrial validation in Hot Stamping
- Alloy development and industrial validation in extrusion
- Validation procedure of new alloys by an OEM

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN SHOCK-TOWER



F state (casted)

After HT

AlSi10MnMg

Rp0,2 = 133 MPa

Rm = 268 MPa

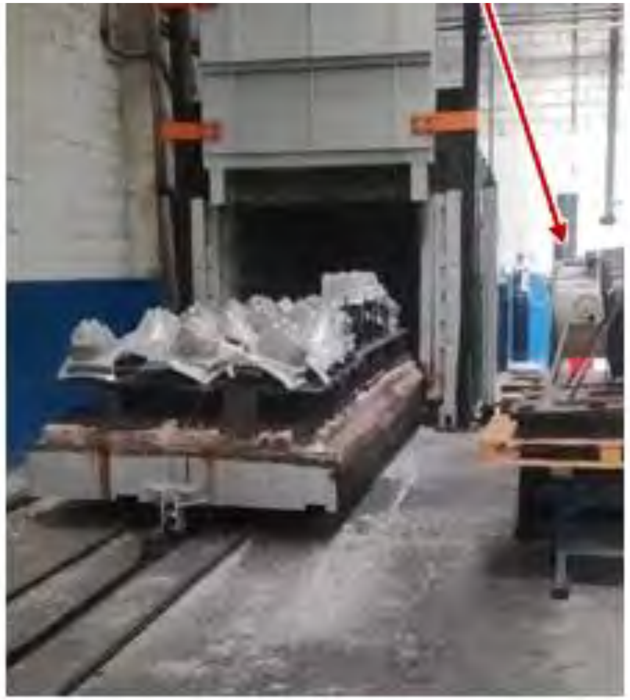
A = 6,8 %

T7:
480ºC/1h
+air cooling
+ 230ºC/2h

Rp0,2 = 129MPa

Rm = 200MPa

A = 12,7%

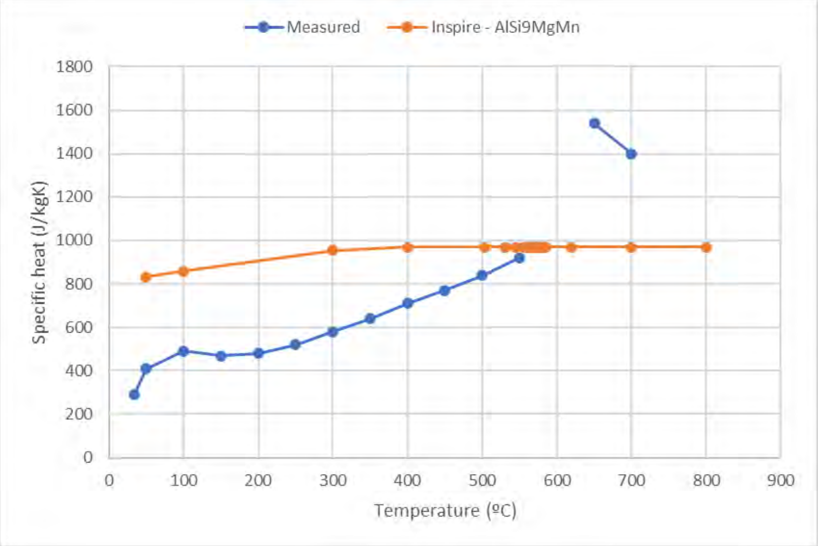


The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN SHOCK-TOWER

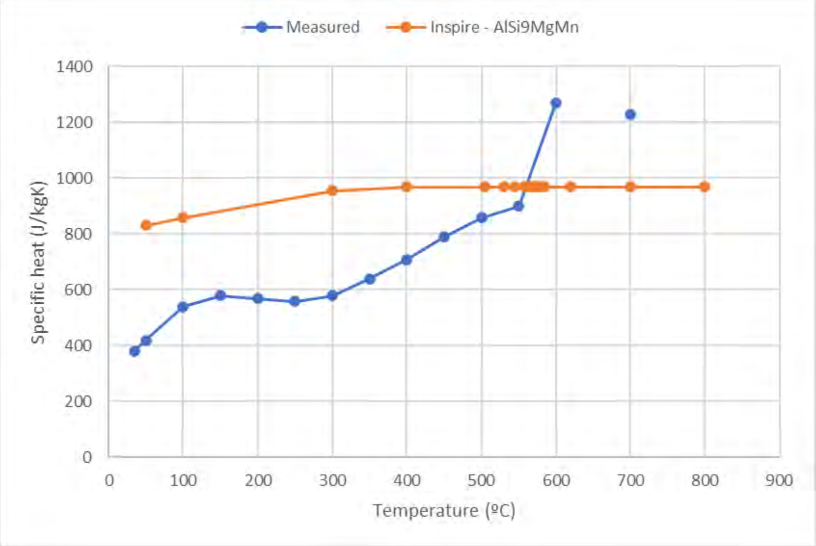
AlSi10MnMg

	Measured – Variant 6	Inspire - AlSi9MgMn
Latent heat (J/kg)	714825	417000
Liquidus temperature (ºC)	599,8	590
Solidus temperature (ºC)	589,8	550



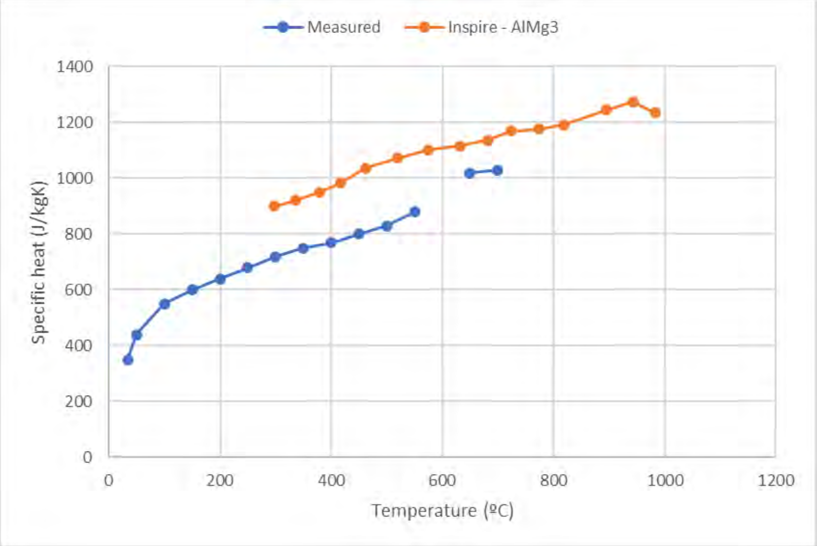
AlSi8MnMg

	Measured – Variant 7	Inspire - AlSi9MgMn
Latent heat (J/kg)	677129	417000
Liquidus temperature (ºC)	599,0	590
Solidus temperature (ºC)	588,6	550



AlMg2

	Measured – Variant 12	Inspire – AlMg3
Latent heat (J/kg)	612828	400000
Liquidus temperature (ºC)	664,3	640
Solidus temperature (ºC)	636,7	590

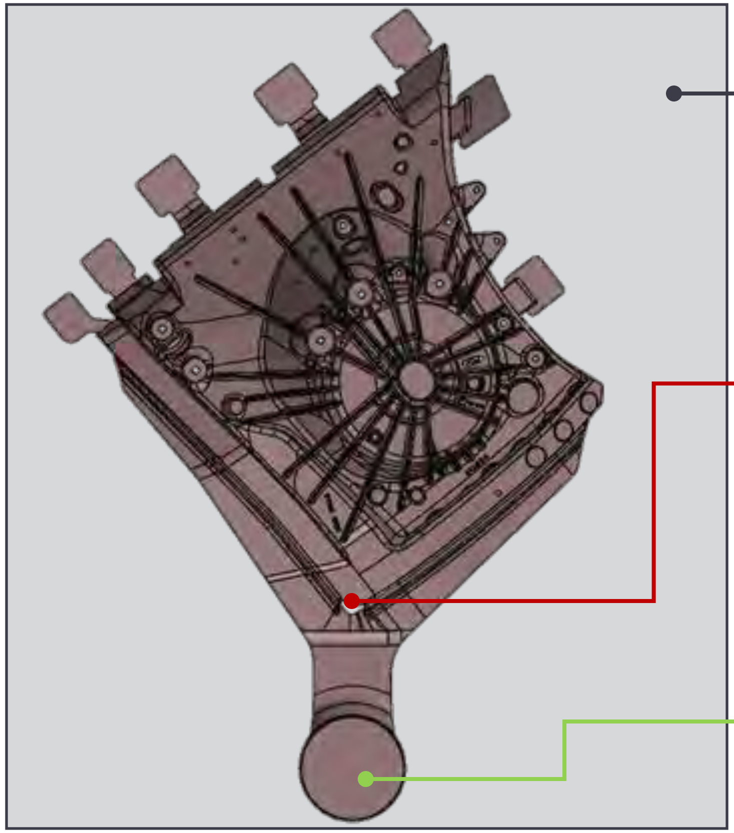


The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN SHOCK-TOWER

Shock tower (EDERTEK): Geometry and mesh

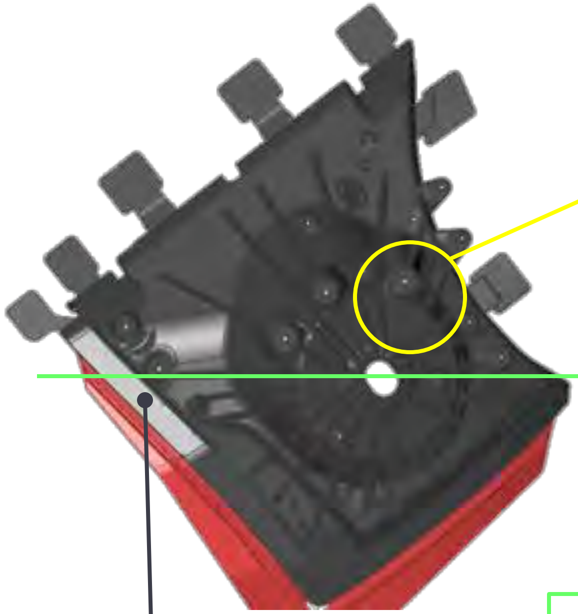
Gravity



Die
T_{die}= 220ºC

Commutation point

Inlet
AlSi10MnMg
AlSi8MnMg
AlMg2
v_1=0,15 m/s
v_2=3,8 m/s
T_{in}= 670ºC



Mesh
Element size: 5 mm
Nº elements > 750k

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN SHOCK-TOWER

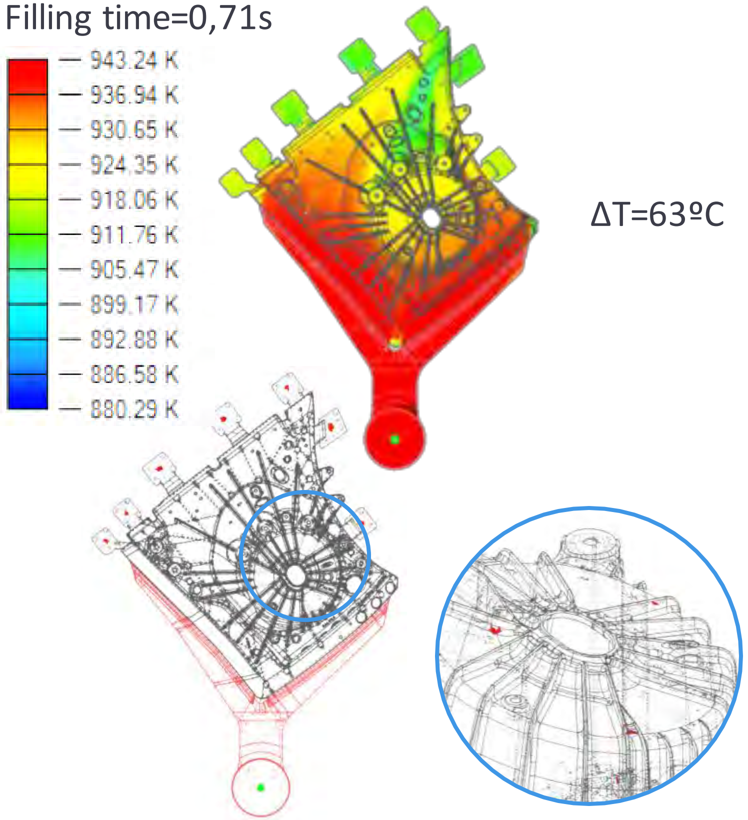
Shock tower (EDERTEK): Thermal conductivity, viscosity and density were obtained from InspireCast data base (AlSi9MgMn). All the other properties required by the software were determined experimentally from parts produced with the alloy variant.

FILLING

SOLIDIFICATION

AlSi10MnMg

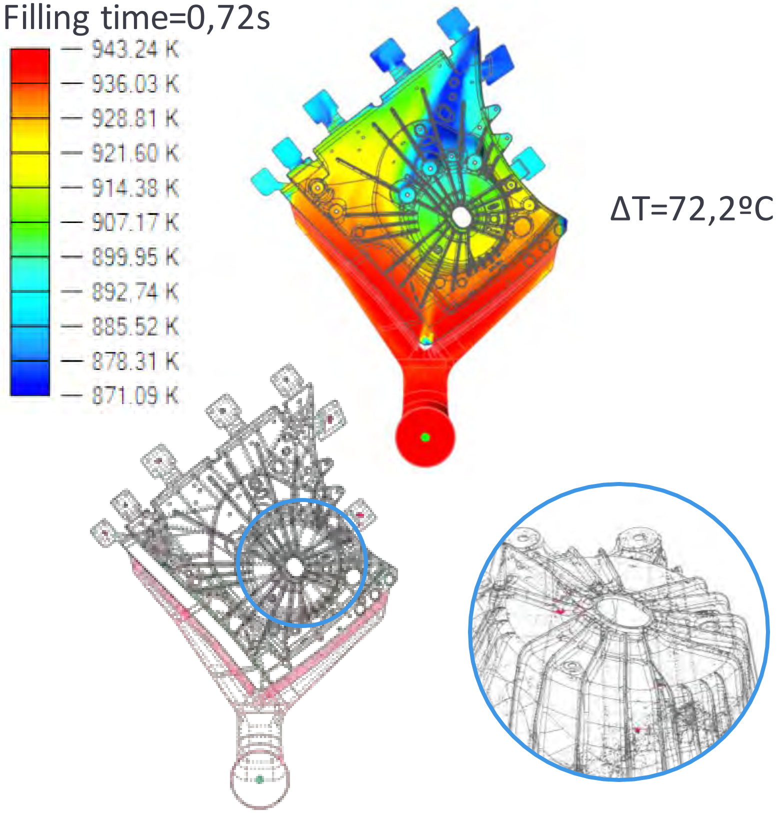
Filling time=0,71s



ΔT=63ºC

AlSi8MnMg

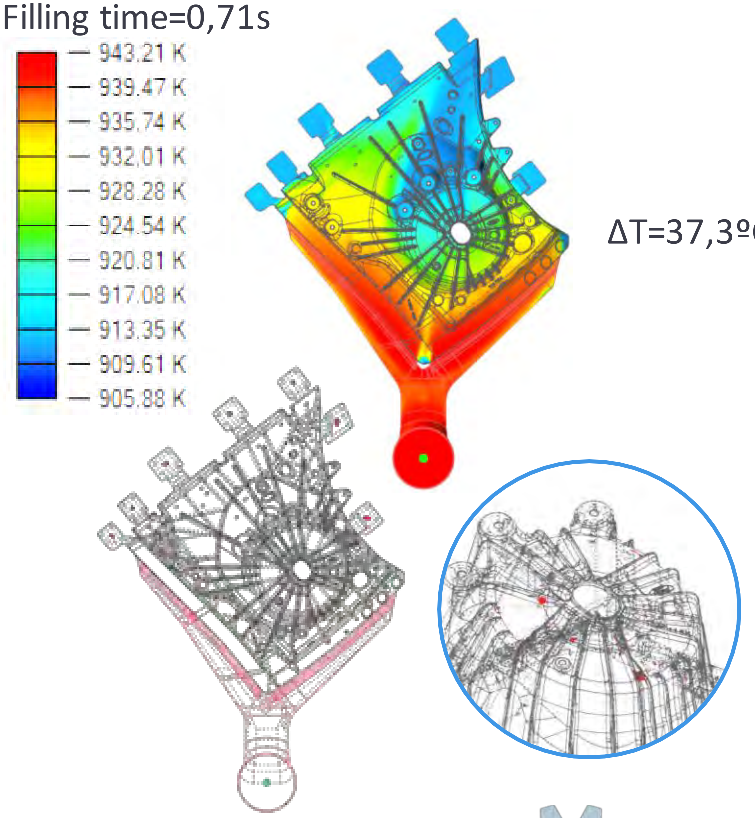
Filling time=0,72s



ΔT=72,2ºC

AMg2

Filling time=0,71s



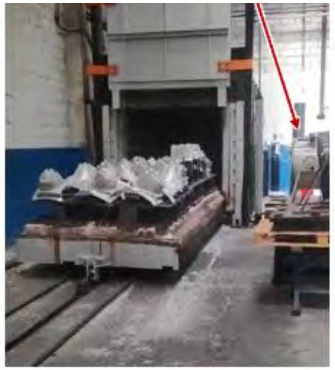
ΔT=37,3ºC

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN SHOCK-TOWER

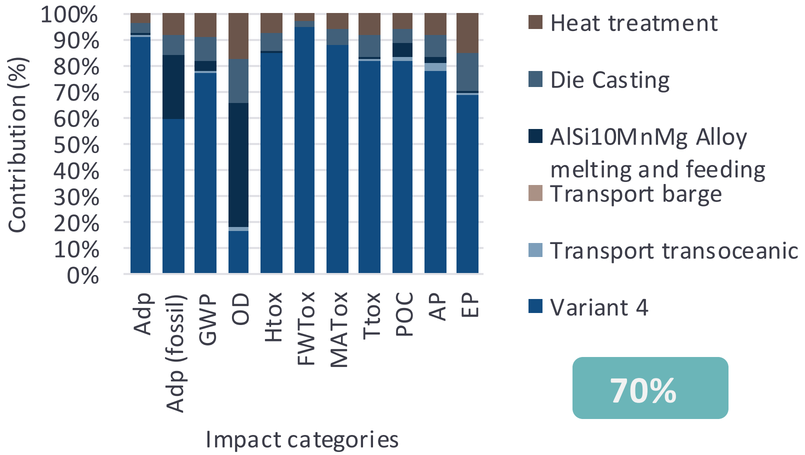
Mechanical properties (tensile test)

	AlSi10MnMg Standard (variant 1)	AlSi10MnMgFe0,3 (Variant6)	AlSi8MnMg (Variant7)		AlMg2 (Variant 12)
F state (casted)	Rp0,2 = 133 MPa Rm = 268 MPa A = 6,8 %	Rp0,2 = 137 MPa Rm = 264 MPa A = 6%	Rp0,2 = 122 MPa Rm = 248 MPa A = 8,7 %		Rp=115MPa Rm = 205 MPa A = 10% (mean value, but with high dispersion)
	T7: 480ºC/1h +air cooling + 230ºC/2h	T7: 480ºC/1h +air cooling + 230ºC/2h	T0_a: 320ºC/1h	T0_b: 380ºC/1h	
After HT	Rp0,2 = 129MPa Rm = 200MPa A = 12,7%	Rp0,2 = 131 MPa Rm = 185 MPa A = 12,2%	Rp0,2 = 119 MPa Rm = 216 MPa A = 7,5%	Rp0,2 = 100 MPa Rm = 184 MPa A = 11,4%	
			No improvement	Improvemet in elongation, but Rp<120Mpa	

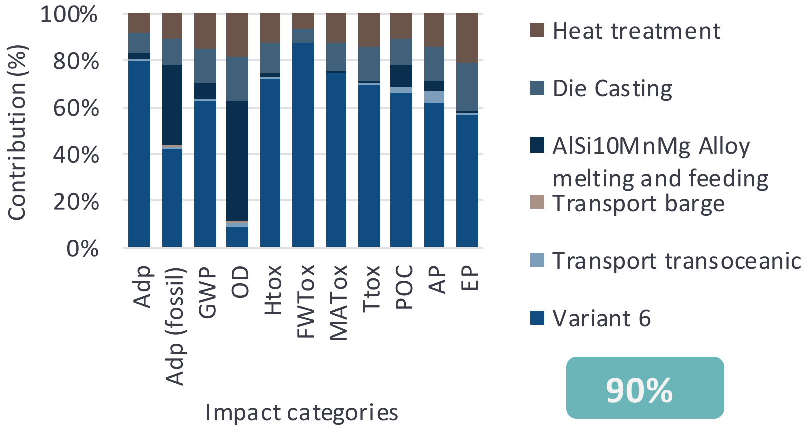


The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

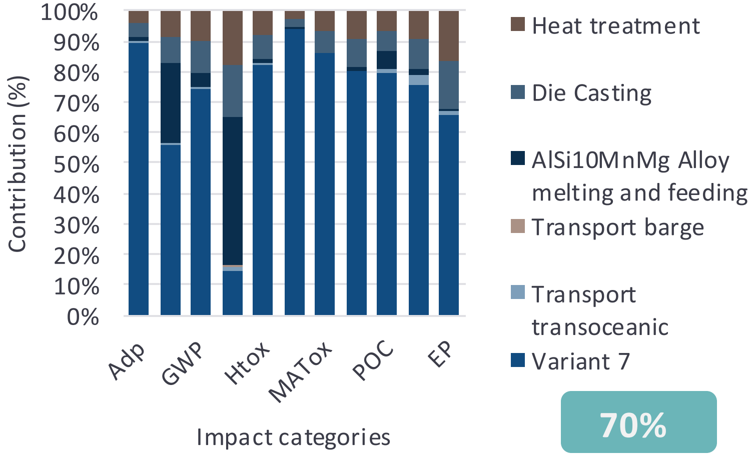
INDUSTRIAL VALIDATION IN SHOCK-TOWER



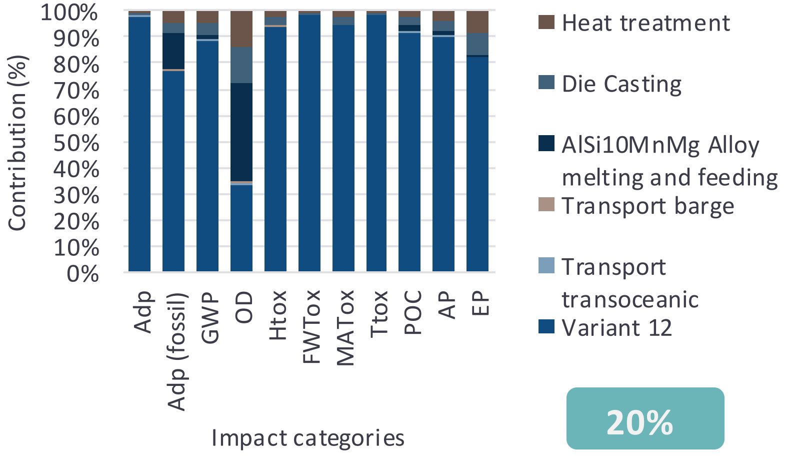
70%



90%



70%



20%

HPDC	TOTAL Shock Tower Baseline	TOTAL Shock Tower Variant 4	TOTAL Shock Tower Variant 6	TOTAL Shock Tower Variant 7	TOTAL Shock Tower Variant 12
Abiotic depletion	2,69E-03	2,34E-05	1,03E-05	2,04E-05	1,05E-04
Abiotic depletion (fossil fuels)	8,18E+01	4,08E+01	2,89E+01	3,75E+01	7,21E+01
Global warming (GWP100a)	7,33E+00	3,15E+00	1,89E+00	2,80E+00	6,30E+00
Ozone layer depletion (ODP)	5,02E-07	1,87E-07	1,72E-07	1,82E-07	2,33E-07
Human toxicity	5,51E+00	2,18E+00	1,22E+00	1,92E+00	5,64E+00
Fresh water aquatic ecotox.	2,66E+01	7,88E+00	3,15E+00	6,84E+00	2,17E+01
Marine aquatic ecotoxicity	2,52E+04	8,64E+03	4,20E+03	7,47E+03	1,98E+04
Terrestrial ecotoxicity	1,53E-02	1,01E-02	5,91E-03	8,99E-03	1,27E-01
Photochemical oxidation	2,37E-03	9,23E-04	4,88E-04	8,02E-04	2,00E-03
Acidification	3,93E-02	1,60E-02	9,22E-03	1,42E-02	3,36E-02
Eutrophication	1,38E-02	6,48E-03	4,68E-03	5,98E-03	1,13E-02
GWP		57,1%	74,2%	61,8%	14,0%

Co
Mg
Cu

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

Summary

- Project introduction and video
- Scrap sorting system
- Development of HPDC SALEMA alloys
- Validation of HPDC SALEMA alloys in Shock Tower
- Alloy development and industrial validation in Hot Stamping
- Alloy development and industrial validation in extrusion
- Validation procedure of new alloys by an OEM

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

SHEET METAL ALLOY DEVELOPMENT

	%Si	% Fe	%Cu	%Mn	%Mg	%Cr	Ti	%Zn
6181A (T4)	0.85	0.29	0.13	0.30	0.76	<0.03	<0.03	0.06

Alloy	Variant	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
6181A	Tipo0 (50 % recycled)	0,89	0,21	0,09	0,01	0,69	0,01	0,02	0,02
6181A	Tipo1 (70% recycled)	1	0,3	0,19	0,28	0,8	0,02	0,07	0,03
6181A	Tipo2 (85% recycled)	1,1	0,35	0,19	0,3	0,84	0,02	0,08	0,03

	%Si	% Fe	%Cu	%Mn	%Mg	%Cr	Ti	%Zn
5754 (EN-573-3)	0.25	0.40	0.1	0.5	2.6-3.6	0.3	0.2	0.15

Alloy	Variant	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
5754	Tipo1 (65% recycled)	0,29	0,31	0,08	0,21	2,88	0,03	0,02	0,03
5754	Tipo2 (80% recycled)	0,32	0,38	0,07	0,24	2,91	0,04	0,03	0,03

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

SHEET METAL ALLOY DEVELOPMENT

Tensile Properties

COLD FORMING ALLOYS

	Rp [MPa]	Rm [MPa]	A%
5754 - Type1	97	210	22.5
5754 - Type2	100	212	22.3
6181A - type0	136	252	21
6181A - type1	163	276	24
6181A -type2	172	282	24

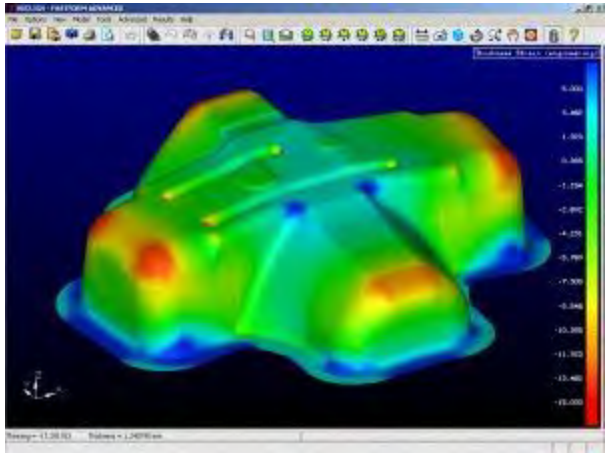
HOT FORMING ALLOYS

	Rp [MPa]	Rm [MPa]	A%
6181A - type0	287	345	18.0
6181A - type1	287	346	16.4
6181A -type2	290	345	18.0
6111	301	376	17

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

SHEET METAL ALLOY DEVELOPMENT

Formability Parameters



Dir.	Rp0.2 [MPa]	Rm [MPa]	Ag [%]	A50 [%]	n	r	$\bar{r}$	Δr
5754 Type 1								
0°	101 ± 2	215 ± 1	16.0 ± 0.7	19.5 ± -	0.29 ± 0.01	0.58 ± 0.03		
45°	95 ± 1	206 ± 1	20.0 ± 0.3	23.3 ± 0.8	0.28 ± 0.01	0.86 ± 0.02	0.75	-0.21
90°	97 ± 1	209 ± 0	20.2 ± 1.6	25.0 ± 1.2	0.27 ± 0.00	0.71 ± 0.01		
5754 type 2								
0º	105 ± 0	219 ± 2	17.2 ± 1.0	19.4 ± 1.1	0.28 ± 0.00	0.61 ± 0.01		
45º	97 ± 1	209 ± 2	20.9 ± 1.2	24.8 ± 0.9	0.27 ± 0.00	0.89 ± 0.01	0.77	-0.23
90º	99 ± 1	210 ± 0	19.1 ± 0.4	22.7 ± -	0.27 ± 0.00	0.71 ± 0.01		

Dir.	Rp0.2 [MPa]	Rm [MPa]	Ag [%]	A50 [%]	n	r	$\bar{r}$	Δr
6181A Type 0								
0º	127 ± 1	211 ± 3	15.9 ± 1.0	18.1 ± 1.3	0.22 ± 0.01	0.60 ± 0.04		
45º	100 ± 3	170 ± 2	15.3 ± 0.9	-	0.23 ± 0.01	0.73 ± 0.07	0.76	0.06
90º	129 ± 1	230 ± 3	17.3 ± 0.3	-	0.25 ± 0.01	0.98 ± 0.07		
6181A Type 1								
0º	125 ± 4	203 ± 2	17.0 ± 0.6	19.4 ± 0.1	0.21 ± 0.01	0.70 ± 0.06		
45º	127 ± 4	215 ± 7	15.4 ± 4.6	19.6 ± 5.5	0.24 ± 0.01	0.52 ± 0.03	0.56	0.10
90º	127 ± 3	219 ± 3	18.3 ± 0.8	-	0.25 ± 0.01	0.52 ± 0.01		
6181A Type 2								
0º	137 ± 1	239 ± 2	17.1 ± 0.6	-	0.25 ± 0.01	0.69 ± 0.03		
45º	131 ± 2	234 ± 2	21.3 ± 1.3	24.5 ± 2.0	0.25 ± 0.01	0.42 ± 0.04	0.53	0.23
90º	122 ± 4	207 ± 3	15.7 ± 3.0	21.7 ± -	0.25 ± 0.01	0.61 ± 0.07		

The project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101003785.

SHEET METAL ALLOY DEVELOPMENT

Essential Work of Fracture

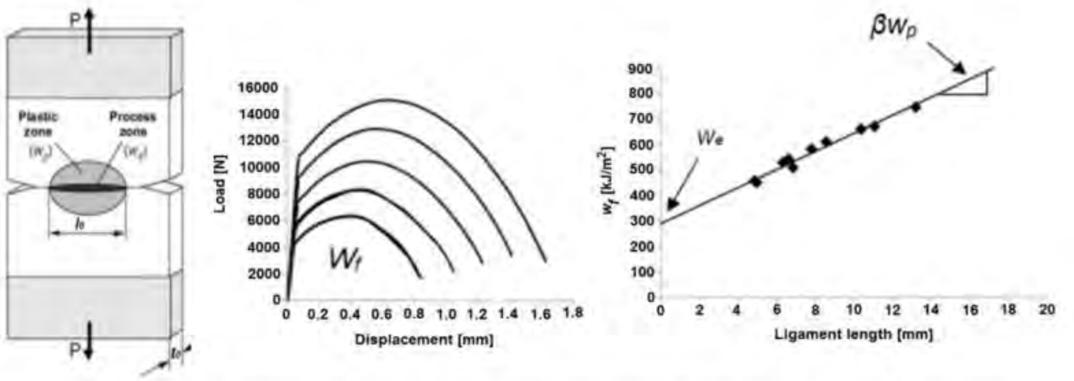


Figure 3.8: Test geometry and methodology for determination of the Essential Work of Fracture.

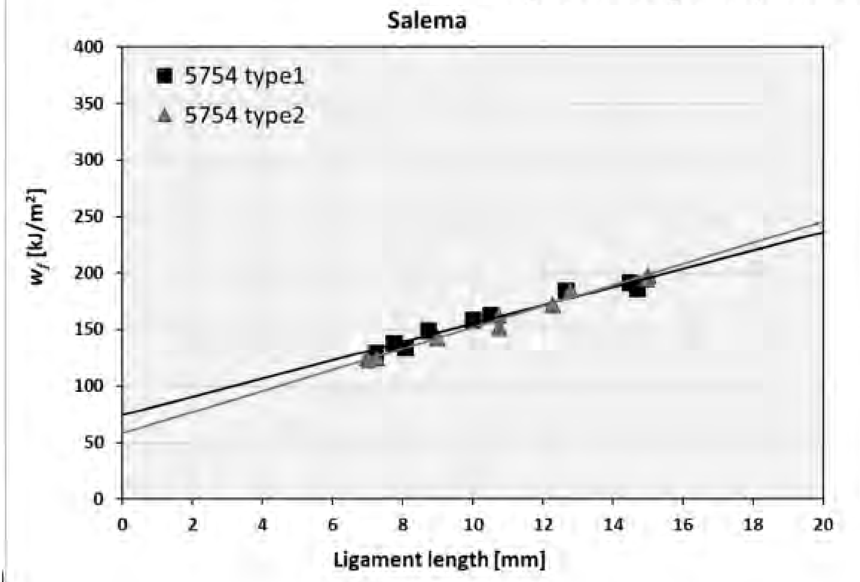


Figure 3.10: EWF results for 5754 variants

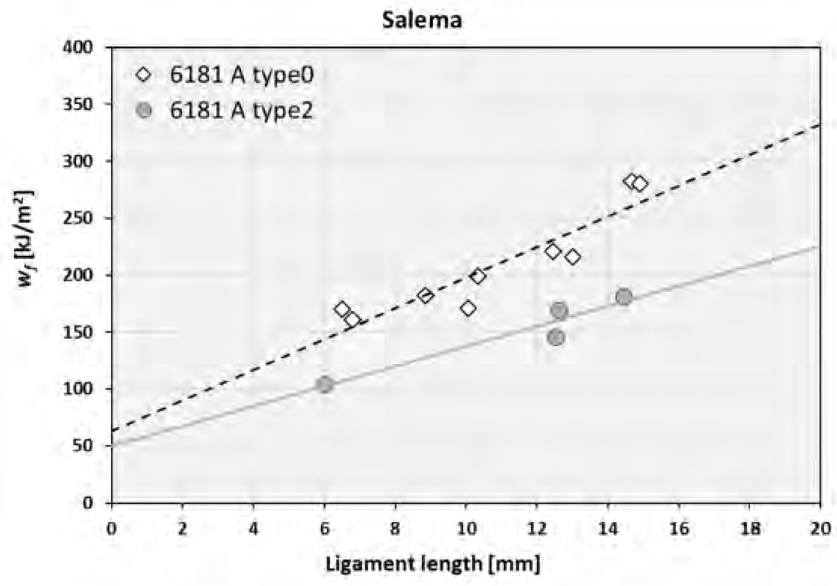
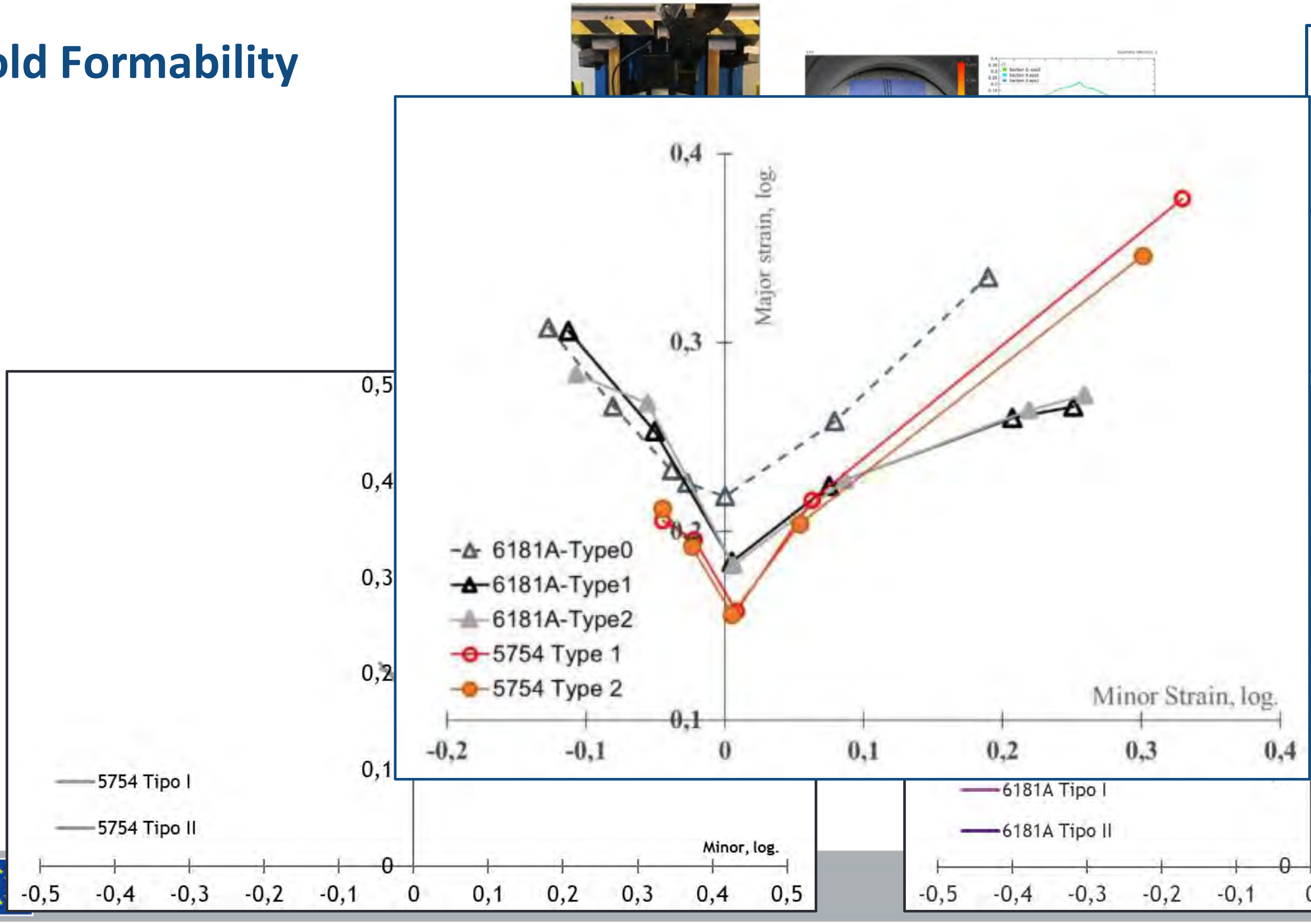
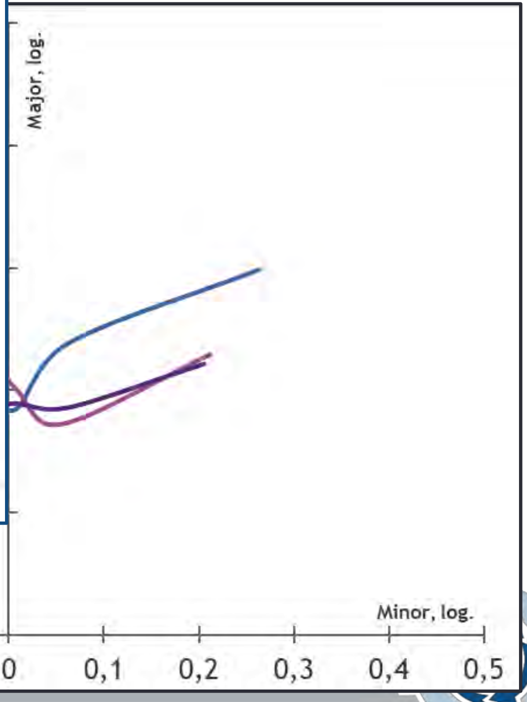


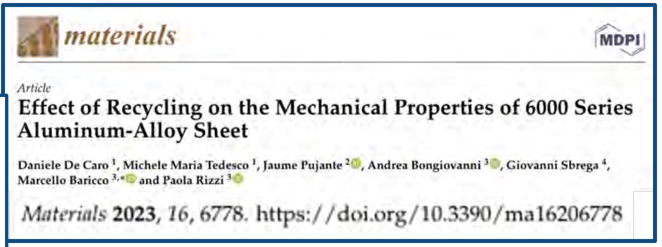
Figure 3.13: EWF results for 6181A; comparison of Type 0 and 2.

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

SHEET METAL ALLOY DEVELOPMENT

Cold Formability



materials

Article

Effect of Recycling on the Mechanical Properties of 6000 Series Aluminum-Alloy Sheet

Daniele De Caro [1], Michele Maria Tedesco [1], Jaume Pujante [2], Andrea Bongiovanni [3], Giovanni Sbrega [4], Marcello Baricco [3,*] and Paola Rizzi [3]

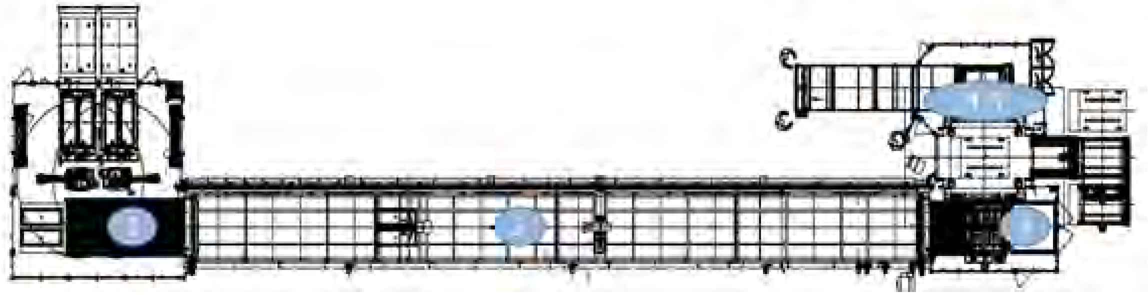
Materials **2023**, *16*, 6778. https://doi.org/10.3390/ma16206778

INDUSTRIAL VALIDATION IN HOT STAMPING

- PROJECT TARGET
  - Use of aluminum with high recycle content
    - 6111 85%
    - 6181A 85%

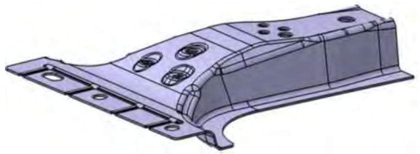
Alloy	Rp [MPa]	Rm [MPa]	A [%]
6181A T4	110-140	205-240	12 a 23
6181A T6	220-310	260-375	4 a 13
6111 T4	150-180	270-290	20-26
6111 T6	250-310	360-390	8-14

  - Process implementation in the current Assets.



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN HOT STAMPING



01
PART DESIGN

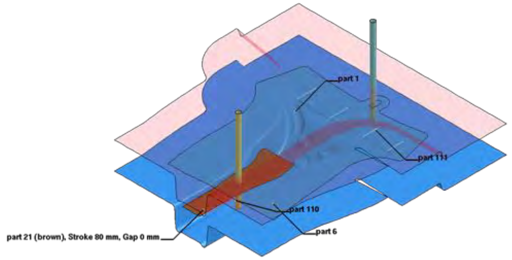
02
PROCESS SIMULATION

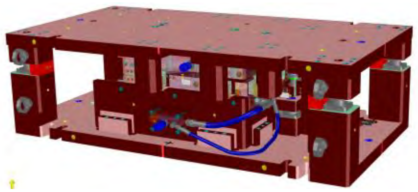
03
PROCESS INFORMATION

04
TOOLING PRODUCTION

05
PRODUCTION TRY-OUTS

Gestamp





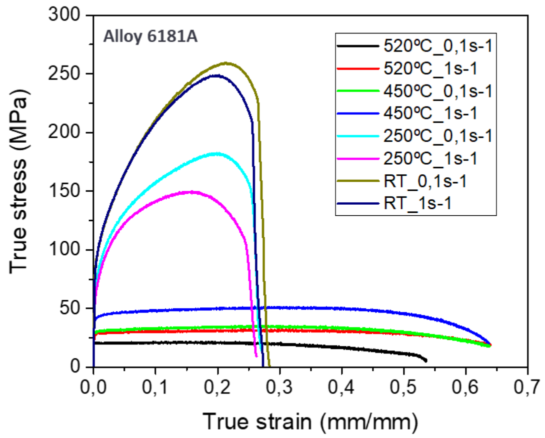
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN HOT STAMPING

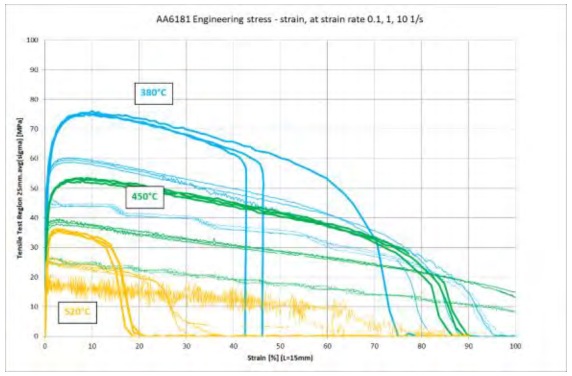
- PROCESS SIMULATION

EURECAT – GESTAMP LABORATORY TEST

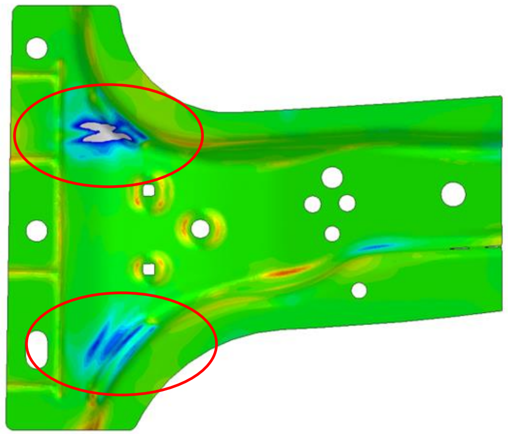
TENSILE TEST

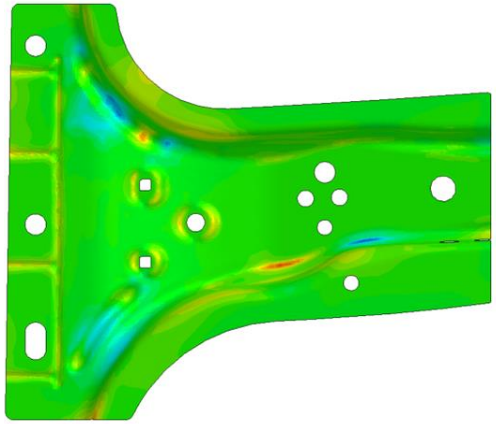


FRICTION TEST



GESTAMP PART PROCESS SIMULATION





MATERIAL DATA CARD

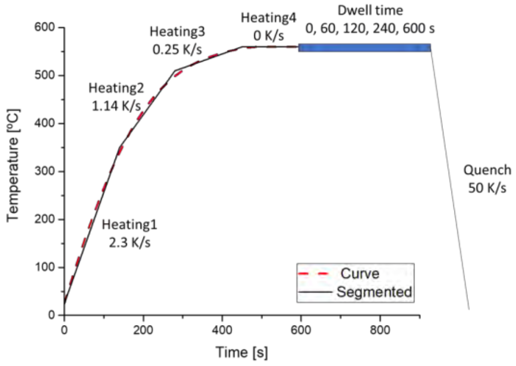
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

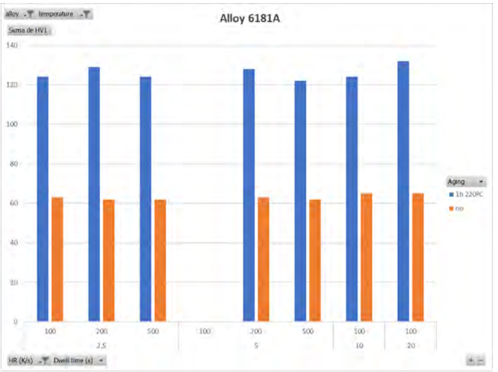
INDUSTRIAL VALIDATION IN HOT STAMPING

- PROCESS PARAMETER

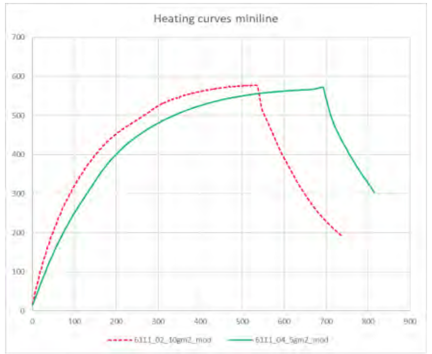
VERIFICATION

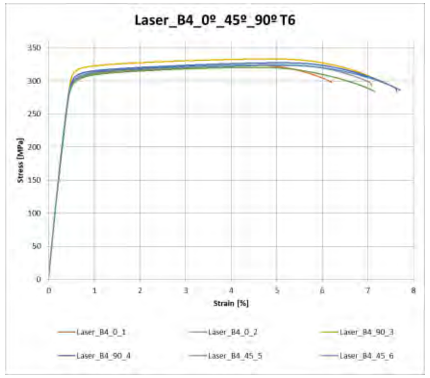
EURECAT LABORATORY TEST





GESTAMP LINE



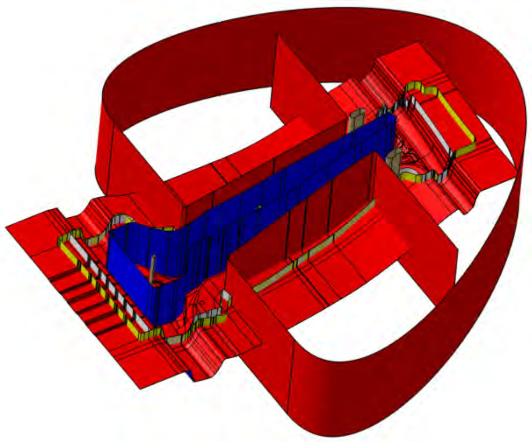


The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN HOT STAMPING

- TOOLING DESIGN & PRODUCTION

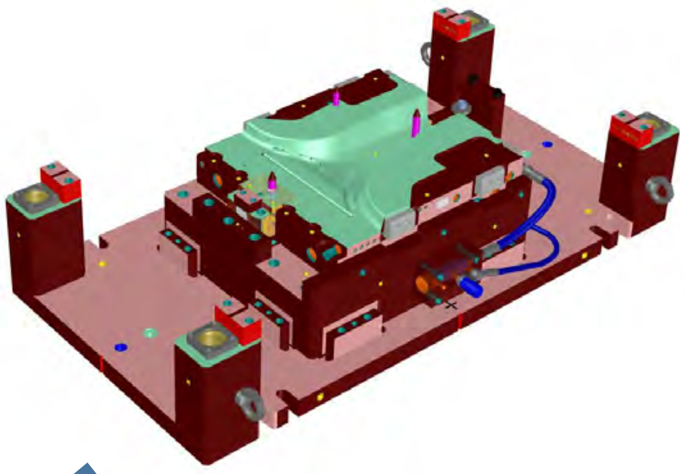
GESTAMP TOOLING "SURFACE"

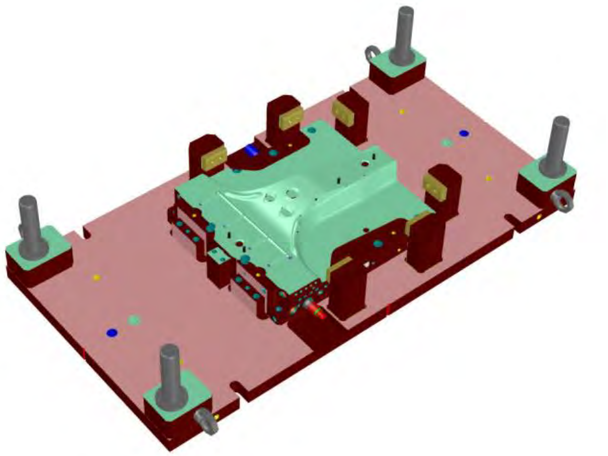


Tool_XXXX_YYZZ.stp contains the following data:

Upper die = Red
Lower die = Blue
Blank guide (optional) = Brown
Upper split surfaces (optional) = Red
Lower split surfaces (optional) = Blue
Upper limit for fine/coarse milling = White
Upper binder limit for fine/coarse milling = Pink
Lower limit for fine/coarse milling = Yellow
Lower binder limit for fine/coarse milling = Grey
Splits for Tool SZ (obtained from Tooling) = Green

GESTAMP TOOLING MANUFACTURE





VIRTUAL → **PHYSICAL**

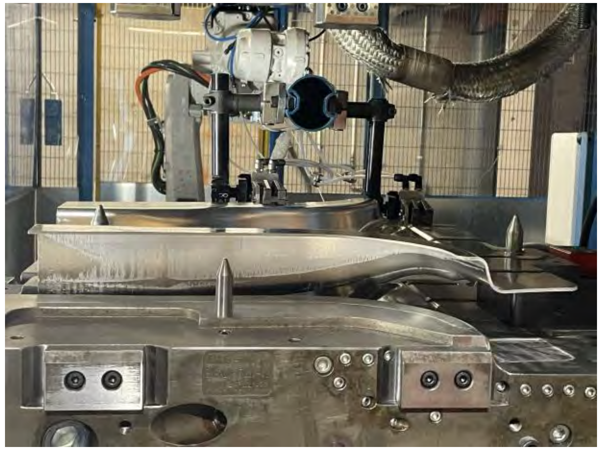
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

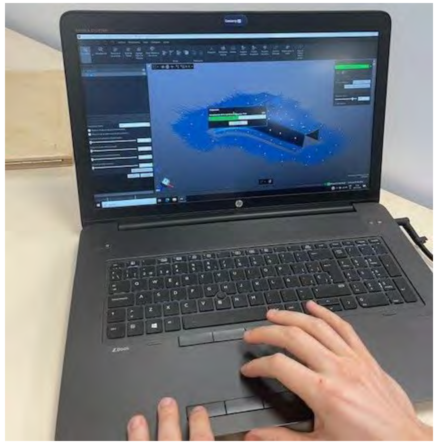
INDUSTRIAL VALIDATION IN HOT STAMPING

- PART PRODUCTION







The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

Manel da Silva, PhD

Technical Coordinator

manel.dasilva@eurecat.org

Follow SALEMA on

https://salemaproject.eu/

LinkedIN:
www.linkedin.com/company/salemaeu/

Twitter:
@salemaEU

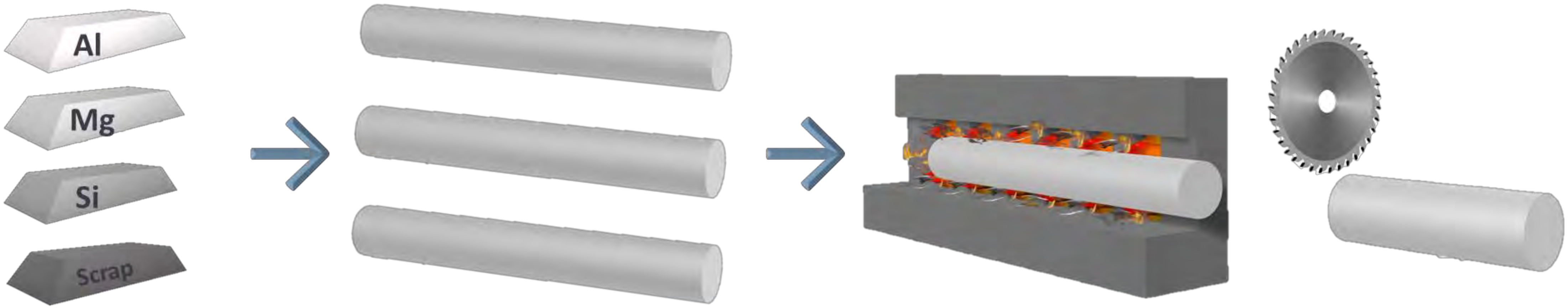
Summary

- Project introduction and video
- Scrap sorting system
- Development of HPDC SALEMA alloys
- Validation of HPDC SALEMA alloys in Shock Tower
- Alloy development and industrial validation in Hot Stamping
- Alloy development and industrial validation in extrusion
- Validation procedure of new alloys by an OEM

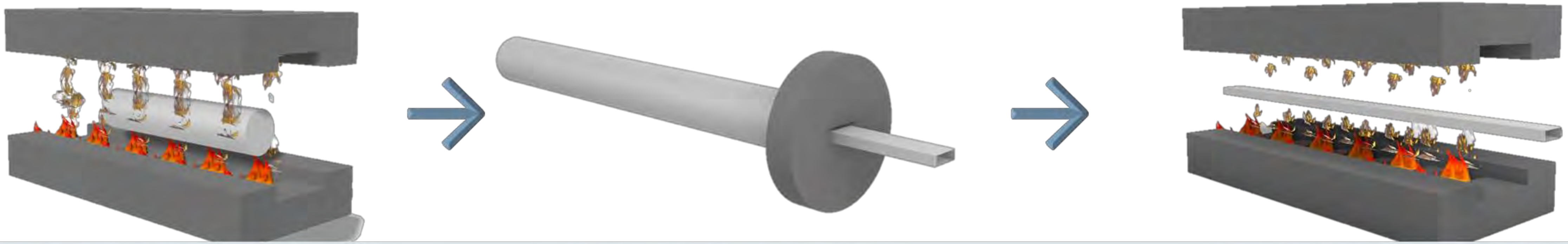
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

ALUMINIUM ALLOY EXTRUSION METHODOLOGY

SALEMA



Alloying | DC Casting | Homogenization | Cutting



Pre-heating | Direct Extrusion | Heat Treatment

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

EXTRUSION ALLOY DEVELOPMENT

	Variant	Content. wt.%										
		Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Pb	Sn	Ti
6111	1	**0.8-1.0**	0-0.4	**0.6-0.8**	0.15-0.45	**0.7-0.9**	0-0.1	0.05	0-0.15	0.05	0.05	0-0.1
	2	**0.6-0.8**	0-0.4	**0.7-0.9**	0.15 - 0.45	**0.5-0.7**	0-0.1	0.05	0-0.15	0.05	0.05	0-0.1
	3	**0.6-0.8**	0-0.4	**0.5-0.7**	0.15-0.45	**0.5-0.7**	0-0.1	0.05	0-0.15	0.05	0.05	0-0.1
6063	1	0.4-0.6	0-0.35	0-0.1	0-0.15	0.5-0.7	0-0.1	0-0.05	0-0.1	0-0.05	0-0.05	0-0.1
	2	0.4-0.6	0-0.35	**0.1-0.15**	**0.15-0.2**	0.5-0.7	0-0.1	0-0.05	**0.1-0.15**	0-0.05	0-0.05	**0.1-0.15**
	3	0.4-0.6	**0.35-0.45**	**0.15-0.2**	**0.2-0.25**	0.5-0.7	0-0.1	0-0.05	**0.1-0.15**	0-0.03	0-0.03	**0.1-0.15**
6082	1	0.9-1.1	0-0.5	0-0.1	0.6-0.8	0.8-1	0-0.25	0-0.05	0-0.2	0-0.05	0-0.05	0-0.1
	2	0.9-1.1	0-0.5	**0.1-0.15**	0.6-0.8	0.8-1	0-0.25	0-0.05	0-0.2	0-0.05	0-0.05	0-0.1
	3	0.9-1.1	0-0.5	**0.15-0.2**	0.6-0.8	0.8-1	0-0.25	0-0.05	0-0.2	0-0.05	0-0.05	**0.1-0.15**

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

EXTRUSION ALLOY DEVELOPMENT

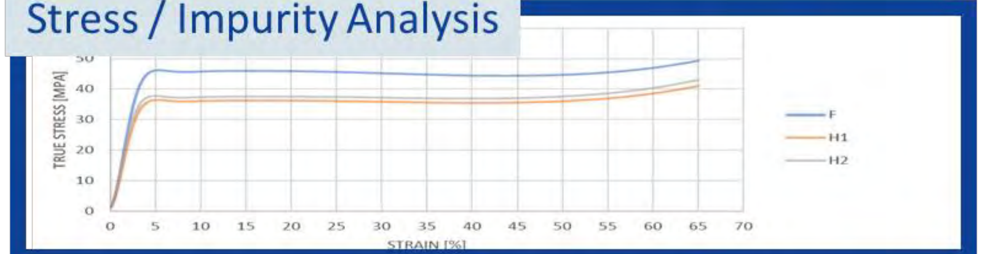
Different Scraps

Lab-Scale Casting

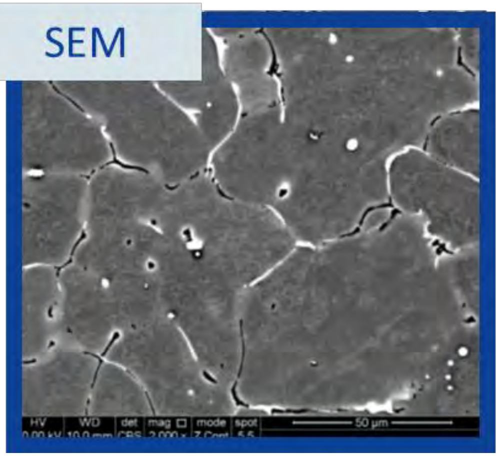
Final Billets

Microstructure

Stress / Impurity Analysis



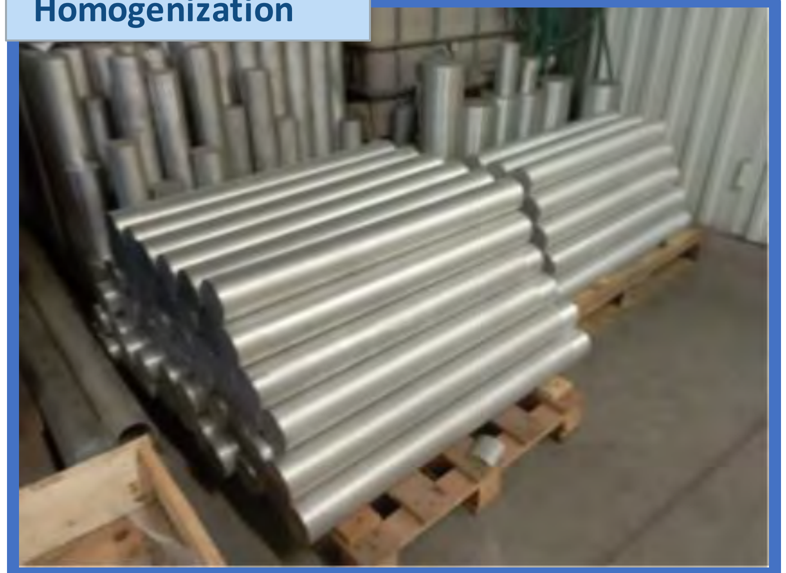
SEM



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

EXTRUSION ALLOY DEVELOPMENT

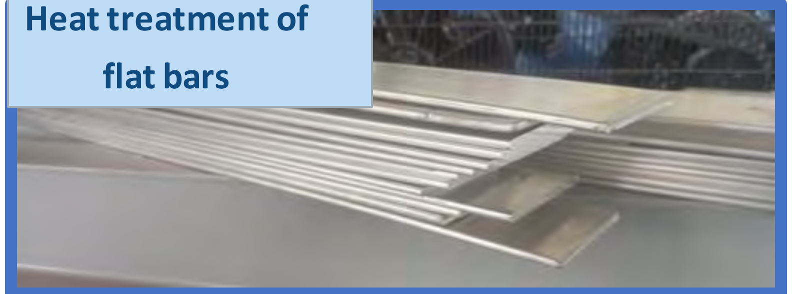
Homogenization



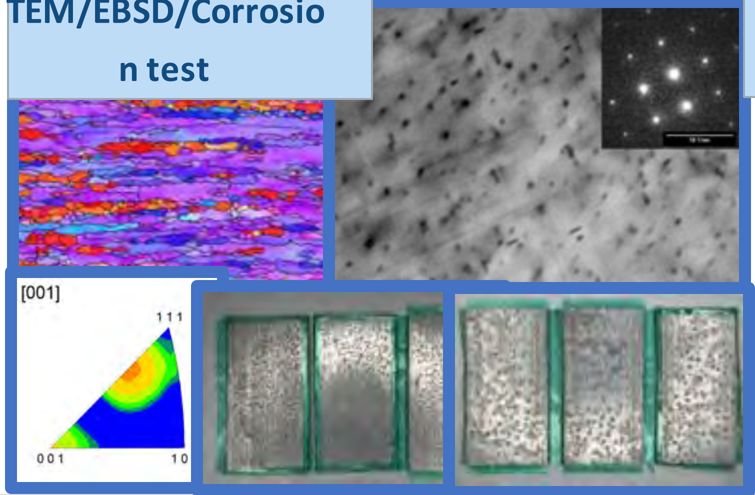
Optimization of extrusion

Extrusion die

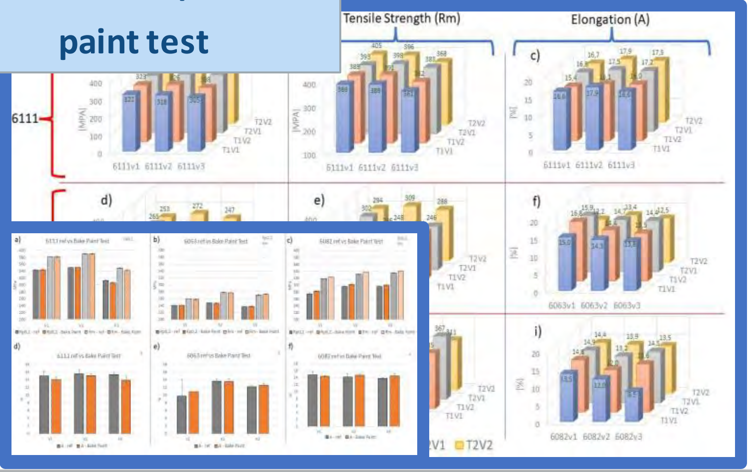
Heat treatment of flat bars



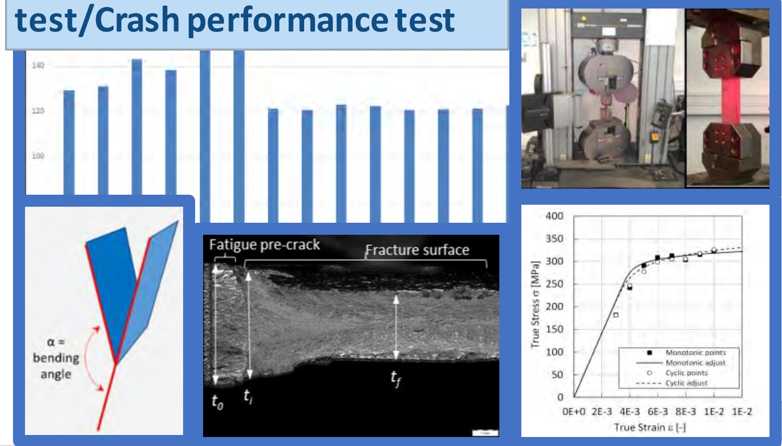
TEM/EBSD/Corrosion test



Tensile test/Bake paint test



Bending test/Fatigue test/Crash performance test



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

EXTRUSION ALLOY DEVELOPMENT

SALEMA

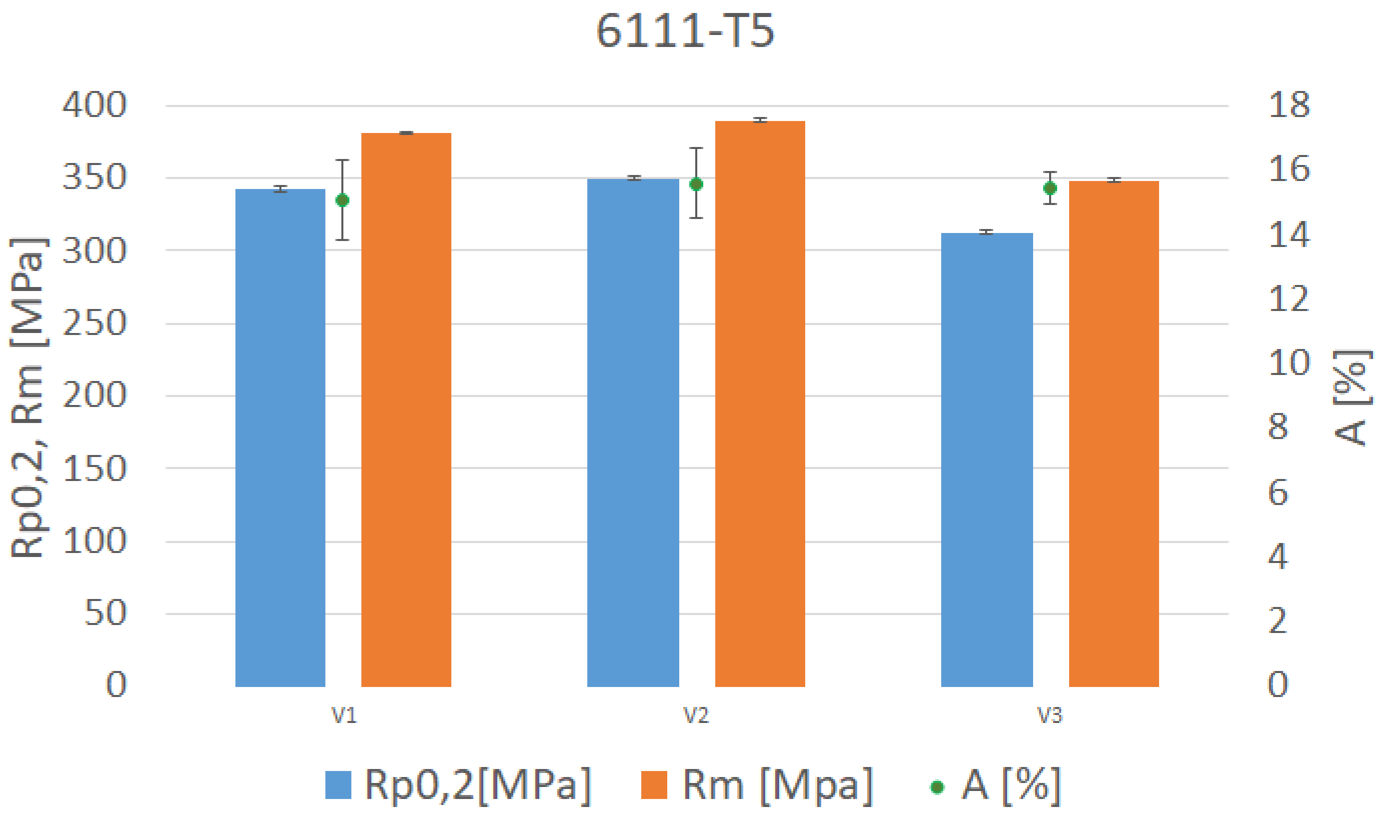
Low CRM 6111

6111	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Variant 1	0.935	0.070	0.779	0.284	0.861	0.0007	0.0045	0.0198
Variant 2	0.719	0.072	0.814	0.290	0.623	0.0010	0.0059	0.0198
Variant 3	0.708	0.073	0.547	0.285	0.629	0.0008	0.0043	0.0198

Static tensile test: EN ISO 6892-1:2020-05

- Crosshead speed1 = 0,75mm/min
- croshead speed2 = 5mm/min.
- Gauge length 50mm

	Rp0,2 [MPa]	Rm [Mpa]	A [%]
V1	342,7	381,3	15,1
V2	349,7	390,0	15,6
V3	312,7	348,7	15,5



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

EXTRUSION ALLOY DEVELOPMENT

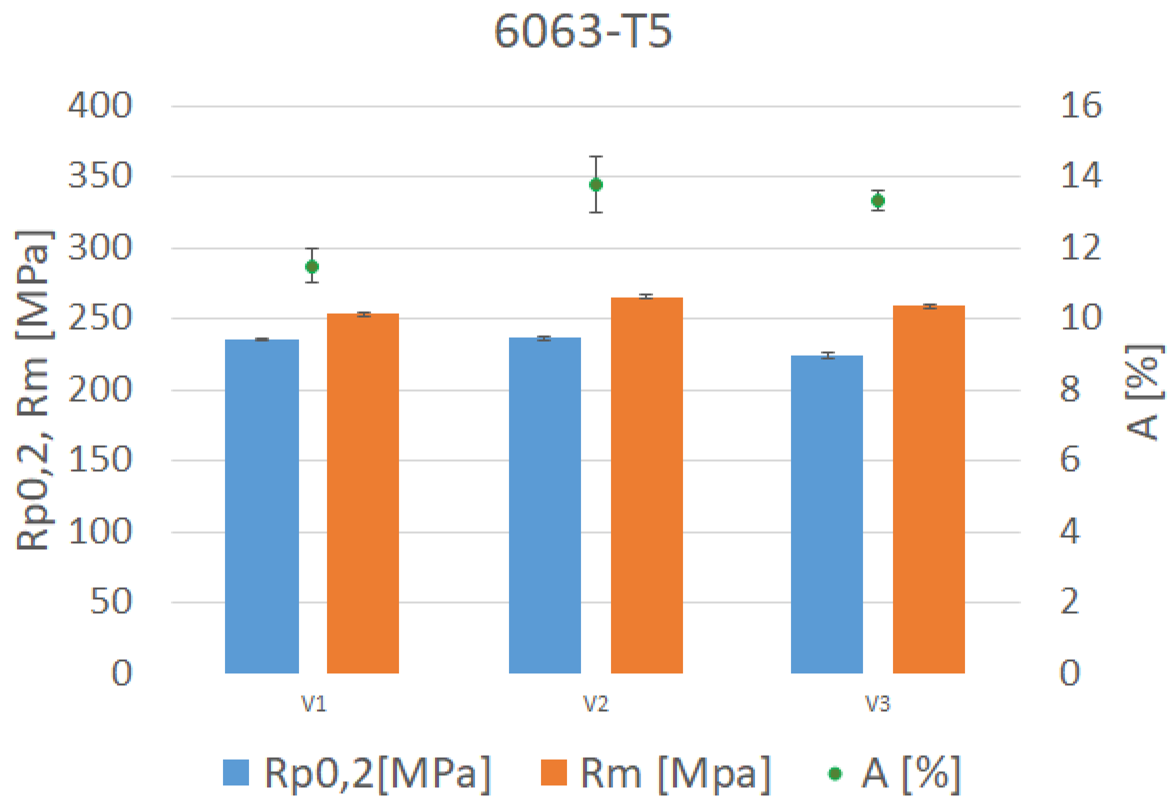
High scrap content 6063

6063	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Variant 1	0.539	0.217	0.026	0.090	0.514	0.022	0.060	0.0400
Variant 2	0.507	0.227	0.120	0.167	0.512	0.025	0.117	0.1490
Variant 3	0.509	0.398	0.173	0.200	0.524	0.025	0.122	0.1440

Static tensile test: EN ISO 6892-1:2020-05

- Crosshead speed1 = 0,75mm/min
- croshead speed2 = 5mm/min.
- Gauge length 50mm

	Rp0,2 [MPa]	Rm [Mpa]	A [%]
V1	235,0	253,3	11,5
V2	236,3	265,7	13,8
V3	224,0	259,0	13,3



EXTRUSION ALLOY DEVELOPMENT

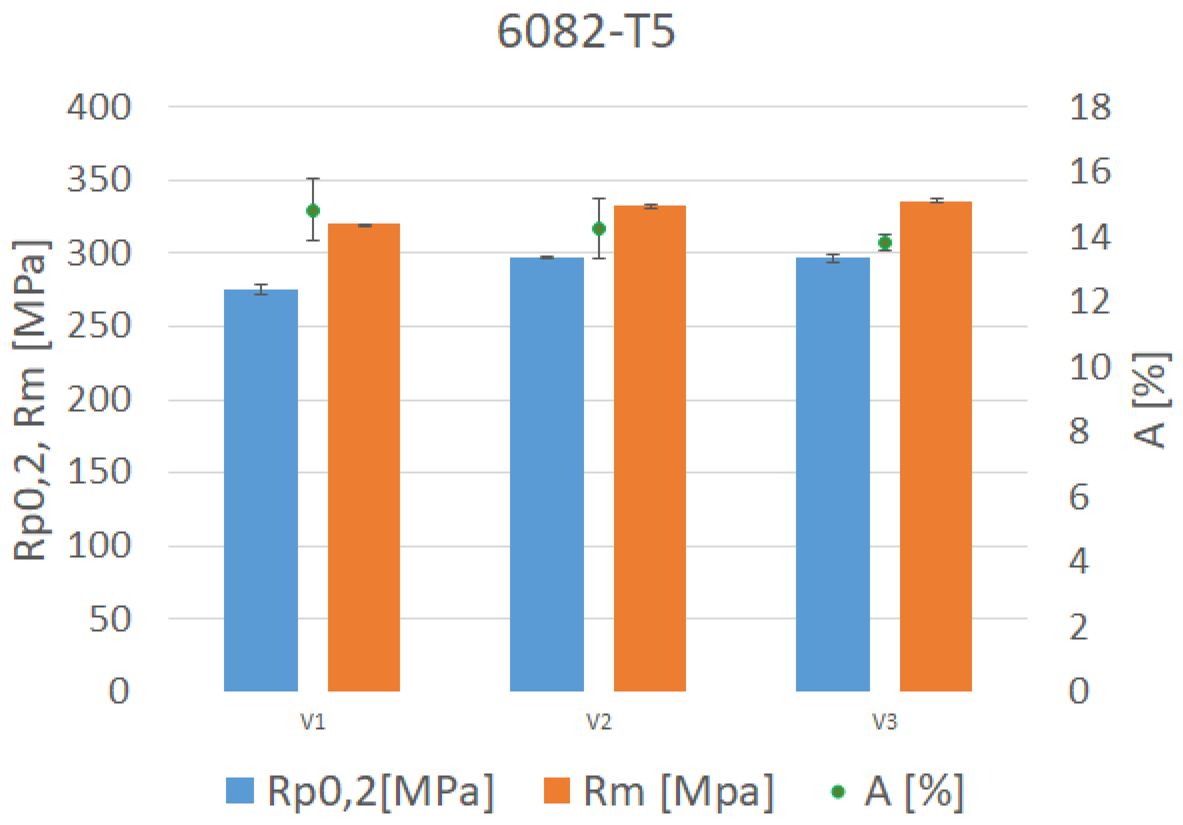
High scrap content 6082

6082	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Variant 1	0.939	0.223	0.043	0.626	0.824	0.071	0.223	0.0450
Variant 2	0.933	0.214	0.105	0.623	0.812	0.068	0.214	0.0440
Variant 3	0.929	0.232	0.167	0.622	0.911	0.071	0.232	0.1440

Static tensile test: EN ISO 6892-1:2020-05

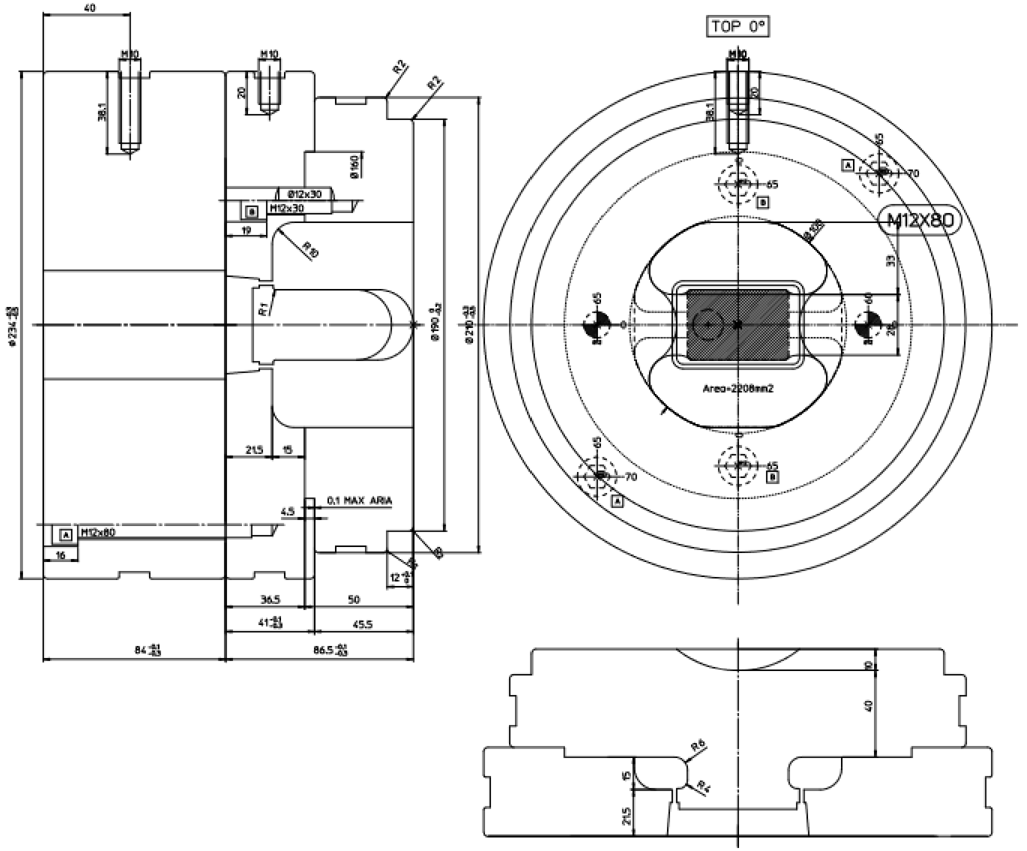
- Crosshead speed1 = 0,75mm/min
- croshead speed2 = 5mm/min.
- Gauge length 50mm

	Rp0,2 [MPa]	Rm [Mpa]	A [%]
V1	275,0	319,7	14,8
V2	297,0	332,0	14,3
V3	296,7	336,0	13,8

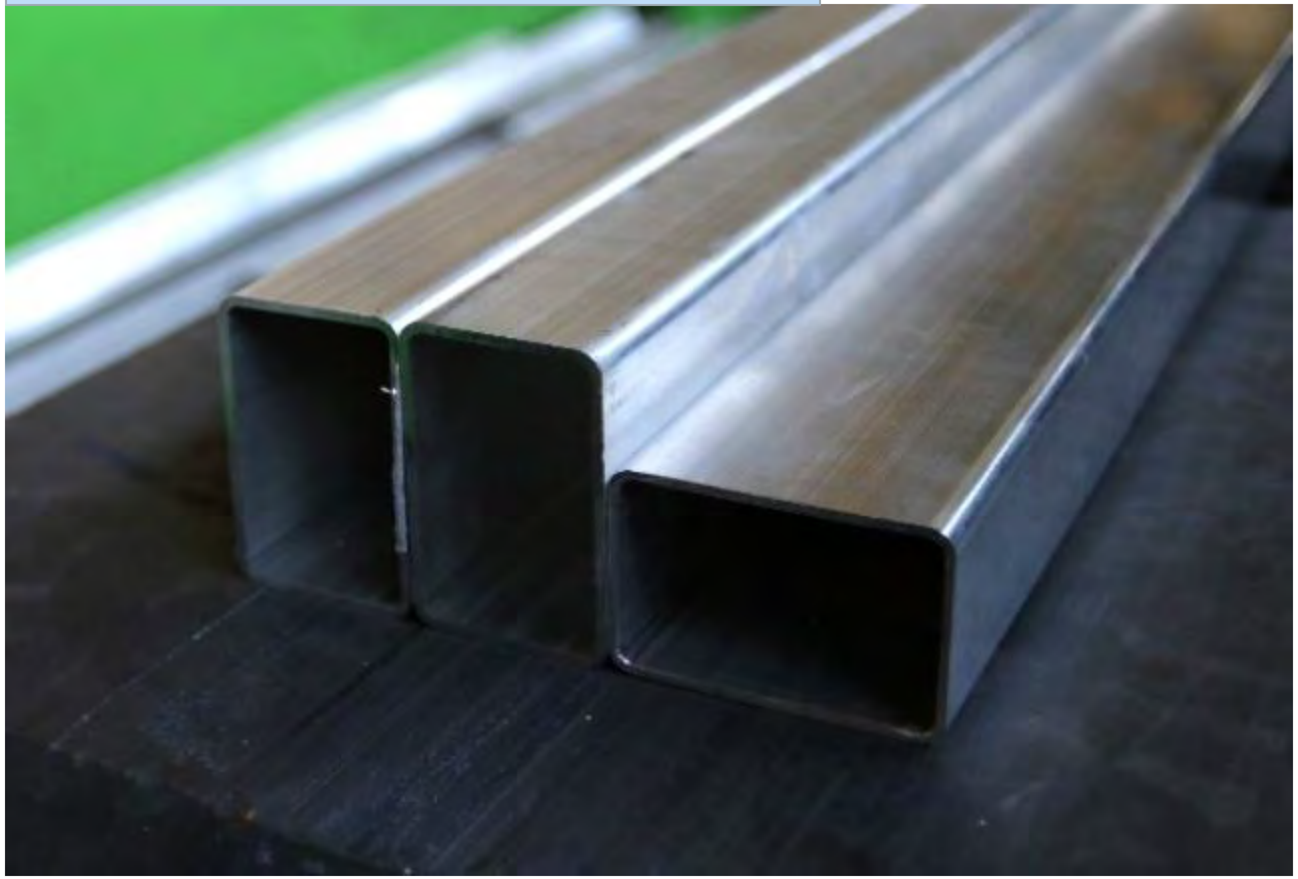


LABORATORY SCALE EXTRUSION DEMONSTRATOR

Die for 60x40x2mm hollow profile design



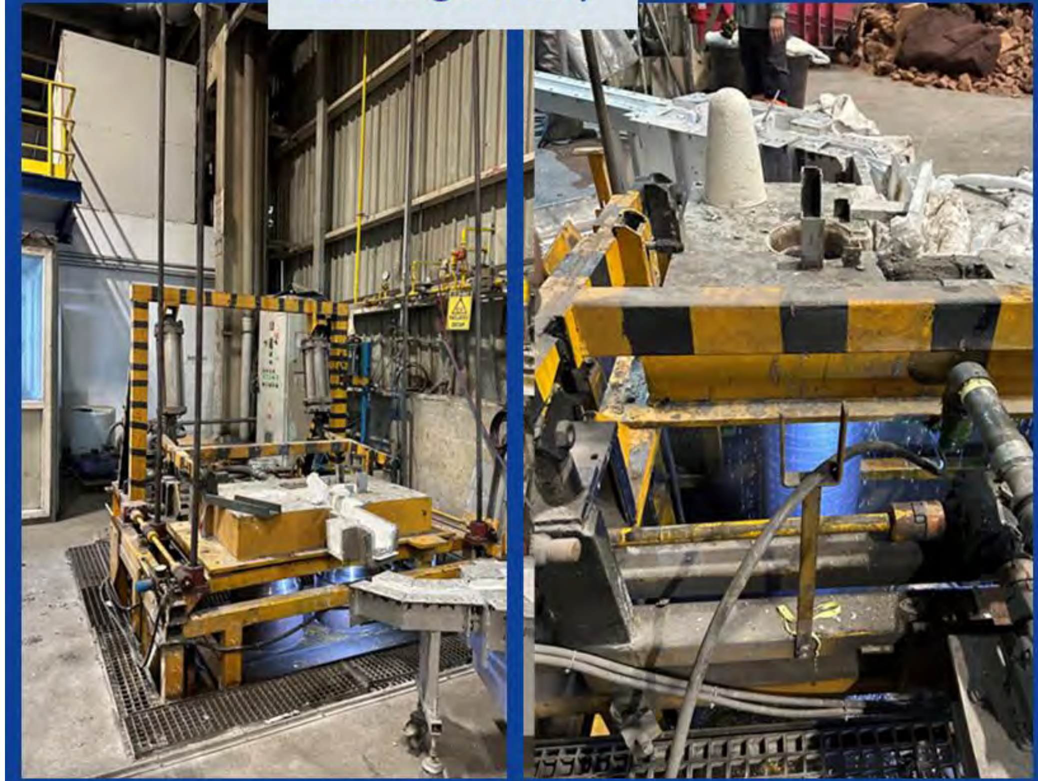
Hollow profiles from 3 SALEMA alloys



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

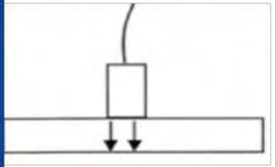
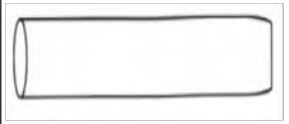
BILLET CASTING

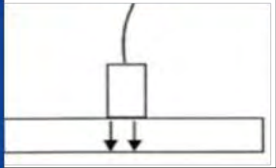
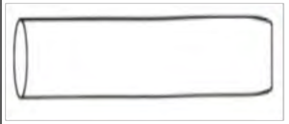
Casting Facility



SALEMA Billet

US Analysis

			Acceptance Criteria	Test Scope	Aging
R&D6063	Length: 1200 mm Diameter: ø355mm	Aluminium	ASTM 594-9 Class A	100%	Homogenization
Test Sketch		Alloy		Total Billet Inspected	
		6063 		1	
				Length and Direction	
				T- 360°	
RESULT					
ACCEPTABLE					

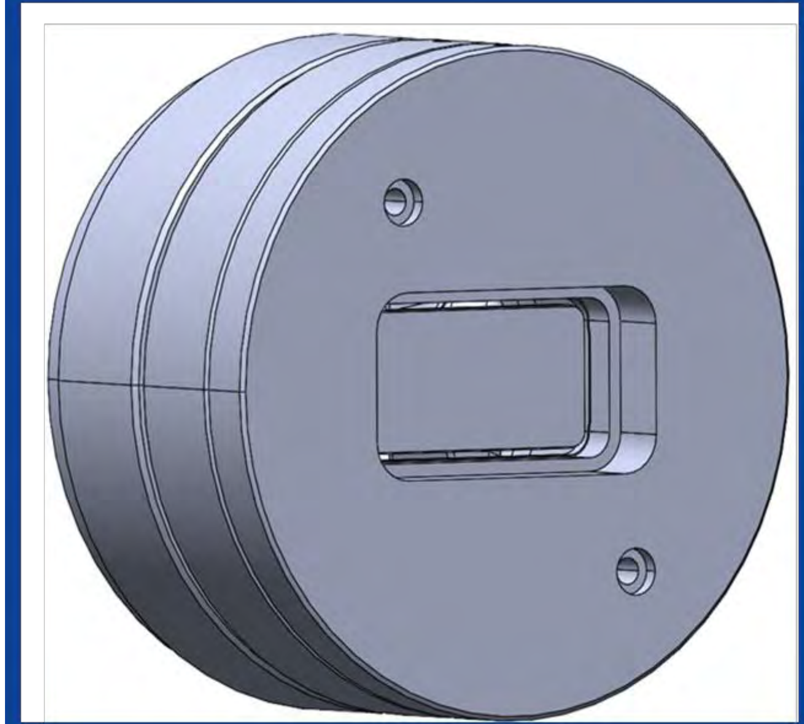
Heat No	Dimensions	Material	Acceptance Criteria	Test Scope	Aging
R&D6082	Length: 1700 mm Diameter: ø355mm	Aluminium	ASTM 594-9 Class A	100%	Homogenization
Test Sketch		Alloy		Total Billet Inspected	
		6082 		1	
				Length and Direction	
				T- 360°	
RESULT					
ACCEPTABLE					

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

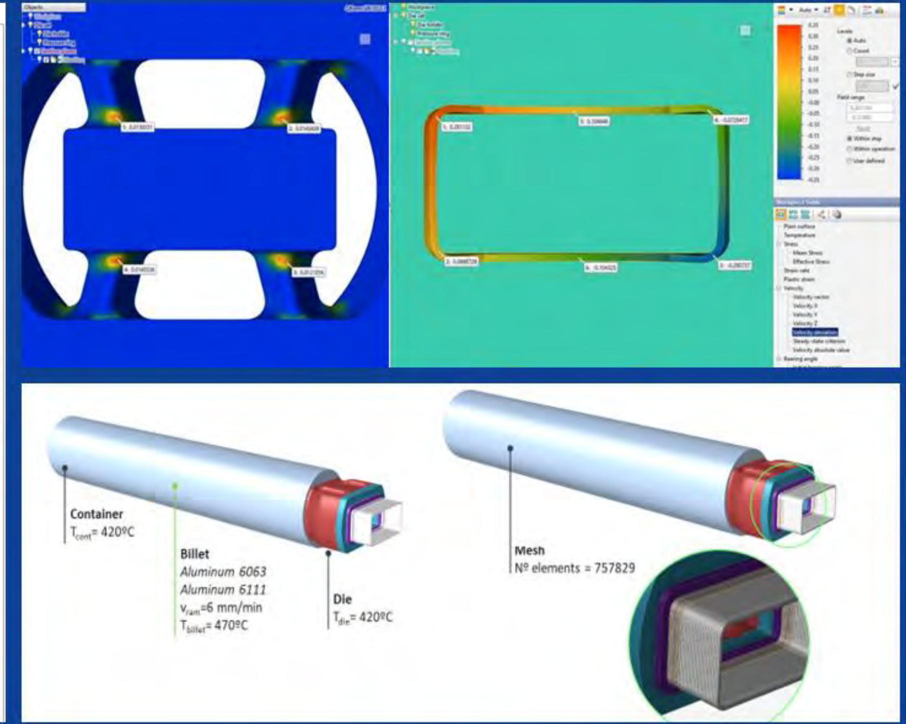
DIE DESIGN

3D CAD MODEL

DIE MANUFACTURE



VIRTUAL



SIMULATION

PHYSICAL

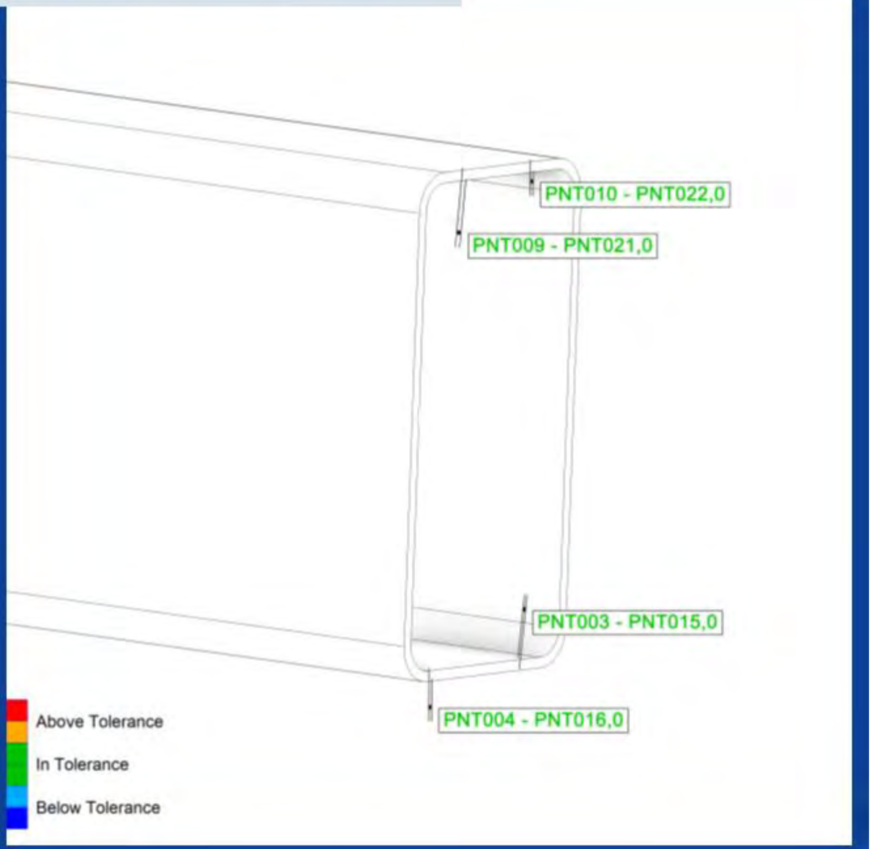
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

EXTRUSION

Extrusion Practices

SALEMA Profile

CMM Measurement



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

CHARACTERIZATION AND TESTS CONDUCTED

SALEMA EU PROJECT WP 6 TASK 4 SPECIMEN and TEST PLAN

BATTERY BOX

Test	Responsible	Amount	Profile No	Alloy	Standard
Tensile Test	ASAS	3	20213	6063	EN ISO 6892-1:2020.
Tensile Test	ASAS	3	20213	6082	EN ISO 6892-1:2020.
Tensile Test	Eurecat	3	20213	6063	400 mm specimen profile
Tensile Test	Eurecat	3	20213	6082	400 mm specimen profile
OES Composition	ASAS	2	20213	6063	
OES Composition	ASAS	2	20213	6082	
EDS Composition	ASAS	1	20213	6063	
EDS Composition	ASAS	1	20213	6082	
Optic Microstructure	ASAS	1	20213	6063	
Optic Microstructure	ASAS	1	20213	6082	
SEM Microstructure	ASAS	1	20213	6063	
SEM Microstructure	ASAS	1	20213	6082	
Bake Paint	ASAS	1	20213	6063	EN ISO 6892-1:2020 at 180°C for 20 mins
Bake Paint	ASAS	1	20213	6082	EN ISO 6892-1:2020 at 180°C for 20 mins
3-Point Bending	ASAS	5	20213	6063	VDA 238 – 100
3-Point Bending	ASAS	5	20213	6082	VDA 238 – 100
Tensile Test - Aniso	ASAS	3	20213	6063	EN ISO 6892-1:2020.
Tensile Test - Aniso	ASAS	3	20213	6082	EN ISO 6892-1:2020.
EBSD Composition	IMN	1	20213	6063	400 mm specimen profile for per alloy
EBSD Composition	IMN	1	20213	6082	
TEM Microstructure	IMN	1	20213	6063	
TEM Microstructure	IMN	1	20213	6082	

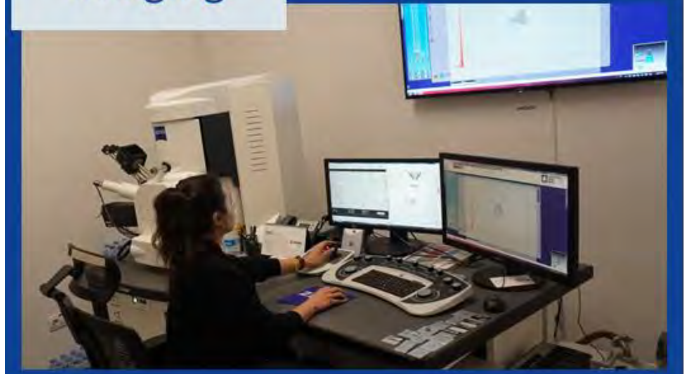
FRONTAL FRAME

Test	Responsible	Amount	Profile No	Alloy	Standard
Tensile Test	ASAS	3	20240	6063	EN ISO 6892-1:2020.
Tensile Test	ASAS	3	20240	6111	EN ISO 6892-1:2020.
Tensile Test	IMN	3	20240	6063	400 mm specimen profile
Tensile Test	IMN	3	20240	6111	400 mm specimen profile
OES Composition	ASAS	2	20240	6063	
OES Composition	ASAS	2	20240	6111	
EBSD Composition	ASAS	1	20240	6063	
EBSD Composition	ASAS	1	20240	6111	
Optic Microstructure	ASAS	1	20240	6063	
Optic Microstructure	ASAS	1	20240	6111	
SEM Microstructure	ASAS	1	20240	6063	
SEM Microstructure	ASAS	1	20240	6111	
Bake Paint	ASAS	1	20240	6063	EN ISO 6892-1:2020 at 180°C for 20 mins
Bake Paint	ASAS	1	20240	6111	EN ISO 6892-1:2020 at 180°C for 20 mins
3-Point Bending	ASAS	5	20240	6063	VDA 238 – 100
3-Point Bending	ASAS	5	20240	6111	VDA 238 – 100
Tensile Test - Aniso	ASAS	3	20240	6063	EN ISO 6892-1:2020.
Tensile Test - Aniso	ASAS	3	20240	6111	EN ISO 6892-1:2020.
OES Composition	IMN	2	20240	6063	400 mm specimen profile for per alloy
OES Composition	IMN	2	20240	6111	
EBSD Composition	IMN	1	20240	6063	
EBSD Composition	IMN	1	20240	6111	
Optic Microstructure	IMN	1	20240	6063	
Optic Microstructure	IMN	1	20240	6111	
TEM Microstructure	IMN	1	20240	6063	
TEM Microstructure	IMN	1	20240	6111	

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

CHARACTERIZATION AND TESTS CONDUCTED

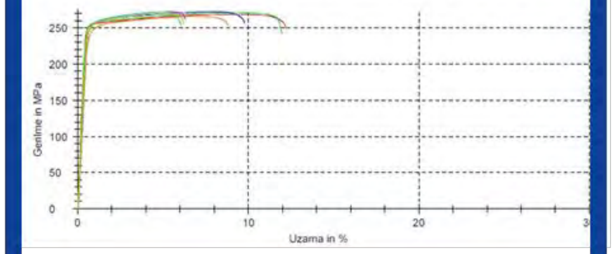
Imaging

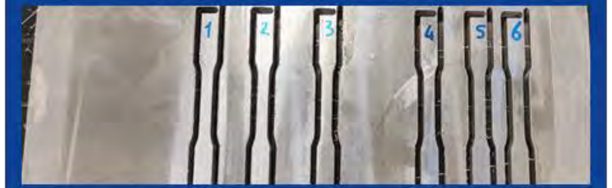


Mechanical Tests

Anisotrophy / Bake Paint

									A_g %
1	01-0	0	4,016	6,95	70000	**248**	**269**	**11,8**	8,54
2	02-0	0	3,954	7,01	70000	**248**	**271**	**11,6**	8,54
3	01-45	45	3,916	6,96	70000	**236**	**272**	**9,4**	7,66
4	02-45	45	3,915	6,94	70000	**223**	**266**	**8,4**	6,65
5	01-90	90	3,914	6,93	70000	**237**	**272**	**5,9**	4,85
6	02-90	90	3,938	6,92	70000	**237**	**272**	**5,7**	4,61
7	03-90	90	3,941	6,93	70000	**239**	**270**	**5,8**	4,68

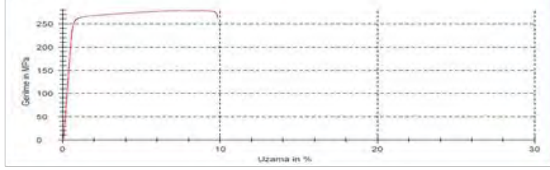




Sonuçlar :

No	Numune Adı	Numune Yönü °	Kalınlık mm	Genişlik mm	E-Mod MPa	**Akma %0,2 MPa**	**Çekme MPa**	**Ae %**	A_g %
1	03 180 °C/20DAK	0	3,92	6,98	70000	**233**	**278**	**9,4**	7,76

Test Grafiği :



Bending

Profile No MARBEL	Profile No ASAS	Sample No	Criteria	α	β	Thickness	Target Angle
	6082	1	.10	55	125	3,73	120
		2	.10	53	127	3,73	120
		3	.10	55	125	3,75	120
		4	.10	57	123	3,71	120
		5	.10	54	126	3,76	120
		6	.10	54	126	3,72	120
		7	.11	50	130	3,69	120
		8	.12	55	125	3,75	120
Profile No MARBEL	Profile No ASAS	Sample No	Criteria	α	β	Thickness	Target Angle
	6063	1	.10	28	152	3,88	120
		2	.10	25	155	3,9	120
		3	.10	25	155	3,87	120
		4	.10	27	153	3,91	120
		5	.10	26	154	3,9	120
		6	.10	20	160	3,87	120
Profile No SALEMA	Profile No ASAS	Sample No	Criteria	α	β	Thickness	Target Angle
	6111	1	.10	24	156	4,35	120
		2	.10	23	157	4,36	120
		3	.10	32	148	4,34	120
		4	.10	33	147	4,3	120
		5	.10	31	149	4,31	120
Profile No SALEMA	Profile No ASAS	Sample No	Criteria	α	β	Thickness	Target Angle
	6063	1	.10	47	133	4,41	120
		2	.10	61	119	4,36	120
		3	.10	63	117	4,42	120
		4	.10	50	130	4,41	120

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

Zeynep Tutku Ozen, PhD-c.

R&D Projects and Incentives Executive

tutku.ozen@asastr.com

Follow SALEMA on

https://salemaproject.eu/

LinkedIN:
www.linkedin.com/company/salemaeu/

Twitter:
@salemaEU

Summary

- Project introduction and video
- Scrap sorting system
- Development of HPDC SALEMA alloys
- Validation of HPDC SALEMA alloys in Shock Tower
- Alloy development and industrial validation in Hot Stamping
- Alloy development and industrial validation in extrusion
- Validation procedure of new alloys by an OEM

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

Validation procedure of new alloys by an OEM

- CRF - Stellantis contribution to demo development
- CRF activities on:
  - WP4 – High Pressure Die Casting (HPDC)
  - WP5 – Cold Stamping
  - WP6 – Extrusion
- Industrial validation in Cold Stamping
- Industrial validation in Frontal Frame
- Key Take-Aways

Fiat Research Center (CRF)

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

CRF CONTRIBUTION ON DEMONSTRATORS

- AUTOMOTIVE REQUIREMENTS ON STRUCTURAL COMPONENTS
  - Participated in the alloy development
  - Mechanical and Functional (weldability, corrosion, adhesion compatibility, etc.) properties
  - Internal and International standard
  - Standard alloys vs SALEMA alloys
  - Comparison based on real structural component requirement

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

CRF ACTIVITIES ON WP 4 – 5 – 6

- CORROSION RESISTANCE
  - Provided mainly by Black E-Coat / Cataphoresis in automotive
    - ASTM B368 - Copper-Accelerated Acetic Acid-Salt Spray (Fog) (CASS test)
    - Cataphoresis compatibility
  - Weight loss differential between variants and alloys
    - ASTM G85:A3 - acidified synthetic sea water testing (SWAAT test)

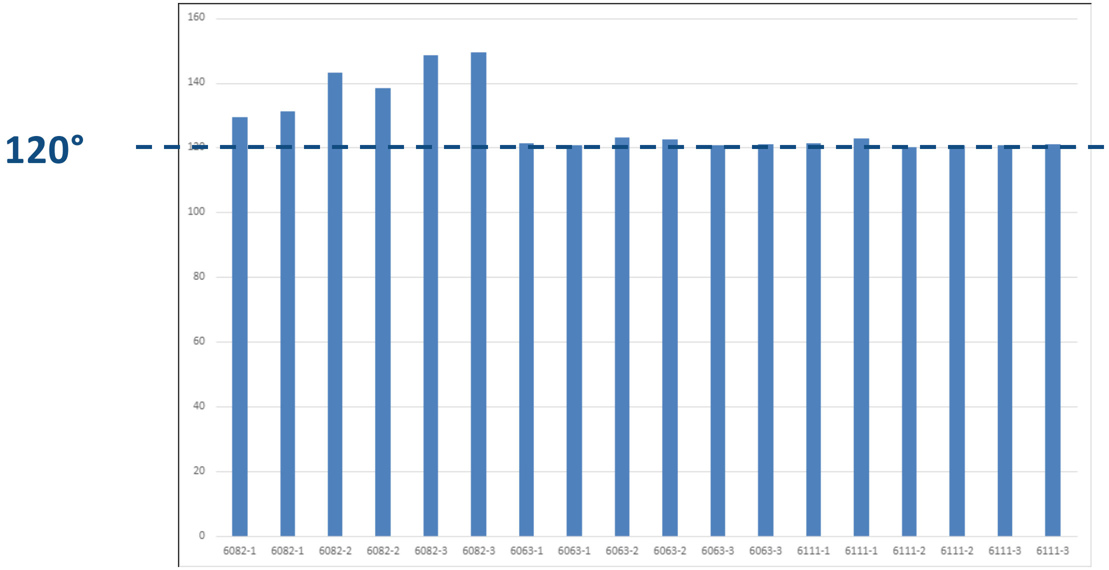
example:
HPDC – WP4

Alloy	Heat Treatment	Initial Weight	Weight after 168 h CASS	Weight loss	
				(g)	%
V4	F	122.2	113.2	9.0	7.4
V6		119.6	109.0	10.6	8.8
V4	T6	120.5	119.3	1.2	1.0
V6		116.5	114.3	2.2	1.9

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

CRF ACTIVITIES ON WP 4 – 5 – 6

- BENDING CHARACTERIZATION
    - Important in wrought alloys, few examples for casting alloys in OEM requirements
    - Stamping and Extruded SALEMA alloys
    - HPDC in samples and in final demo → good behavior towards F vs HT temper



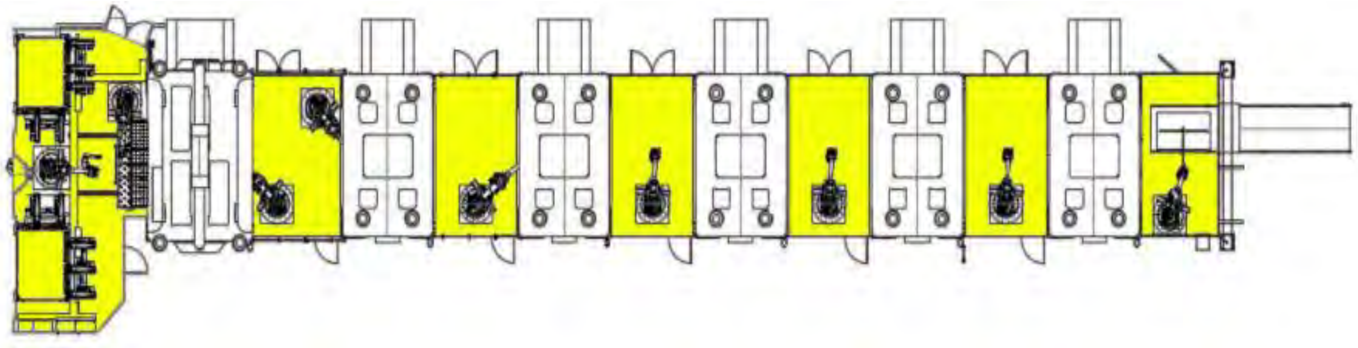
Alloy	Heat Treatment	Bending VDA 238-100	
		average	st.dv
V4	F	22.3	7.0
	T6	58.5	0.6
V6	F	23.1	9.9
	T6	51.4	1.9

The project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN COLD STAMPING

- PROJECT TARGET
  - Use of aluminum with high recycle content
    - 5754 H0 temper 70 - 85%
    - 6181A T4 temper 70 - 85%
  - Inner hood demonstrator (Jeep Renegade)
  - Thickness 0,9 mm
  - Use the current assets in production for primary alloys

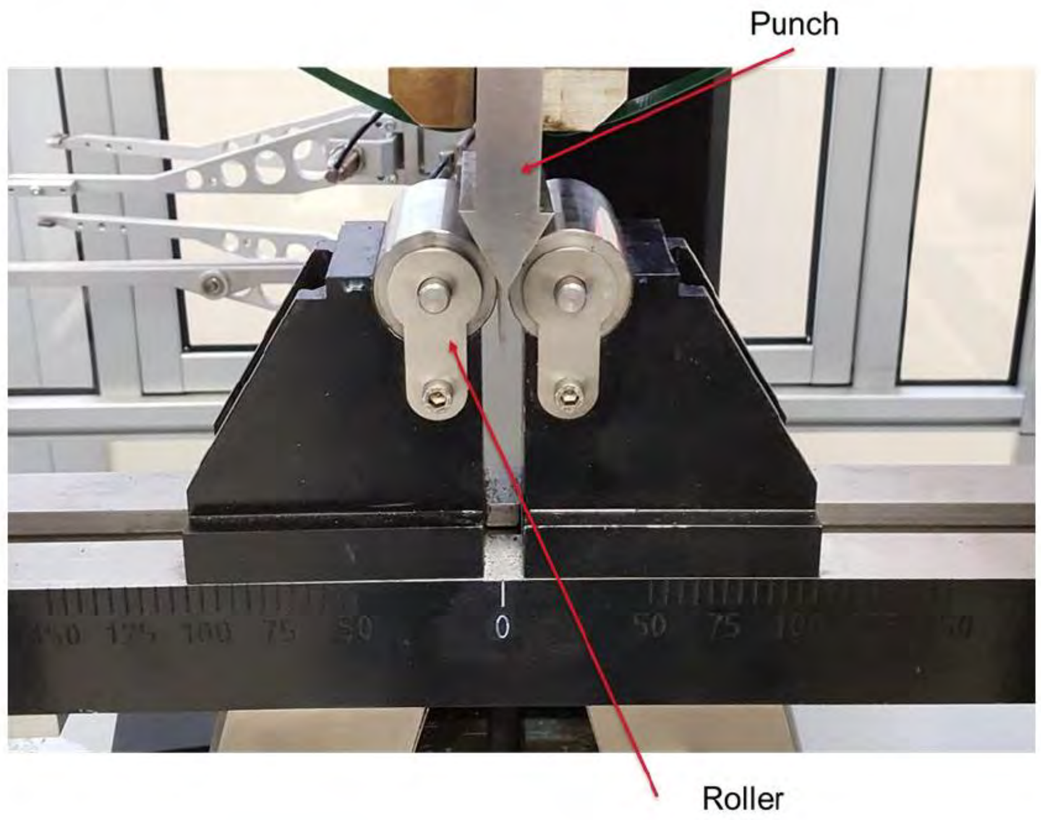
	Rp [MPa]	Rm [Mpa]	A [%]	Bending α [°]
5754 70%	97	210	22	110
5754 85%	100	212	22	
6181A 70%	163	276	24	110
6181A 85%	172	282	24	



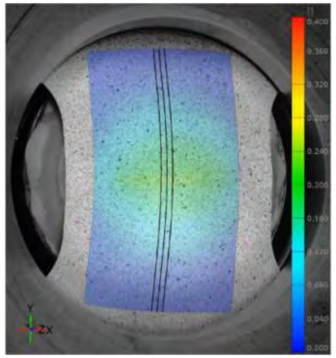
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

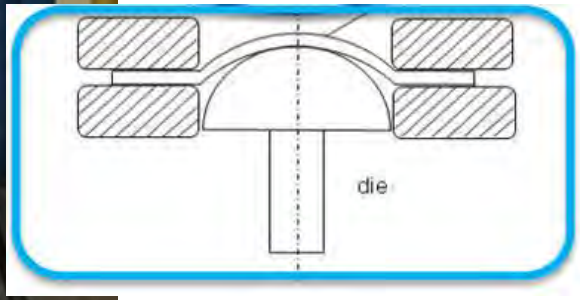
INDUSTRIAL VALIDATION IN COLD STAMPING

- BENDABILITY VDA 238-100



- COLD FORMING: FLD



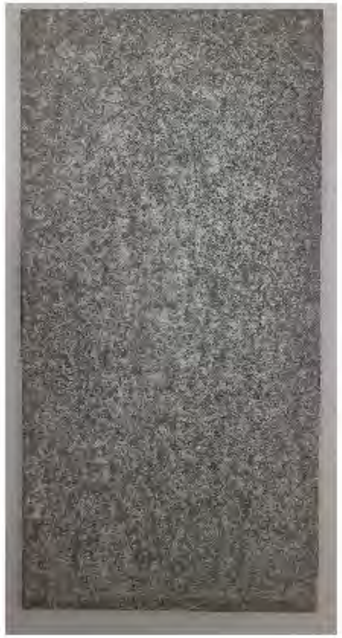


The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN COLD STAMPING

- CORROSION RESISTANCE
  - ASTM G85:A3 (SWAAT)

weight loss differential



5754

6181A

  - ASTM B368 (CASS)

cataphoresis compatibility

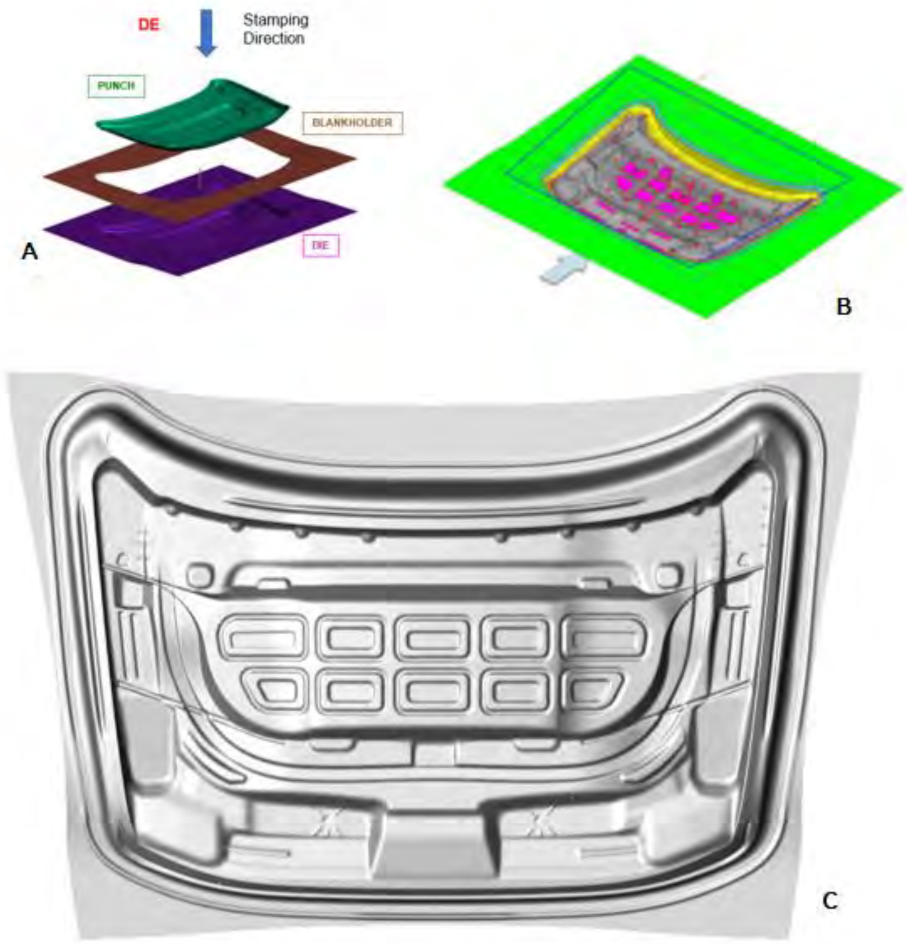
5754

6181A

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN COLD STAMPING

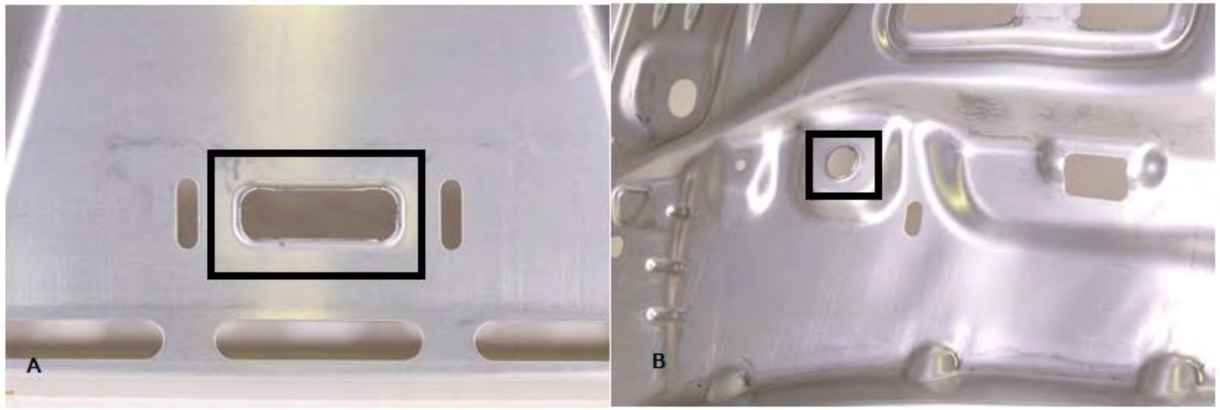
- DEMONSTRATOR MANUFACTURING
  - Mirafiori Press Shop, Mirafiori Plant, Turin, ITALY



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN COLD STAMPING

- QUALITY ASSESSMENT



5754

No cracks in maximum deformation zones (holes)

Keeps performance regardless high recycled content

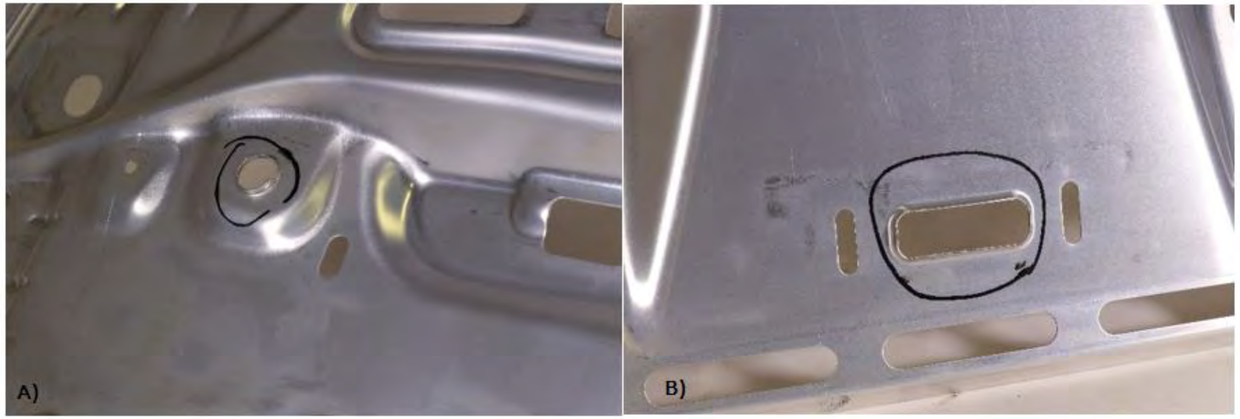
OK for current production

6181A TRY AGAIN

Cracks on most deformed zones

Show sensitivity to high recycle content

Need some design tuning for current production



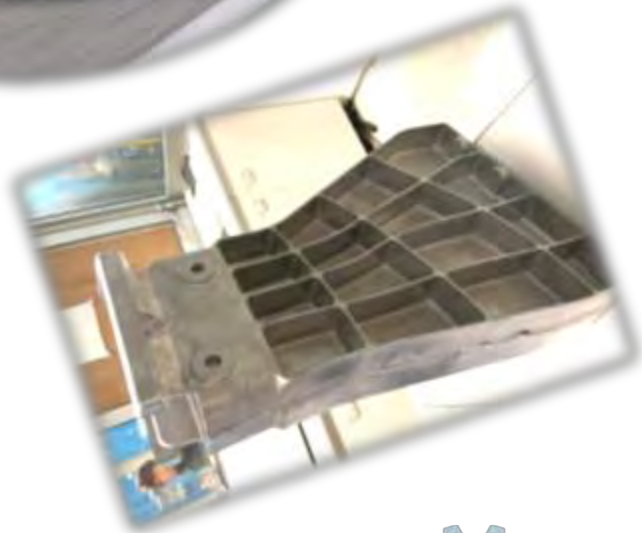
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN FRONTAL FRAME

- Demonstrator Development

  - **FROM**: Low Pressure Die Casting (LPDC) in Maserati MC20
  - **TO**: High Pressure Die Casting (HPDC) for segment C-D car
  - Main advantages: - high volume production
    - cost reduction thanks near net shape features
  - Mechanical requirements:

Rp [MPa]	Rm [Mpa]	A [%]
180	230	10



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN FRONTAL FRAME

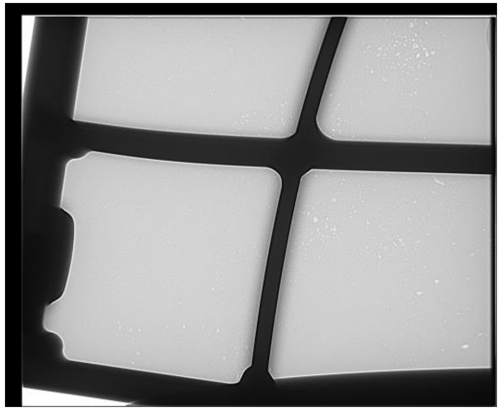
- PRODUCTION IN ENDURANCE S.P.A

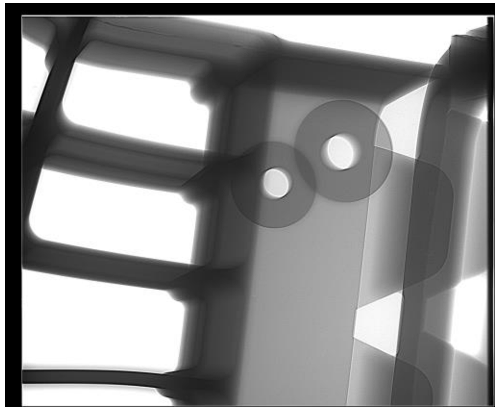
VIDEO

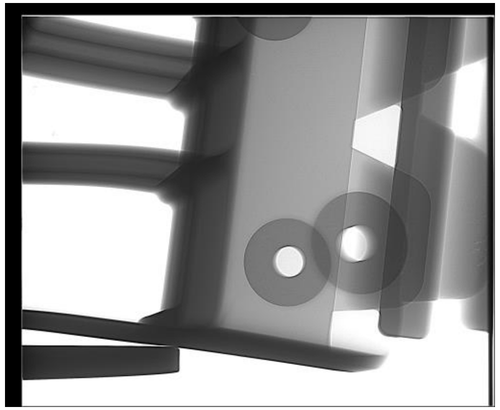
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN FRONTAL FRAME

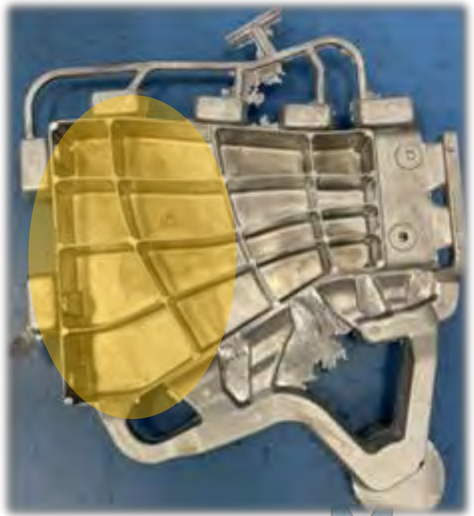
X-RAY MAPPING COMPLETED







Very sound area



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN FRONTAL FRAME

- MECHANICAL CHARACTERIZATION
  - TENSILE
  - FATIGUE
  - TOUGHNESS
  - X-RAY
  - **MICROSTRUCTURE**
  - **BENDING**
  - **HETEROGENEOUS WELDING WITH SHEETS ALLOYS**

Eurecat

&

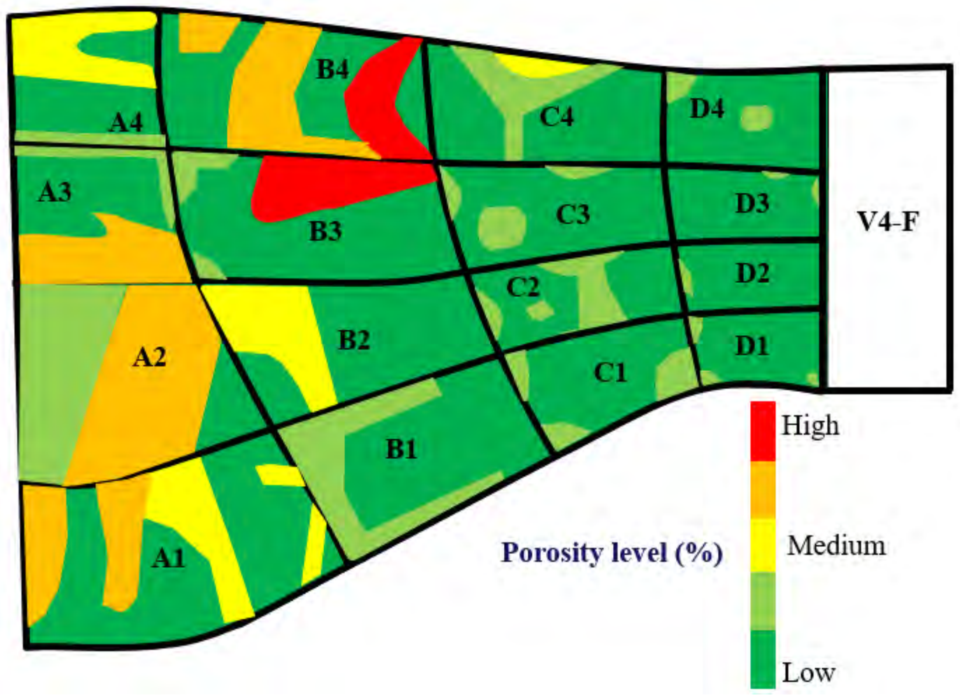
University of Padova

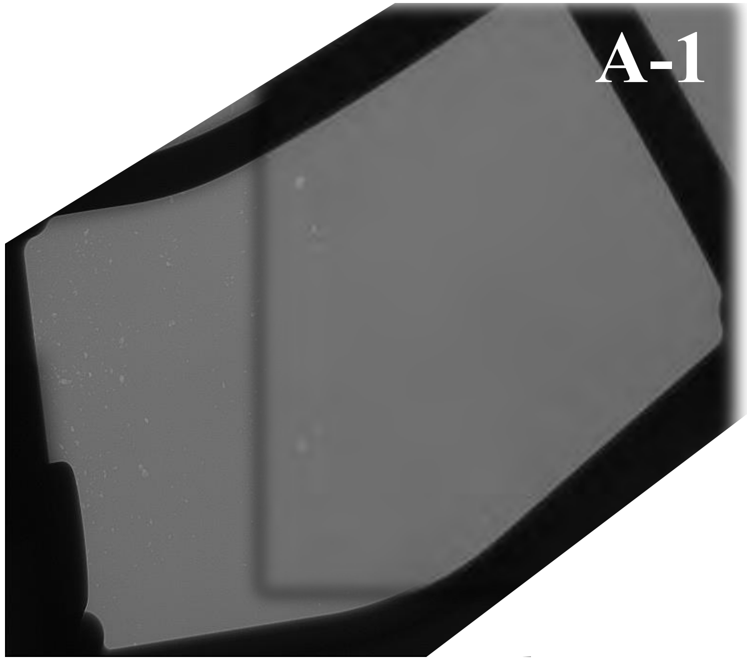
	angle [°]	st.dv
As Cast	25,1	7,5
T5	13,2	9,2
T6	54,4	3,7

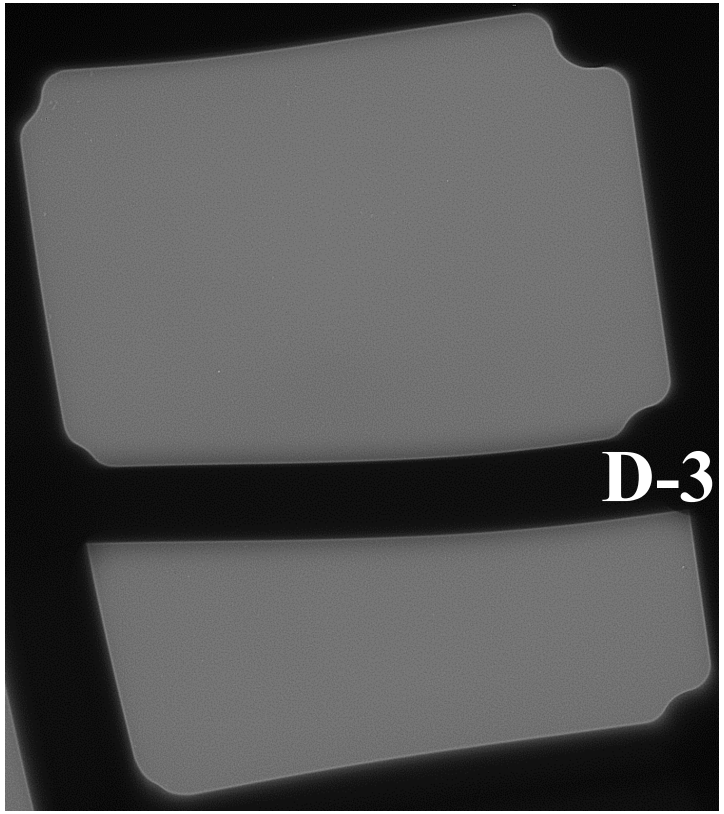
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN FRONTAL FRAME

- X-RAY ANALYSIS (University of Padova, Osama Asghar – Franco Bonollo)



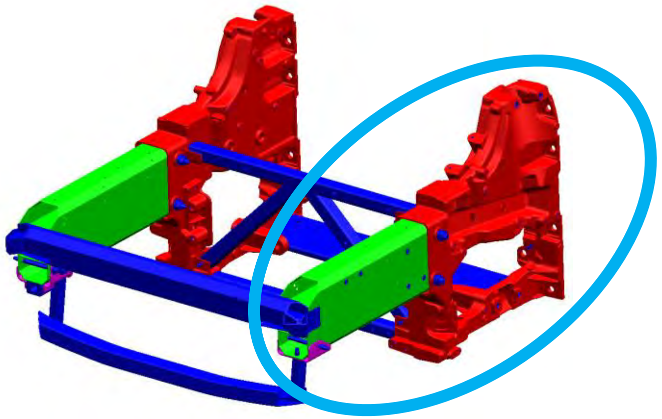




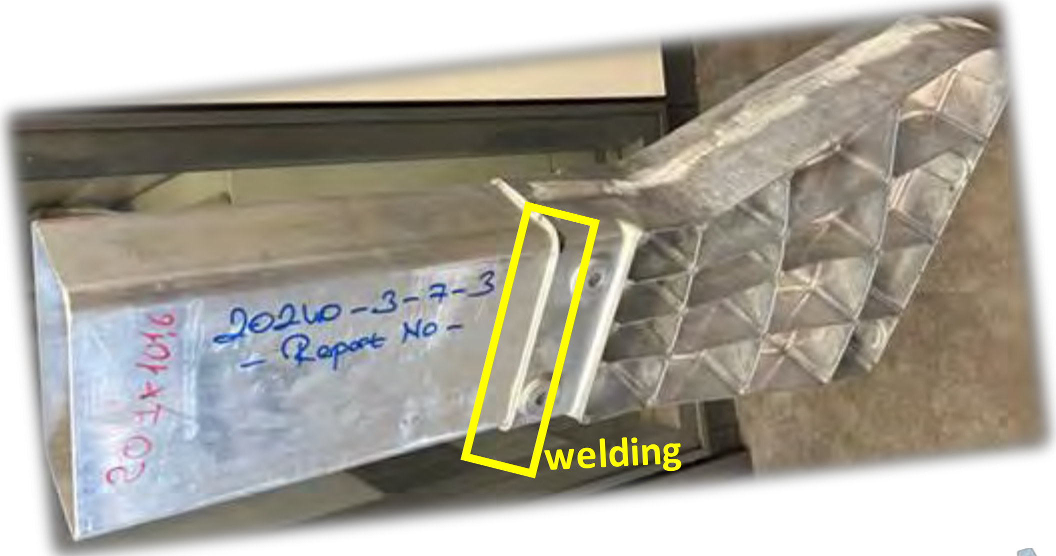
The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN FRONTAL FRAME

- FINAL ASSEMBLY HPDC – EXTRUDED



- WELDING VALIDATION
  - Micrographic inspection
  - Tensile test on welding bead
  - Non-Destructive Testing



The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

INDUSTRIAL VALIDATION IN FRONTAL FRAME

- KEY TAKE-AWAYS:
  - Alloy is suitable for structural components
  - No major differences compared to primary alloys in manufacturing
  - Design tuning needed for improving crash behavior
  - Crash test missing before complete industrialization
- FURTHER DEVELOPMENT OF DEMONSTRATOR – EU project
  - **FLEXCRASH** – Improve strength and crash behavior with hybrid AM
  - **RESTORE** – Remanufacturing with hybrid for another vehicle segment

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003785.

Andrea Bongiovanni

PhD researcher, CRF

andrea.bongiovanni@external.crf.it

Follow SALEMA on

https://salemaproject.eu/

LinkedIN:
www.linkedin.com/company/salemaeu/

Twitter:
@salemaEU