Mechanical Properties comparison between simulated and measured data on an AlSi7Mg03 LPDC Crossmember through T6 heat treatment

mazzucconi
FUTURE CASTING

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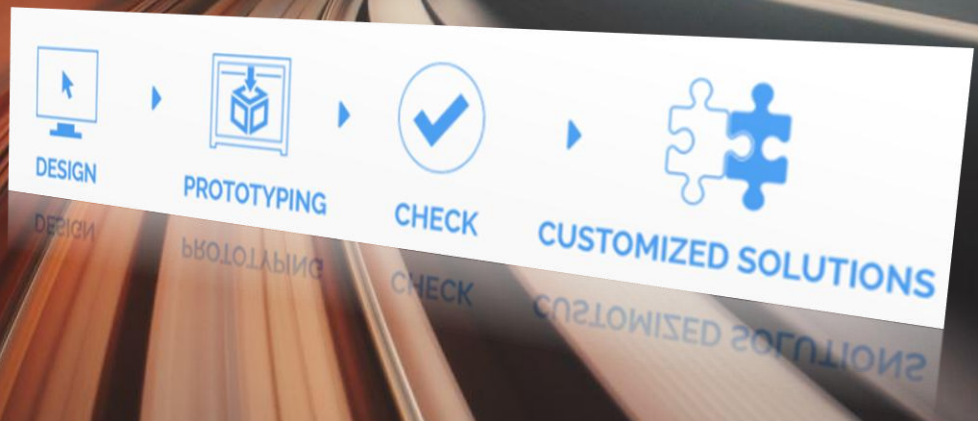
FUTURE CASTING

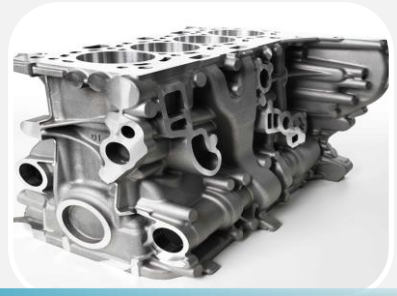
LPDC

GRAVITY

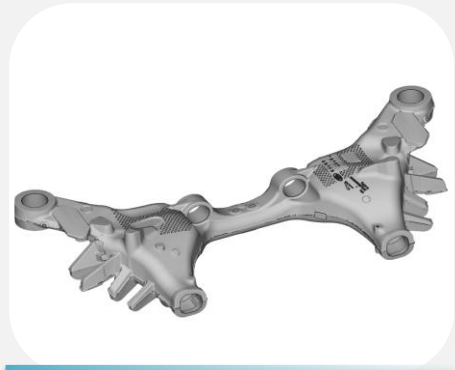
HPDC



MM Products



Powertrains




Subframes

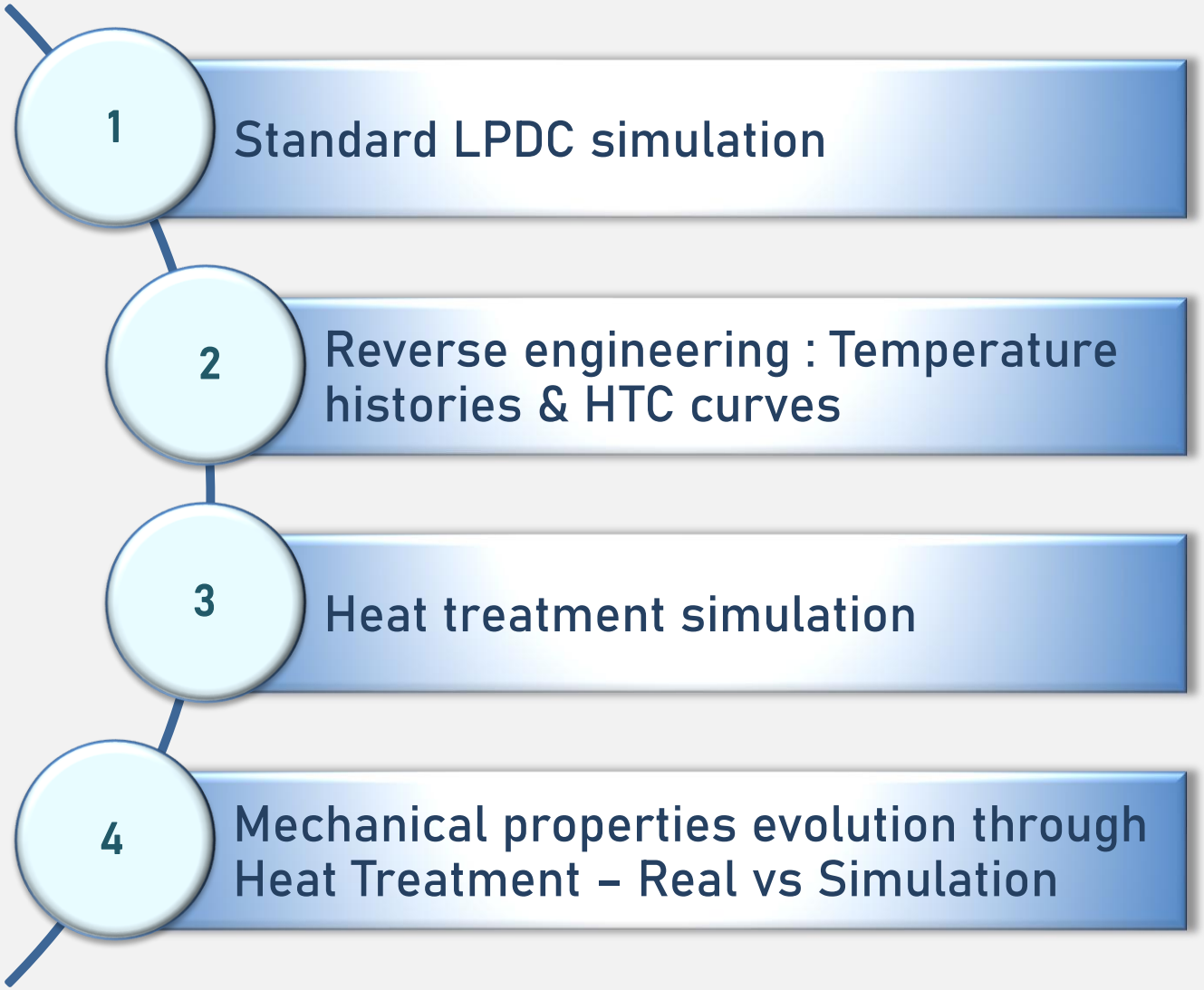


Suspensions

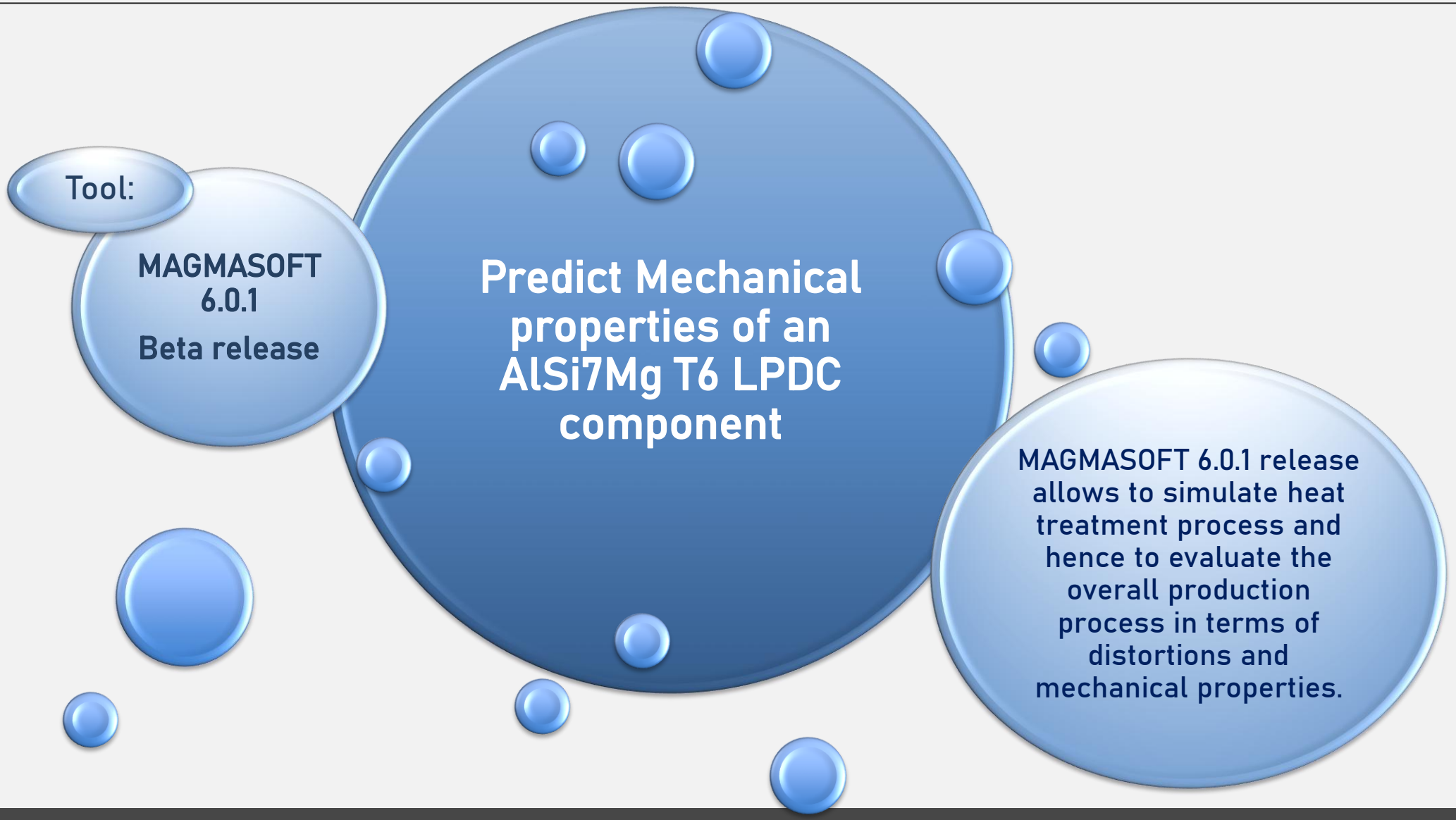

Motorbike frames


Steering systems

Contents

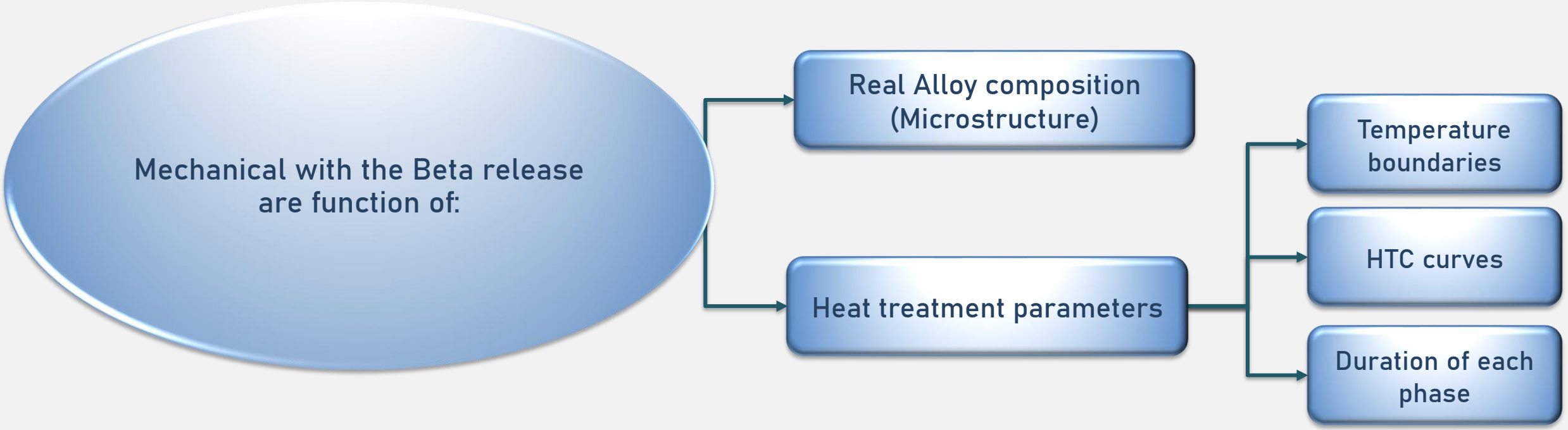


Objective

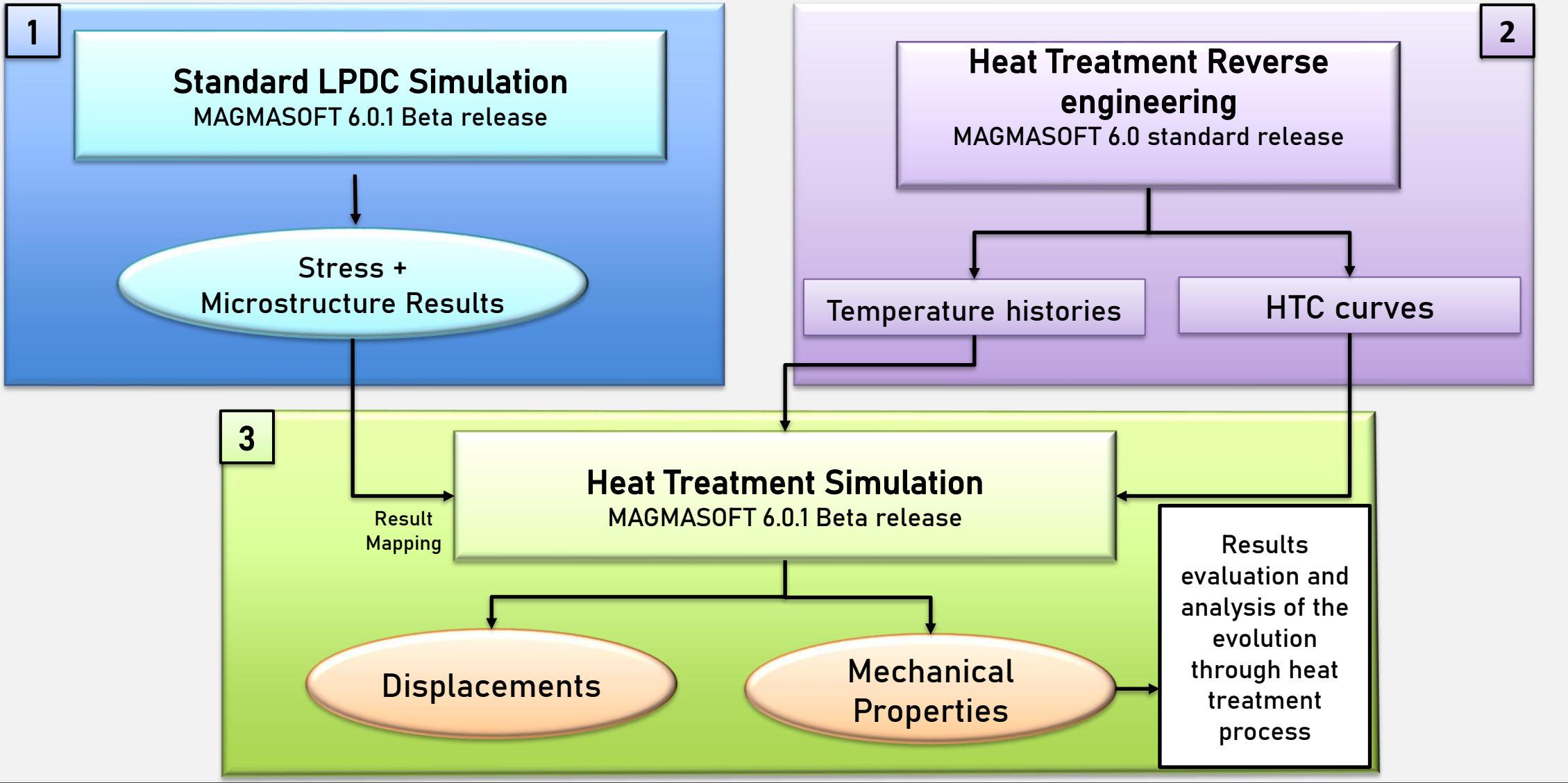


What is new in MAGMASOFT 6.0.1 release

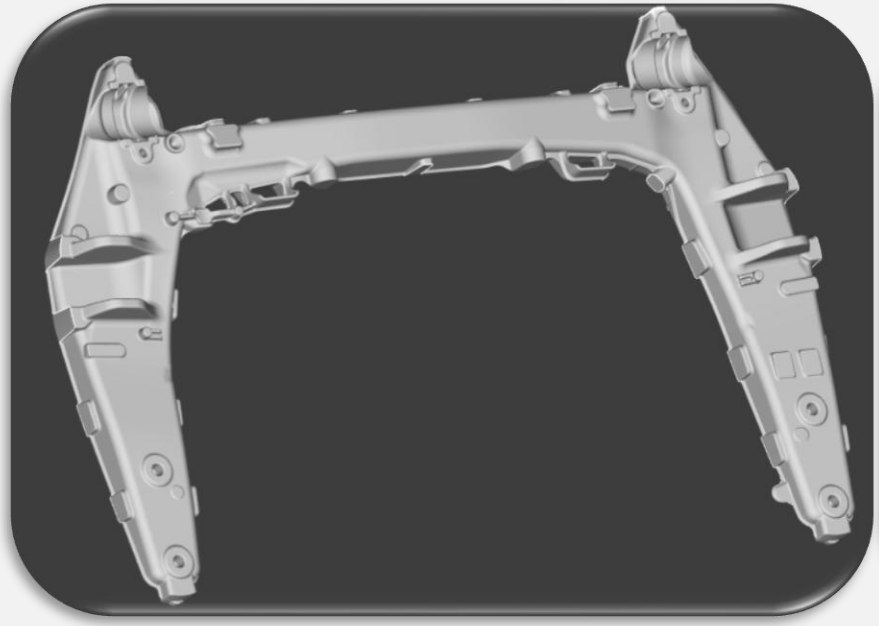
Microstructural behaviour of the alloy during the heat treatment process is crucial for the calculation and the simulation of mechanical properties.

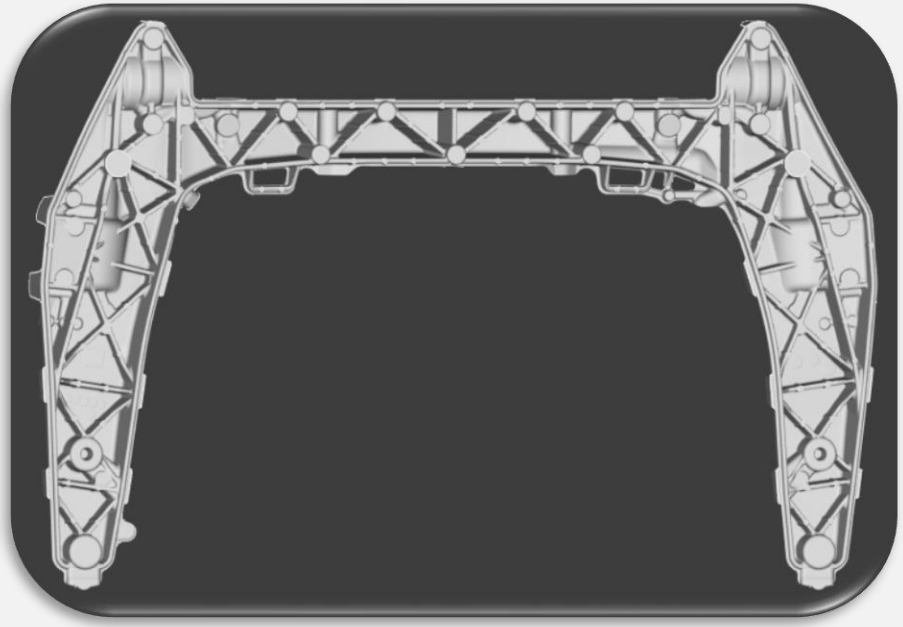


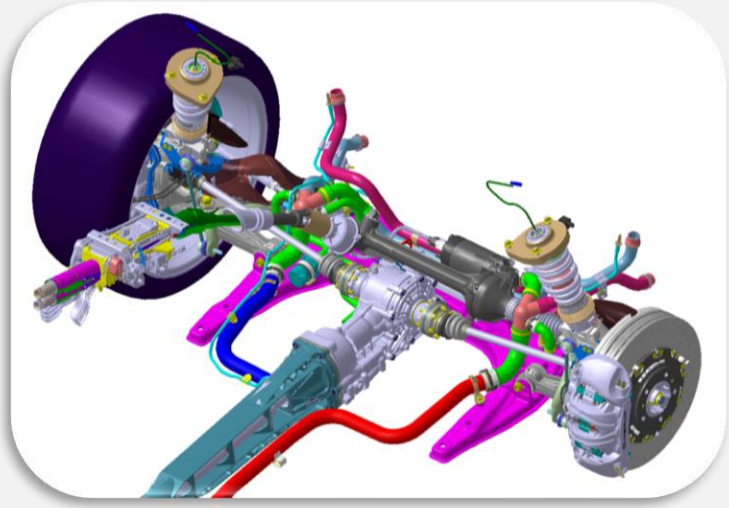
Workflow



Casting Part







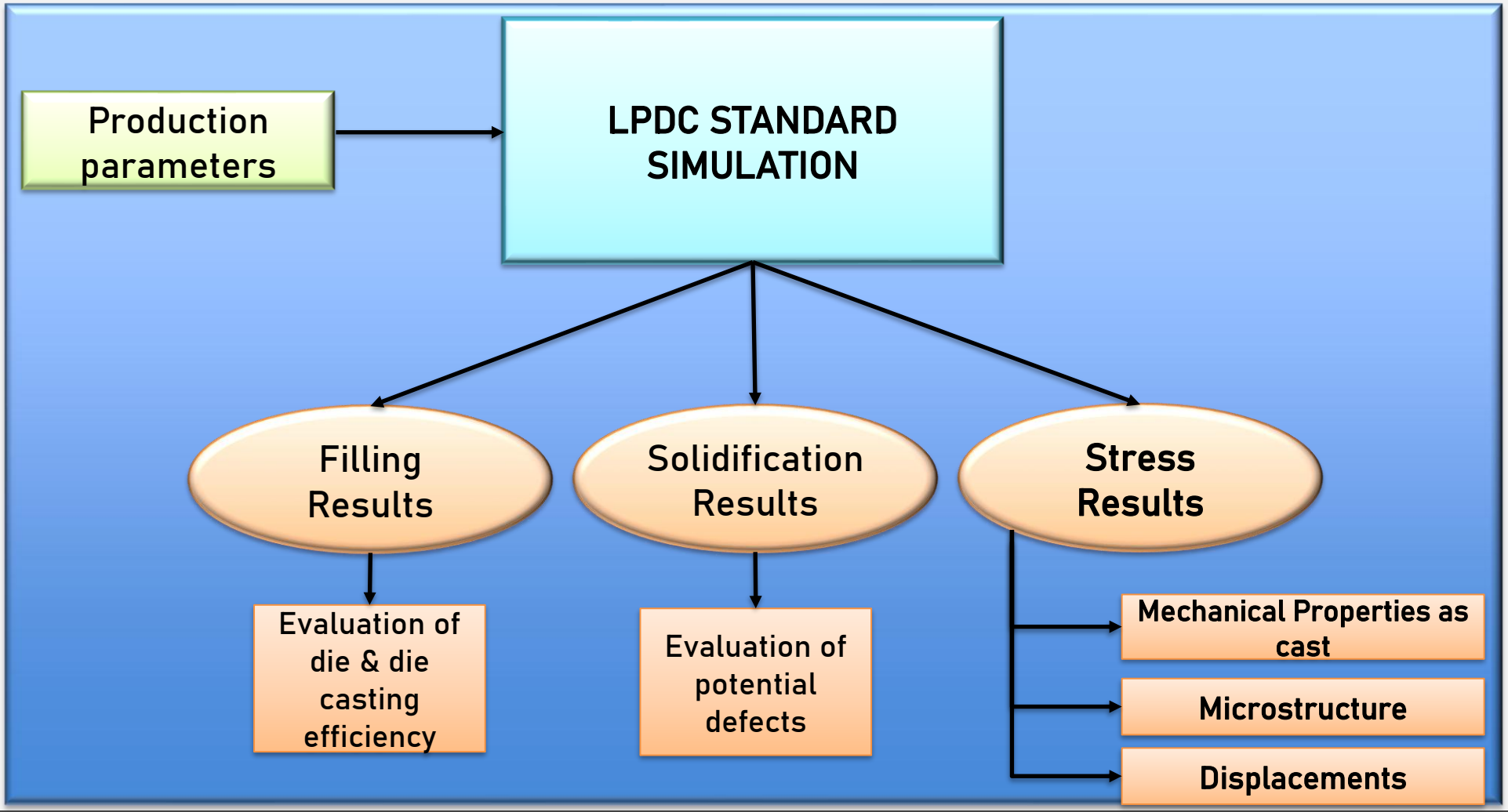
Part Name	Front Crossmember	**Part Weight**	7,220 Kg
Alloy type	EN AC – AlSi7Mg0,3	**Dimensions**	902 mm x 587 mm x 81 mm
Process	LPDC	**Heat Treatment**	T6

1

STANDARD LPDC SIMULATION

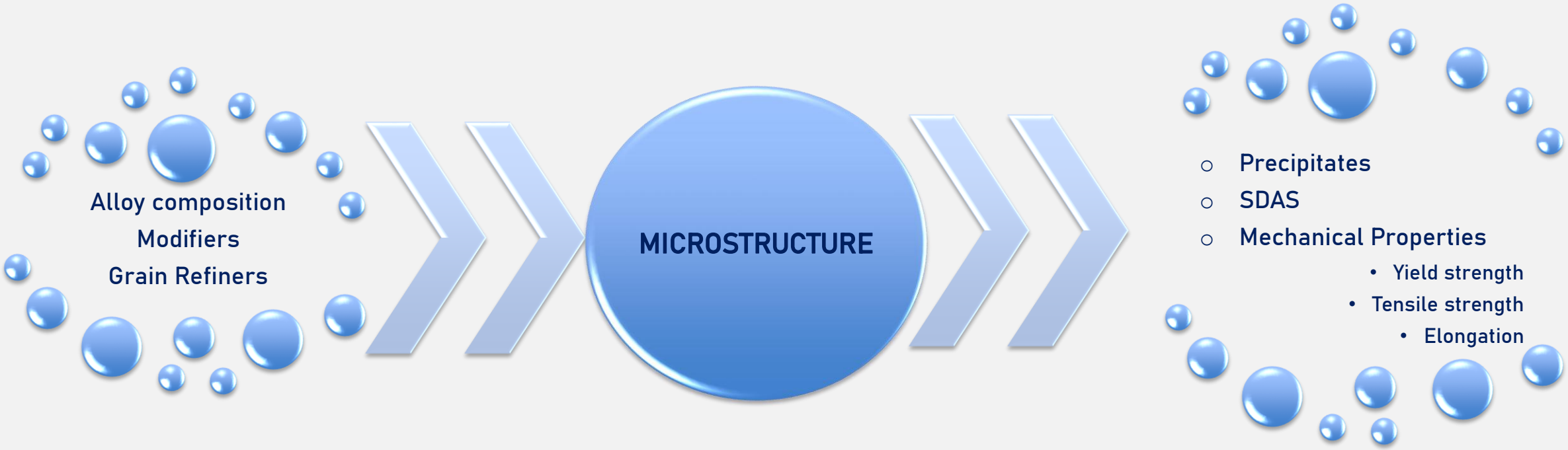
1 Standard LPDC Simulation

LPDC THERMAL PROJECT



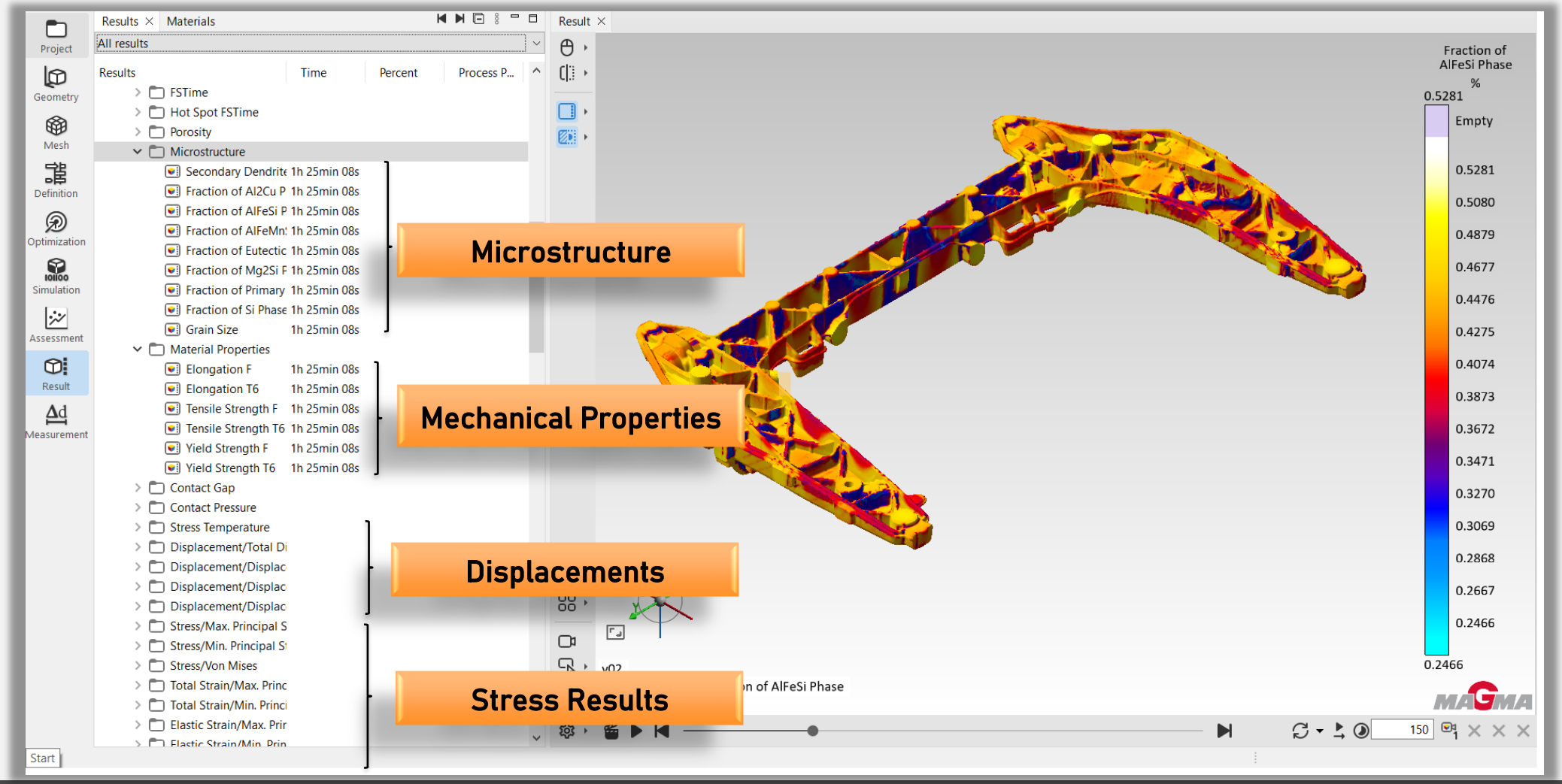
1 Standard LPDC Simulation

MICROSTRUCTURE CALCULATION



1 Standard LPDC Simulation

LPDC SIMULATION RESULTS

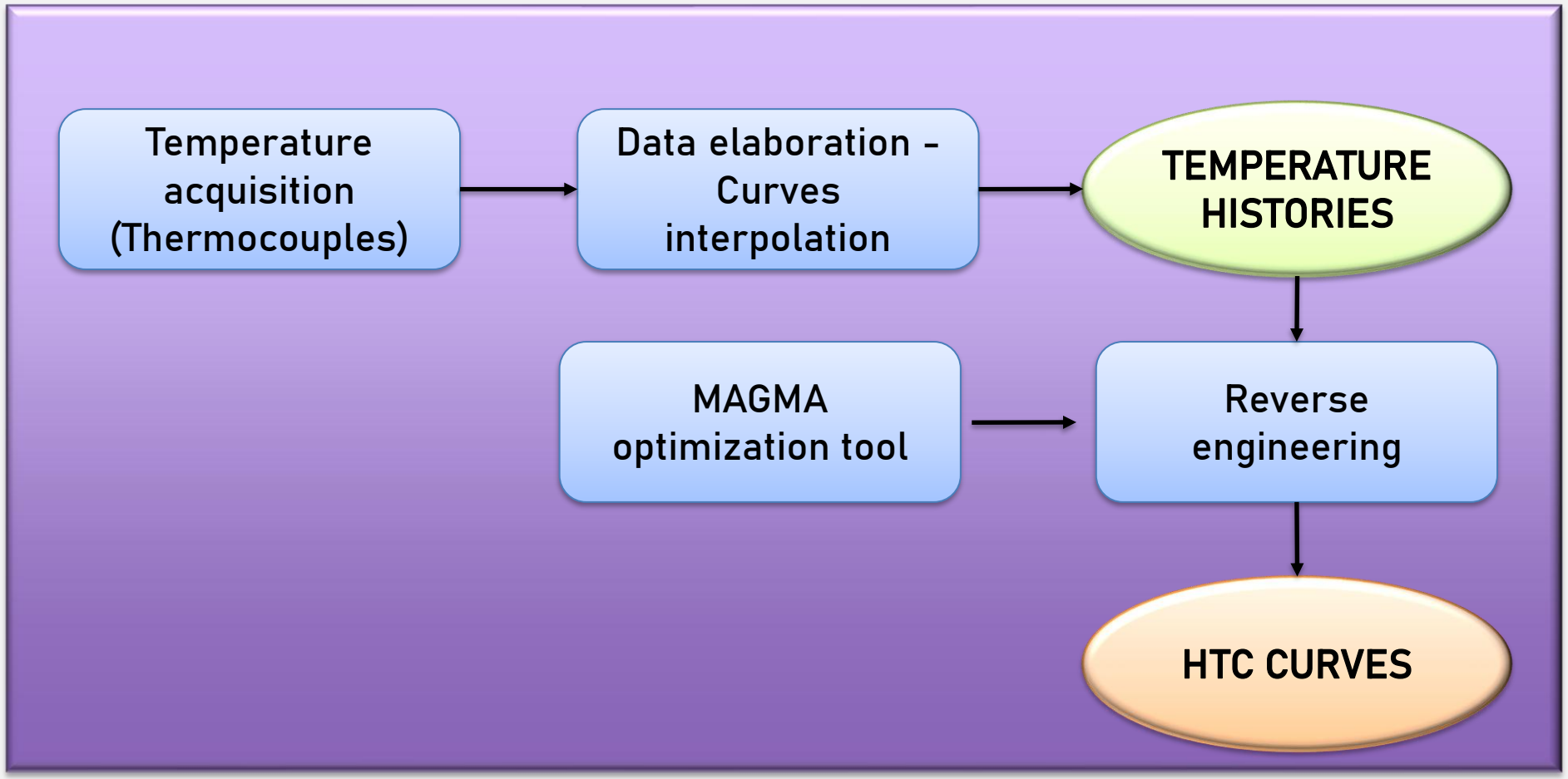


2

HT REVERSE ENGINEERING

2 HT Reverse engineering

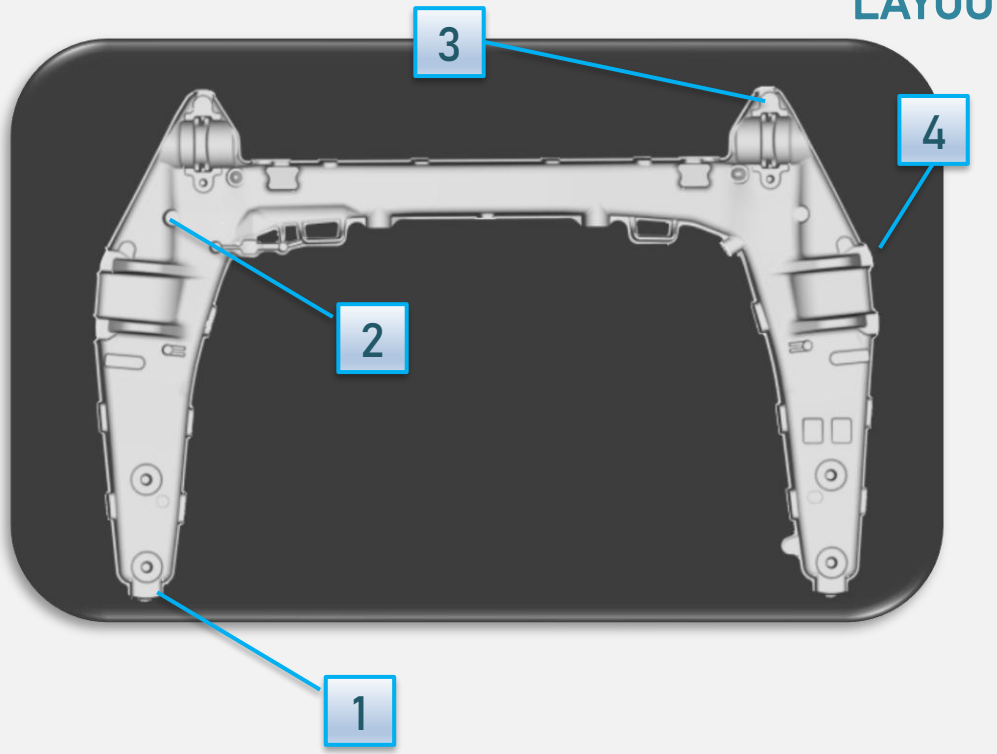
WORKFLOW

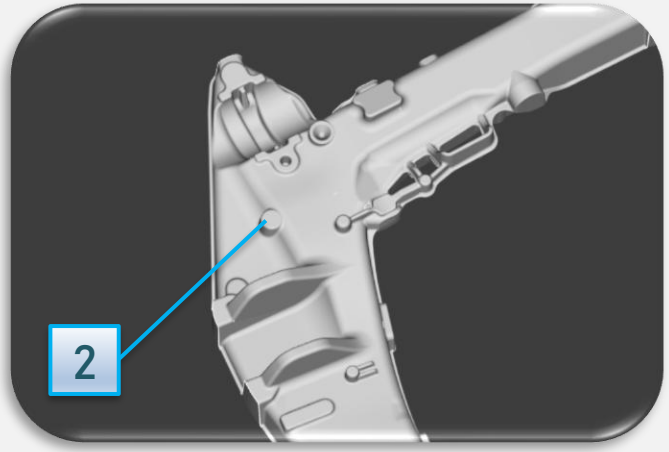


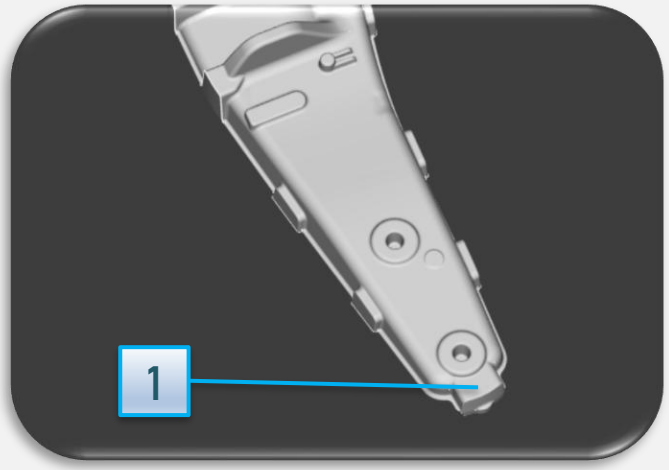
2 HT Reverse engineering

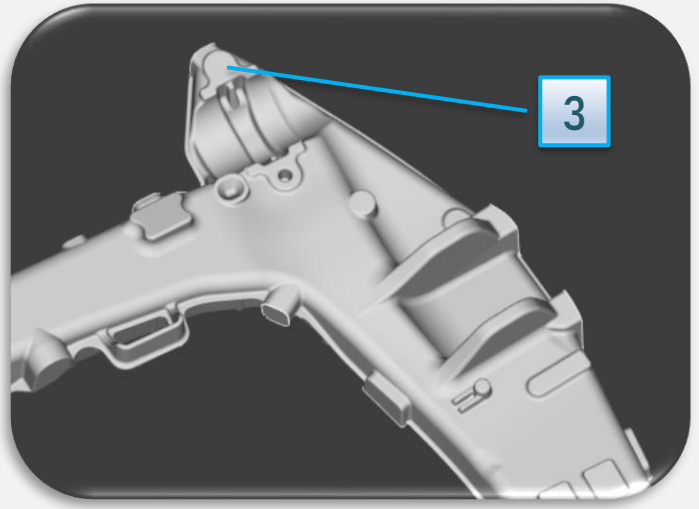
TEMPERATURE ACQUISITION

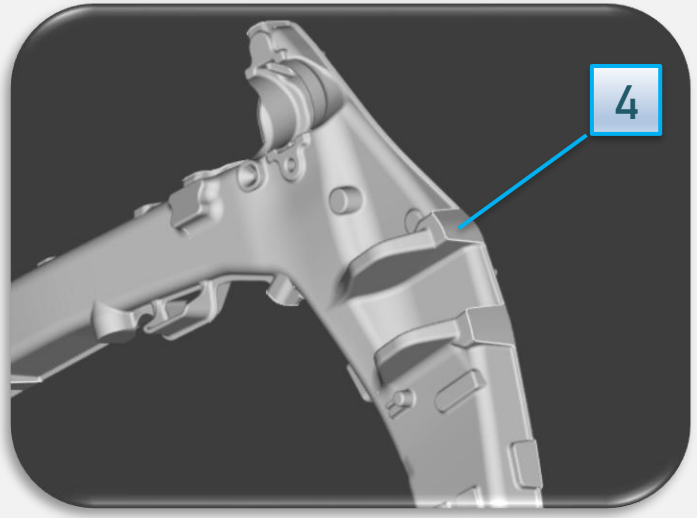
LAYOUT OF CASTING THERMOCOUPLES









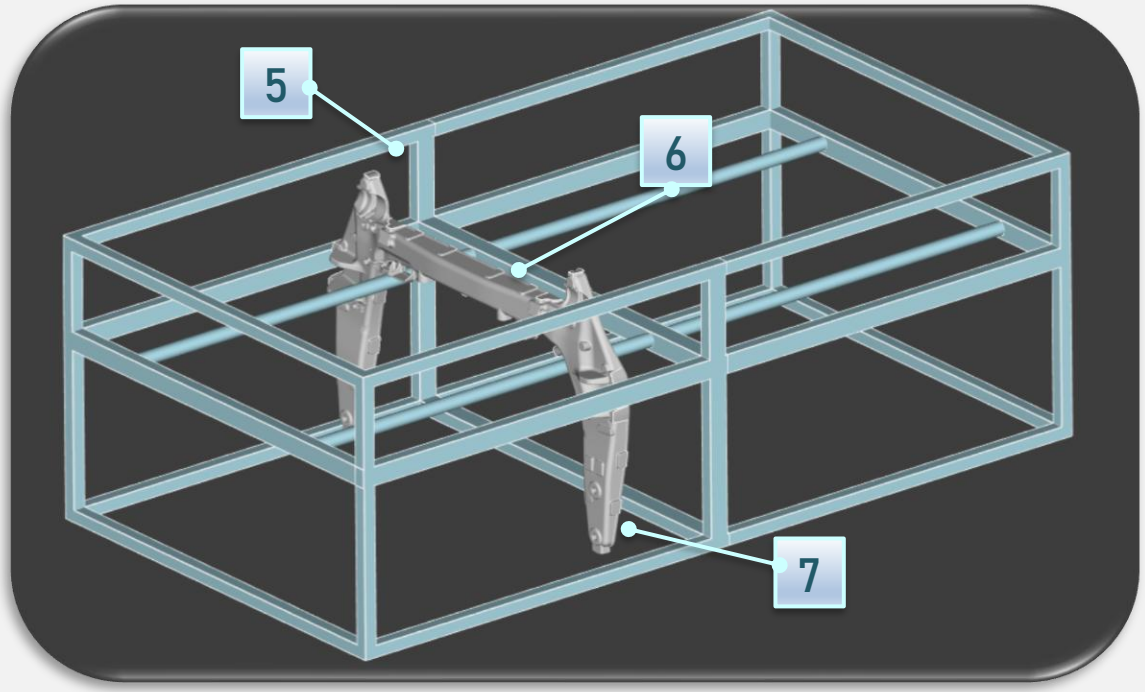


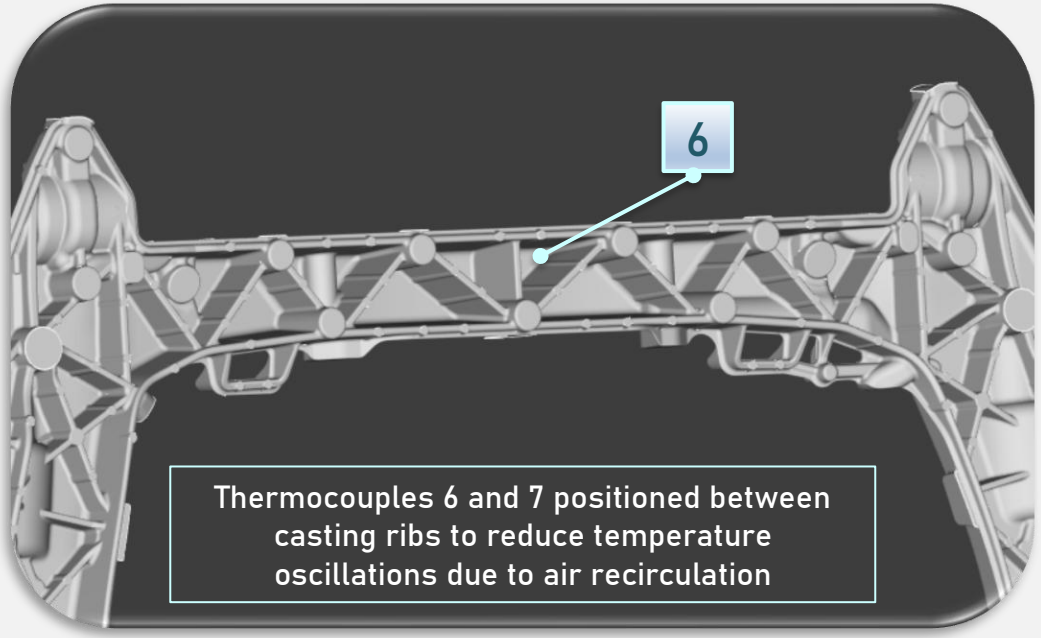
2

HT Reverse engineering

TEMPERATURE ACQUISITION

LAYOUT OF RACK THERMOCOUPLES





Solution – Quenching - Aging Data acquisition every 1s

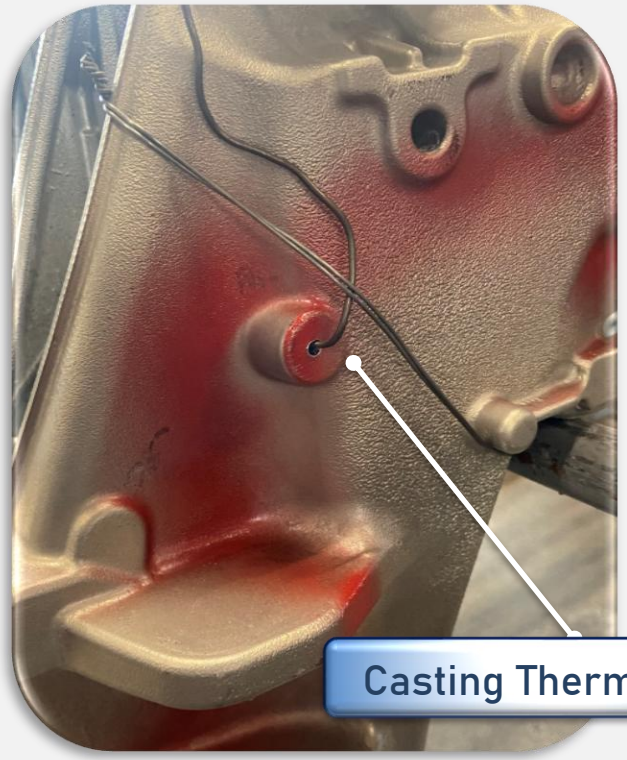
2 HT Reverse engineering

TEMPERATURE ACQUISITION

DATA-ACQUISITION TEST LAYOUT

Drilled part and thermocouple wires inserted

DATA LOGGER

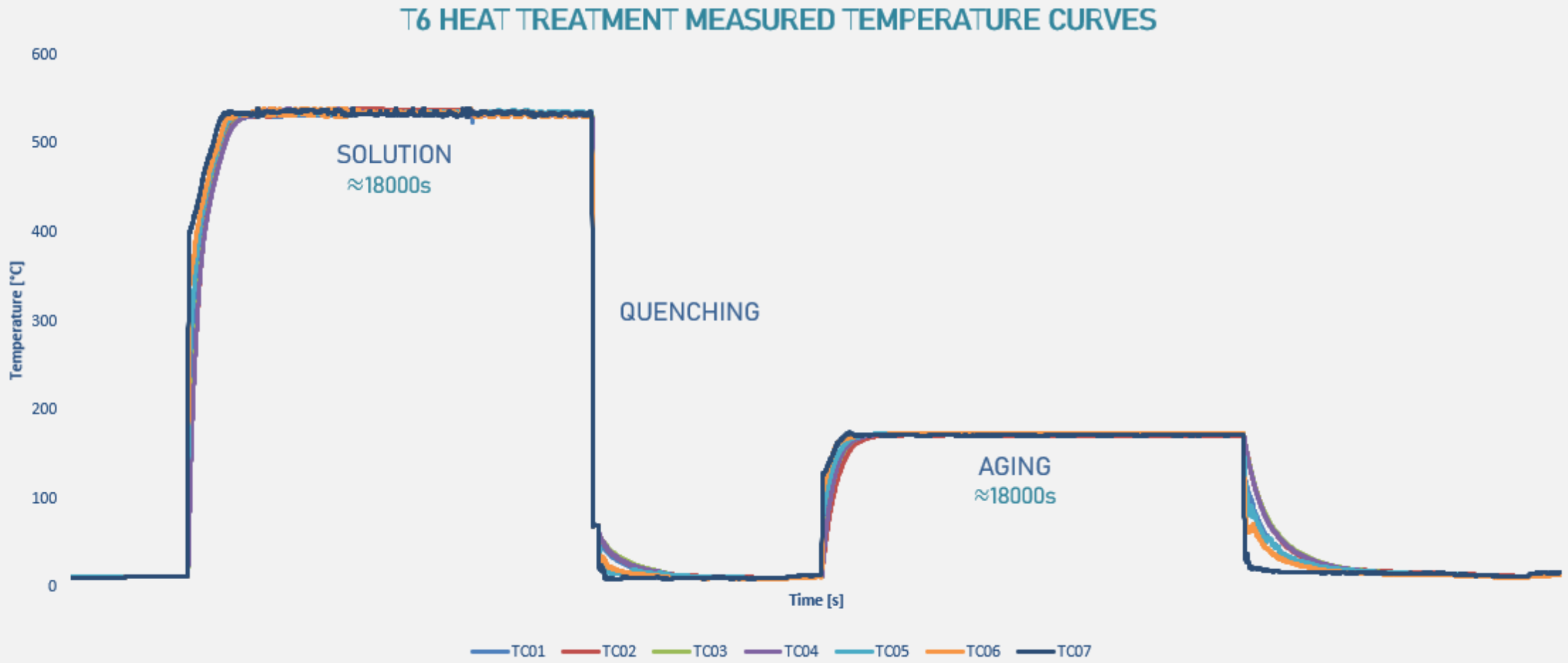


Casting Thermocouple

Rack Thermocouple

2 HT Reverse engineering

RESULTS FROMTHERMOCOUPLE ACQUISITION

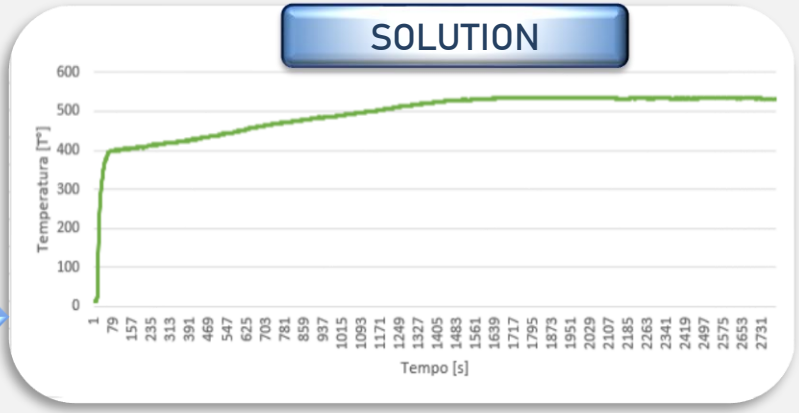


2 HT Reverse engineering

TEMPERATURE HISTORIES

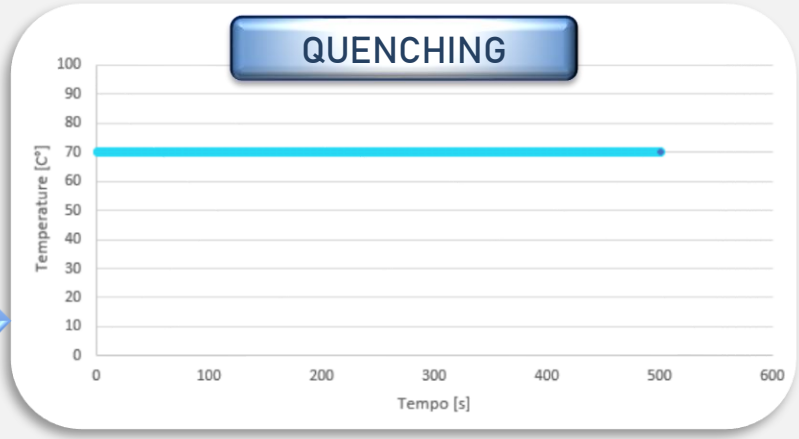
SOLUTION

TC07



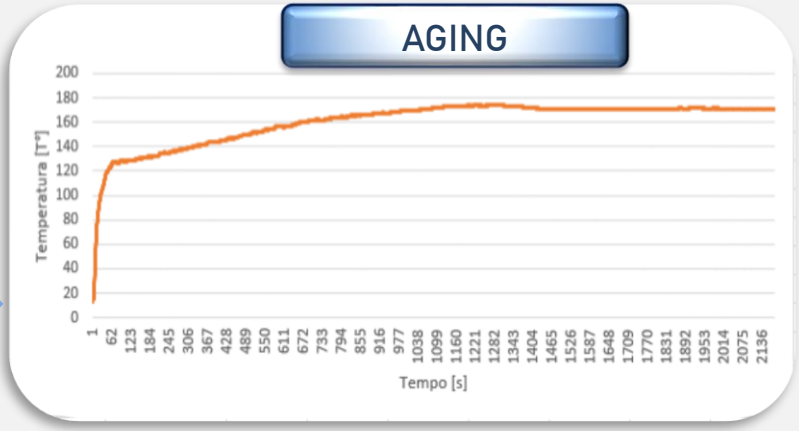
QUENCHING

All TC



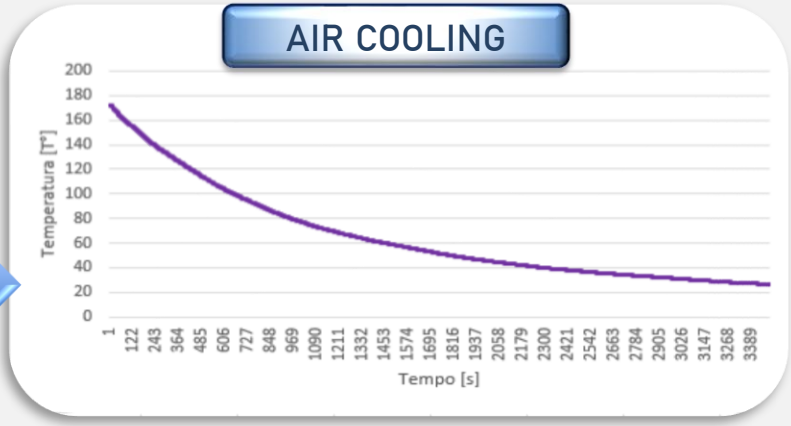
AGING

TC07



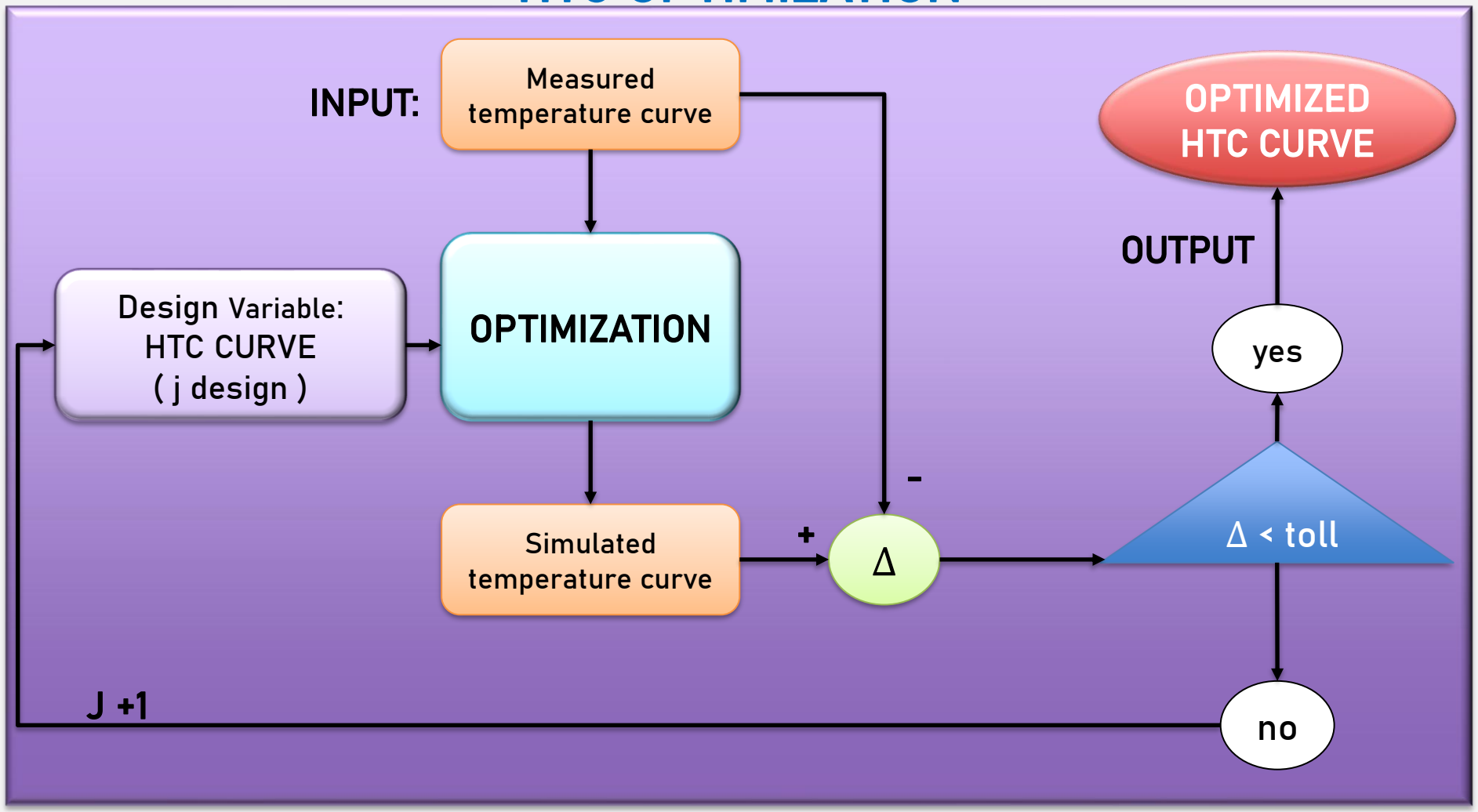
AIR COOLING

TC07



HT Reverse engineering

HTC OPTIMIZATION



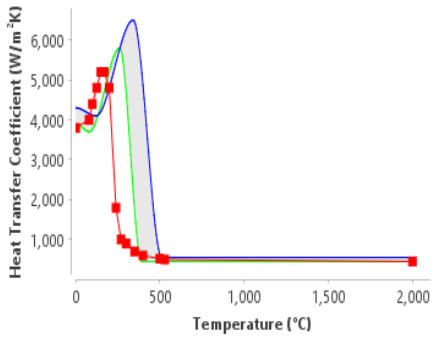
2.1

HT Reverse engineering

HTC OPTIMIZATION EXAPMLE

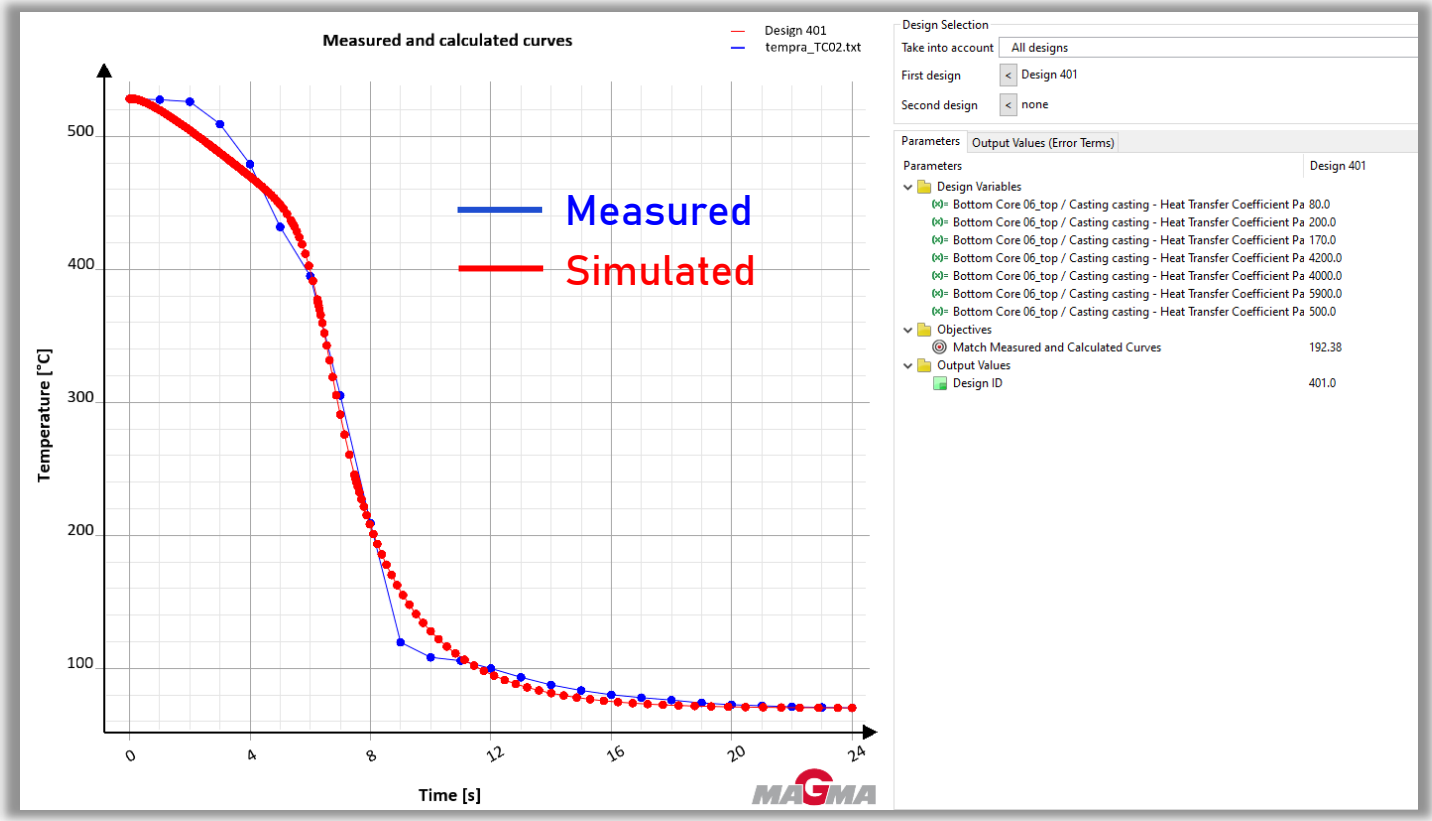
DESIGN VARIABLES

Design Variables

Design Variable	Parametric Function
Bottom Core 06_top / Casting casting - Heat Transfer Coefficient Parametric Function	

Parametric Function Parameter, Interval 1	Lower Limit	Upper Limit	Step
X0	1.0	1.0	0.0
Y0	3900.0	4300.0	100.0
W0	1.0	1.0	0.0
W1	80.0	120.0	10.0
W2	180.0	220.0	20.0
W3	130.0	170.0	10.0
Y1	3700.0	4100.0	100.0
Y2	5800.0	6500.0	100.0
Y3	450.0	550.0	50.0

COMPARISON MEASURED - SIMULATED



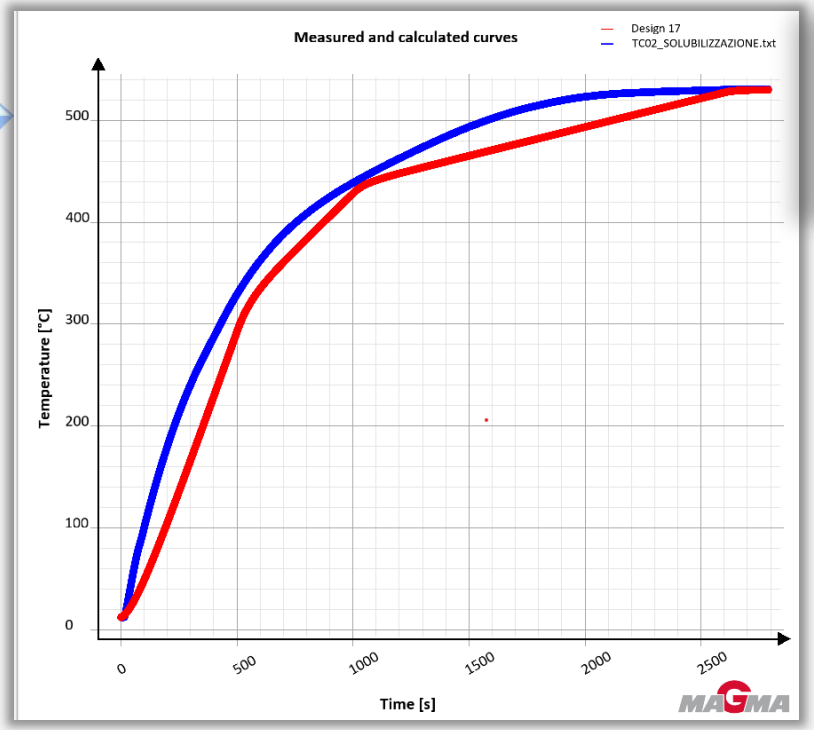
2.1 HT Reverse engineering

HTC OPTIMIZATION RESULTS – Solution phase

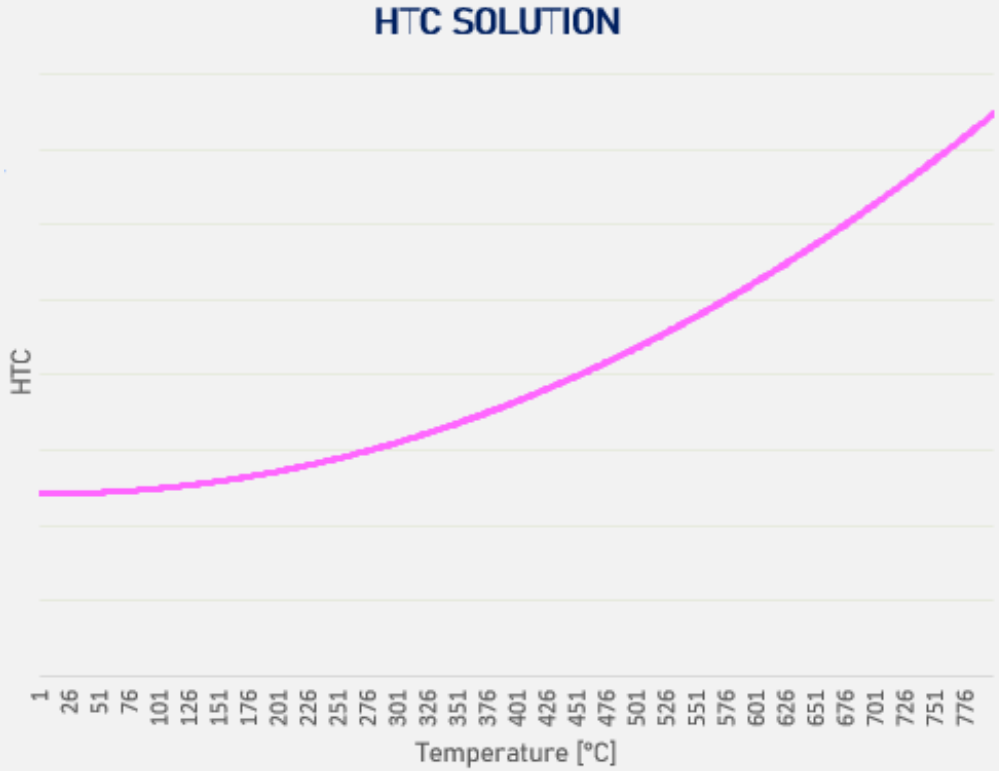
OPTIMIZED FUNCTION

$$y_0 = y_0 + (y_1 - y_0) \cdot \left(\frac{x - x_0}{w_0}\right)^k$$

Temperature Curves match



Solution HTC Curve



2.1 HT Reverse engineering

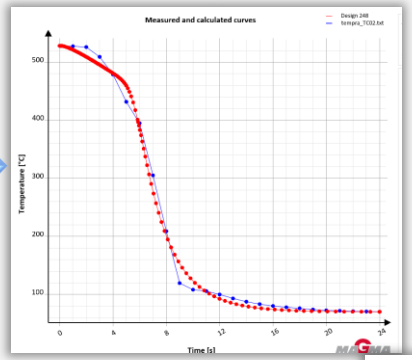
HTC OPTIMIZATION RESULTS – Quenching phase

OPTIMIZED FUNCTION

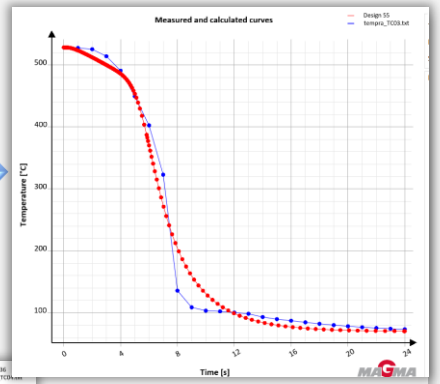
2°degree polynomial passing through the points:

$$(x_0 + w_0, y_0) \quad (x_0 + w_0 + w_1, y_1)$$
$$(x_0 + w_0 + w_1, y_1) \quad (x_0 + w_0 + 2 \cdot w_1, y_2)$$

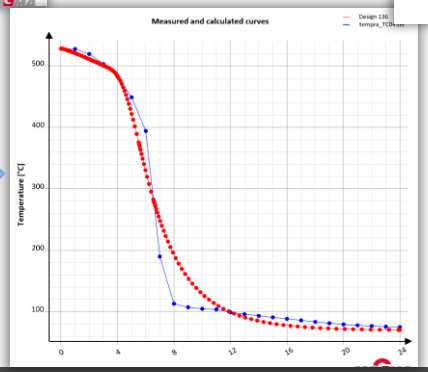
TC02



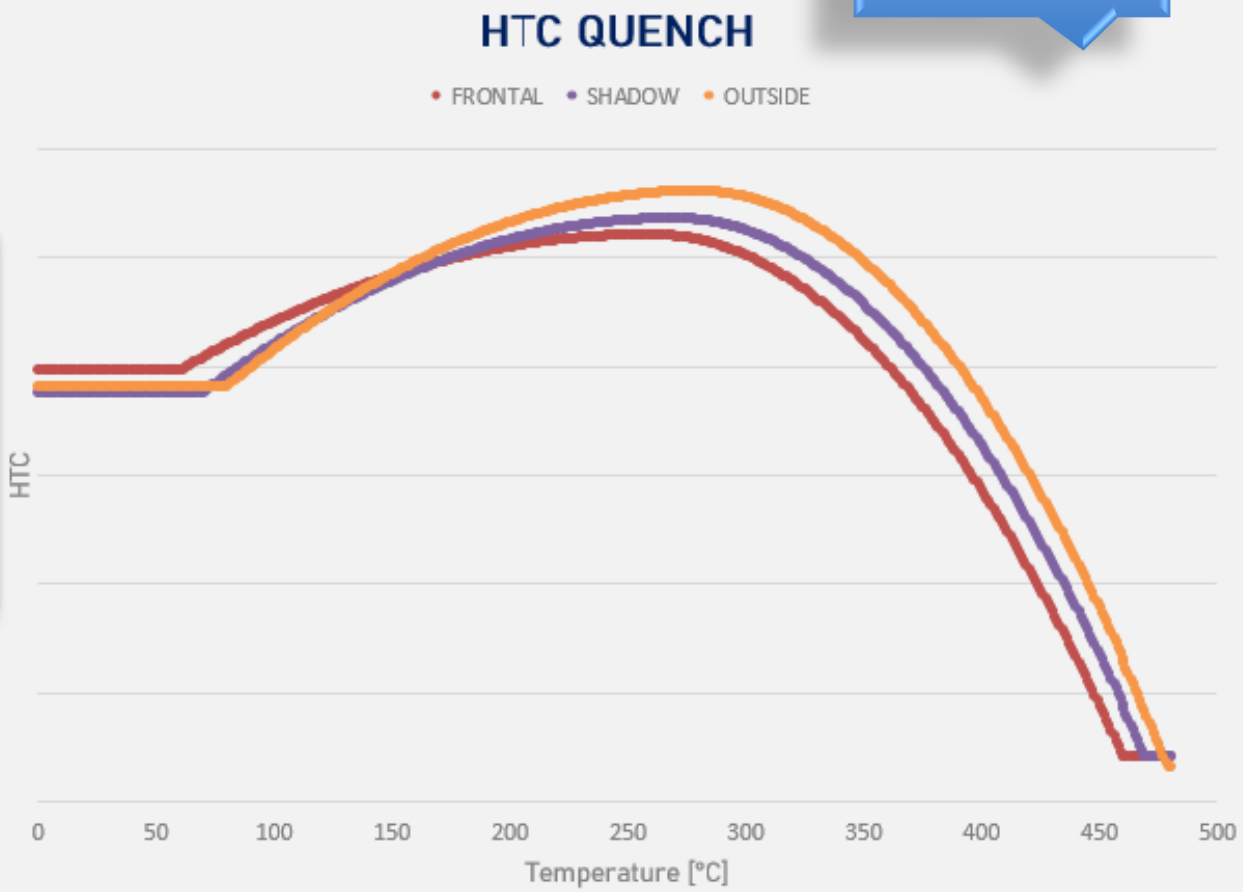
TC03



TC04



Quench HTC Curves



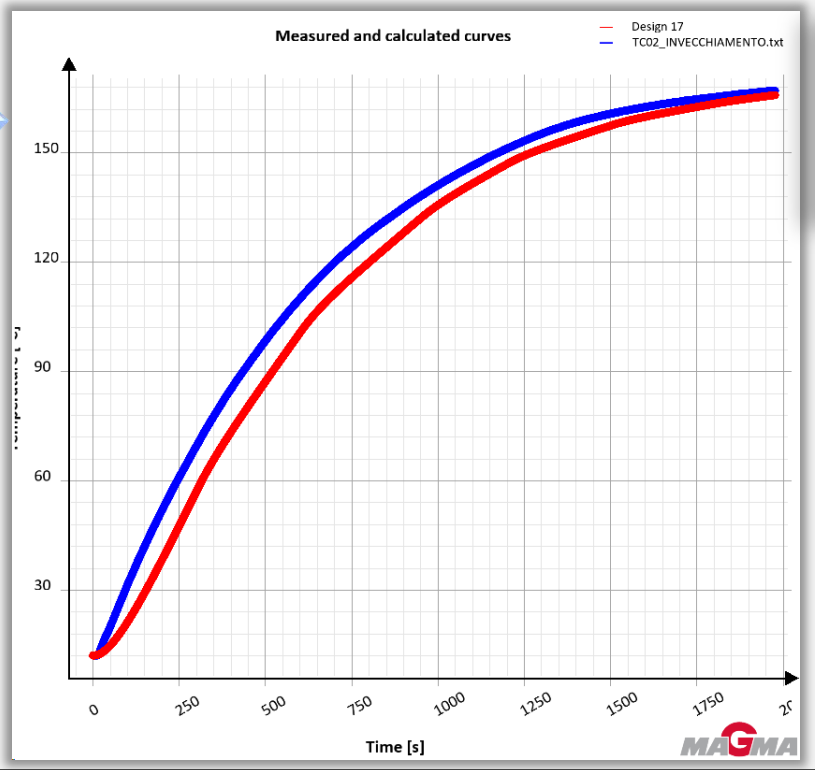
HT Reverse engineering

HTC OPTIMIZATION RESULTS – Aging phase

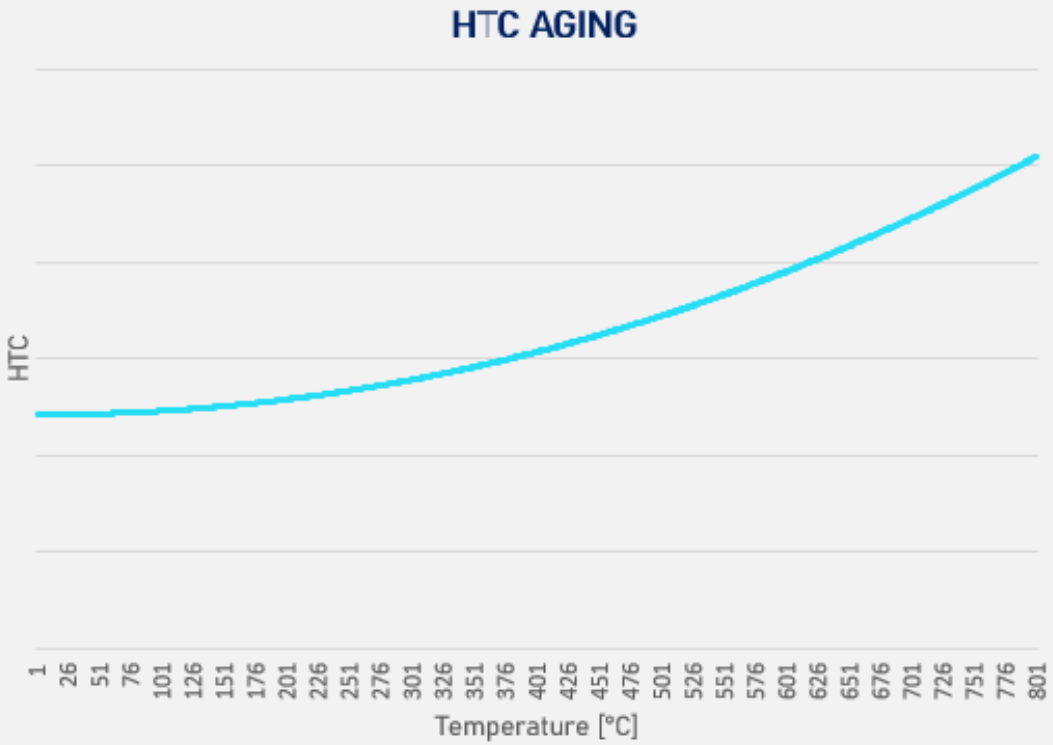
OPTIMIZED FUNCTION

$$y_0 = y_0 + (y_1 - y_0) \cdot \left(\frac{x - x_0}{w_0}\right)^k$$

Temperature Curves match



Aging HTC Curve



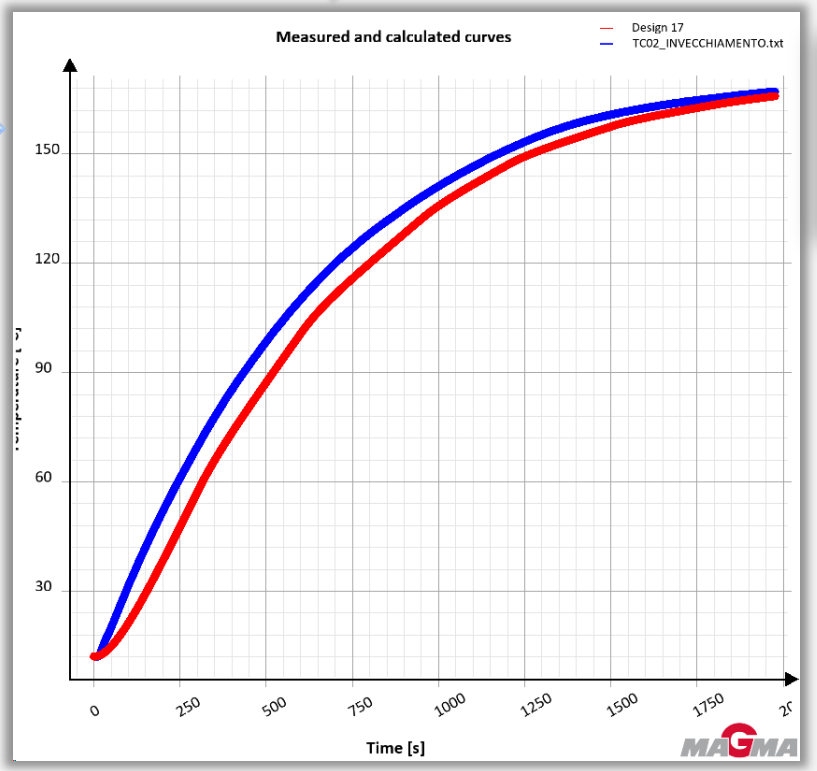
HT Reverse engineering

HTC OPTIMIZATION RESULTS – Air cooling phase

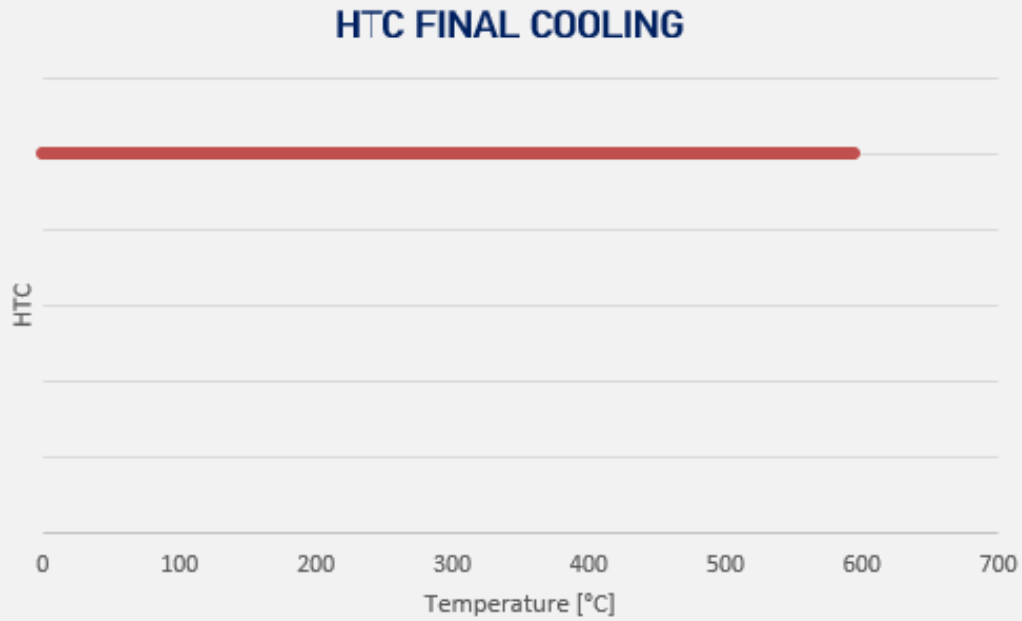
OPTIMIZED FUNCTION

$$y_0 = y_0 + (y_1 - y_0) \cdot \left(\frac{x - x_0}{w_0}\right)^k$$

Temperature Curves match



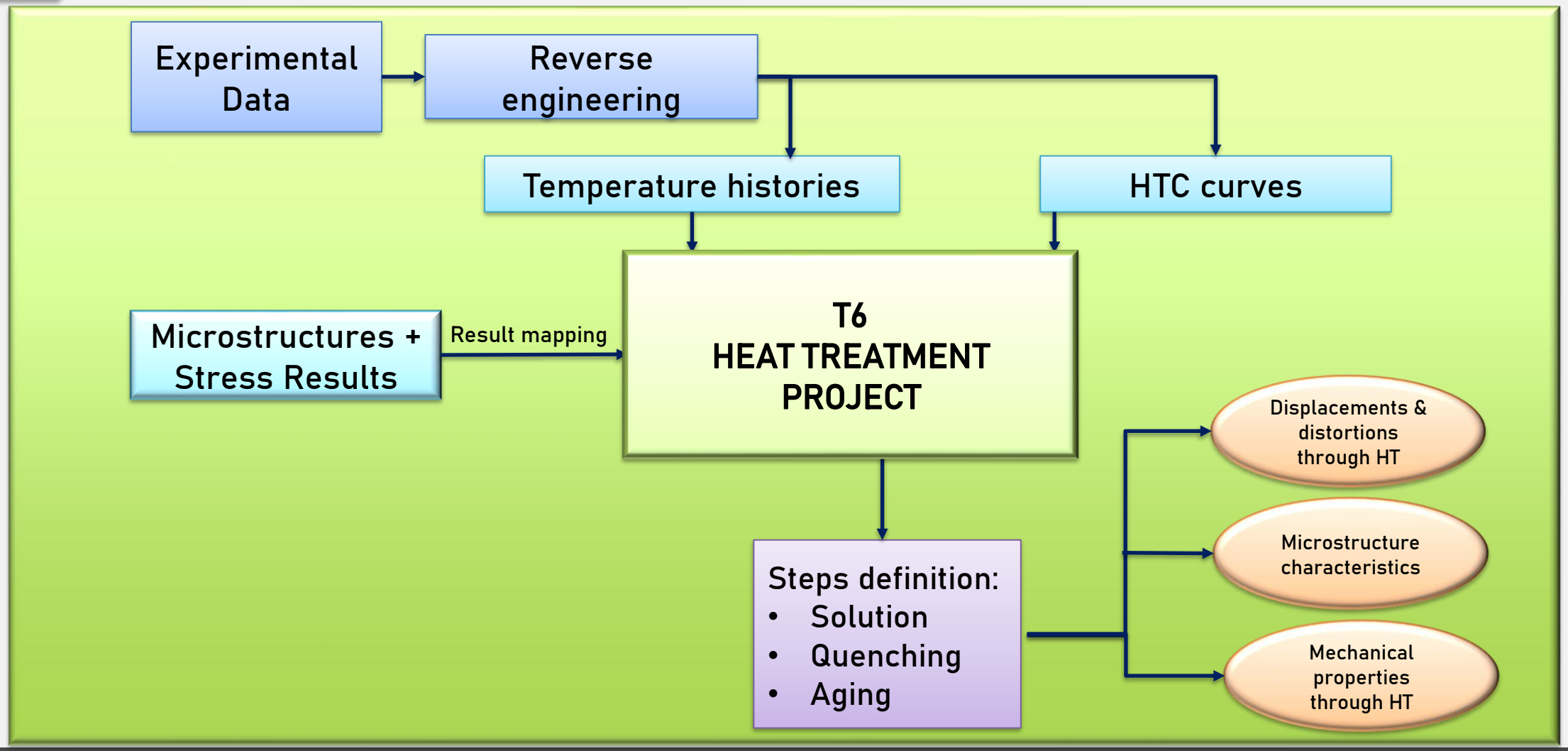
Air cooling HTC Curve



3

HEAT TREATMENT SIMULATION

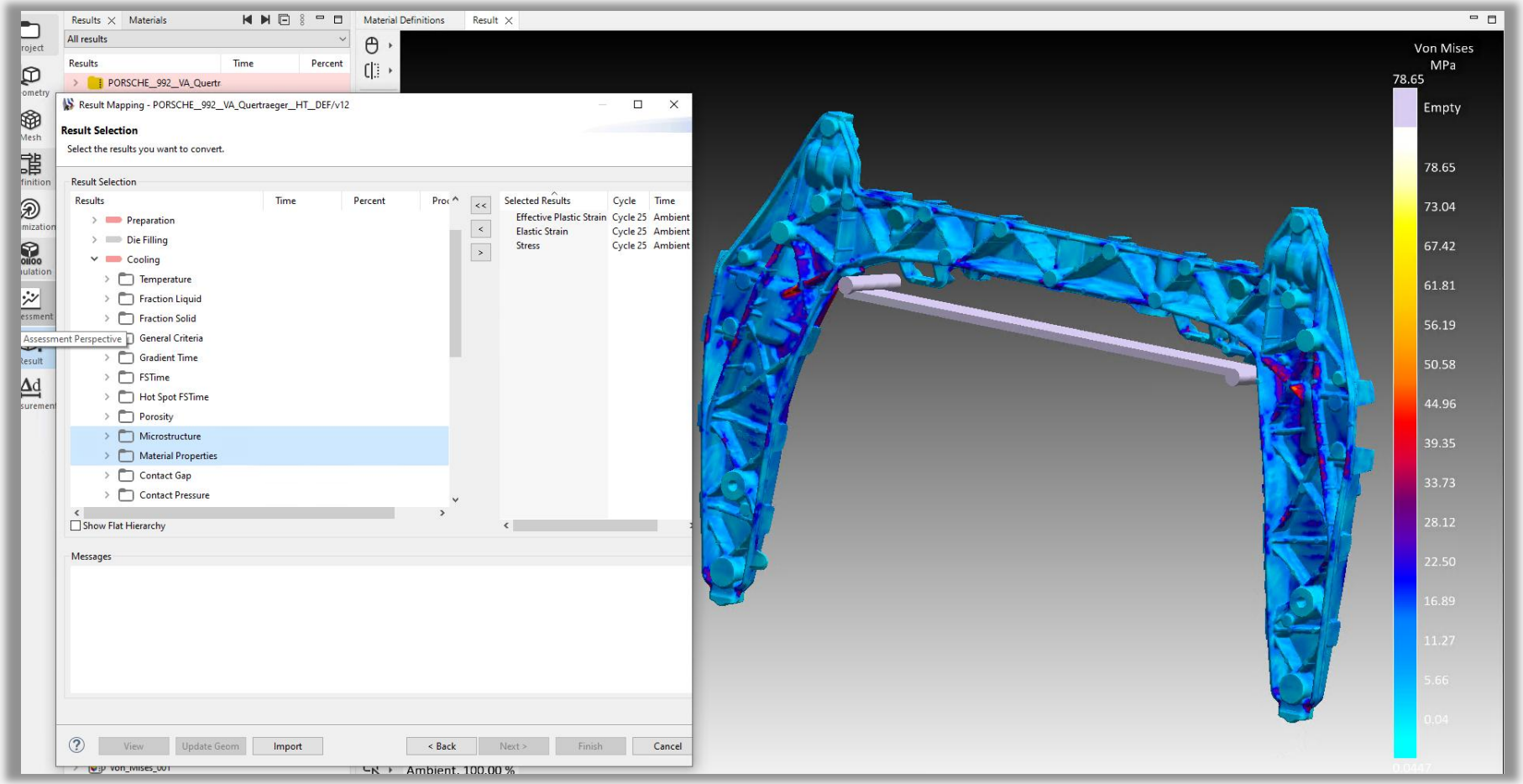
3 Heat Treatment Simulation



3 Heat Treatment Simulation

IMPORT RESULTS – RESULT MAPPING

Microstructure and Mechanical Properties results from the last cycle of the standard thermal project need to be imported and manually mapped into the heat treatment project.



3 Heat Treatment Simulation

HEAT TREATMENT STEPS DEFINITION

Initial temperature condition: Uniform initial temperature

Heat treatment initial temperature: 20.0 °C

T6 Heat treatment steps

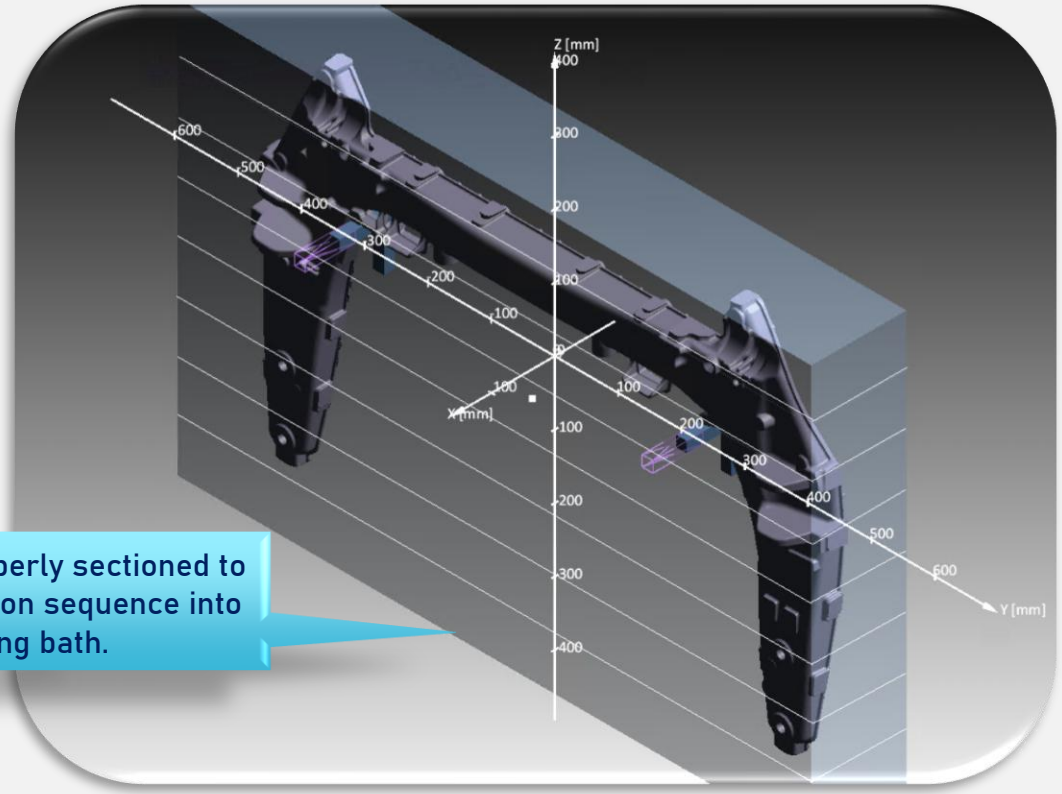
Material Selection | Process Steps

Steps in Heat Treatment Process

Step	Type	Temperature History	Stop Condition
001	Solution Treatment	Project/SOLUTION_HTT	after 18000.0 s
002	Cooling	Project/Al_quench_20C	after 15.0 s
003	Quenching	Project/Al_Quench_70C	after 0.35 s
004	Quenching	Project/Al_Quench_70C	after 0.35 s
005	Quenching	Project/Al_Quench_70C	after 0.35 s
006	Quenching	Project/Al_Quench_70C	after 0.35 s
007	Quenching	Project/Al_Quench_70C	after 0.35 s
008	Quenching	Project/Al_Quench_70C	after 0.35 s
009	Quenching	Project/Al_Quench_70C	after 0.35 s
010	Quenching	Project/Al_Quench_70C	after 260.0 s
011	Cooling	Project/Al_quench_20C	after 3600.0 s
012	Aging	Project/AGING_HTT	after 18000.0 s
013	Cooling	Project/Al_quench_18C	as soon as max. temp. in Casting ID 1 falls below 20.0 °C

Boundary Definition

Material 1	Mat ID	Material 2	Mat ID	Database/Filename	Type
Casting		Permanent Mold			
Casting	ID 1	Bottom Core	05	Project/Al_Default_Cooling__20	Radiation and Convection
Casting	ID 1	Bottom Core	01	Project/Quench_opt_FRONTAL	Heat Transfer Coefficient
Casting	ID 1	Bottom Core	02	Project/Al_Default_Cooling__20	Radiation and Convection
Casting	ID 1	Bottom Core	03	Project/Al_Default_Cooling__20	Radiation and Convection
Casting	ID 1	Bottom Core	04	Project/Al_Default_Cooling__20	Radiation and Convection
Casting	ID 1	Bottom Core	06	Project/Al_Default_Cooling__20	Radiation and Convection
Casting	ID 1	Bottom Core	07	Project/Al_Default_Cooling__20	Radiation and Convection
Casting	ID 1	Bottom Core	08	Project/Al_Default_Cooling__20	Radiation and Convection

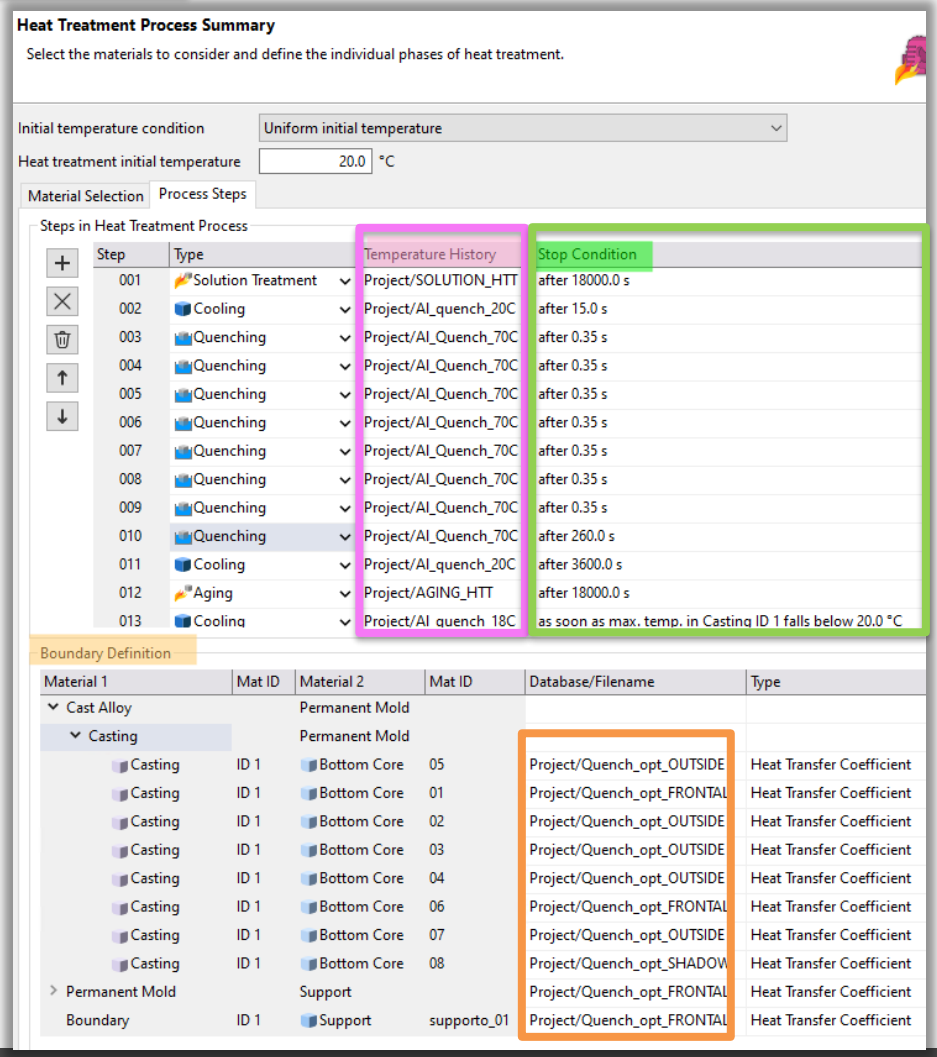


Dummy mold properly sectioned to simulate immersion sequence into quenching bath.

Sections allow to differentiate boundary conditions and simulate the casting sinking into the bath

3 Heat Treatment Simulation

HEAT TREATMENT STEPS DEFINITION



For each phase of the treatment, the following must be specified:

Temperature History — Temperature boundary condition (furnace and water bath)

HTC — Temperature dependent heat transfer coefficient between casting and environment

Duration — of each phase

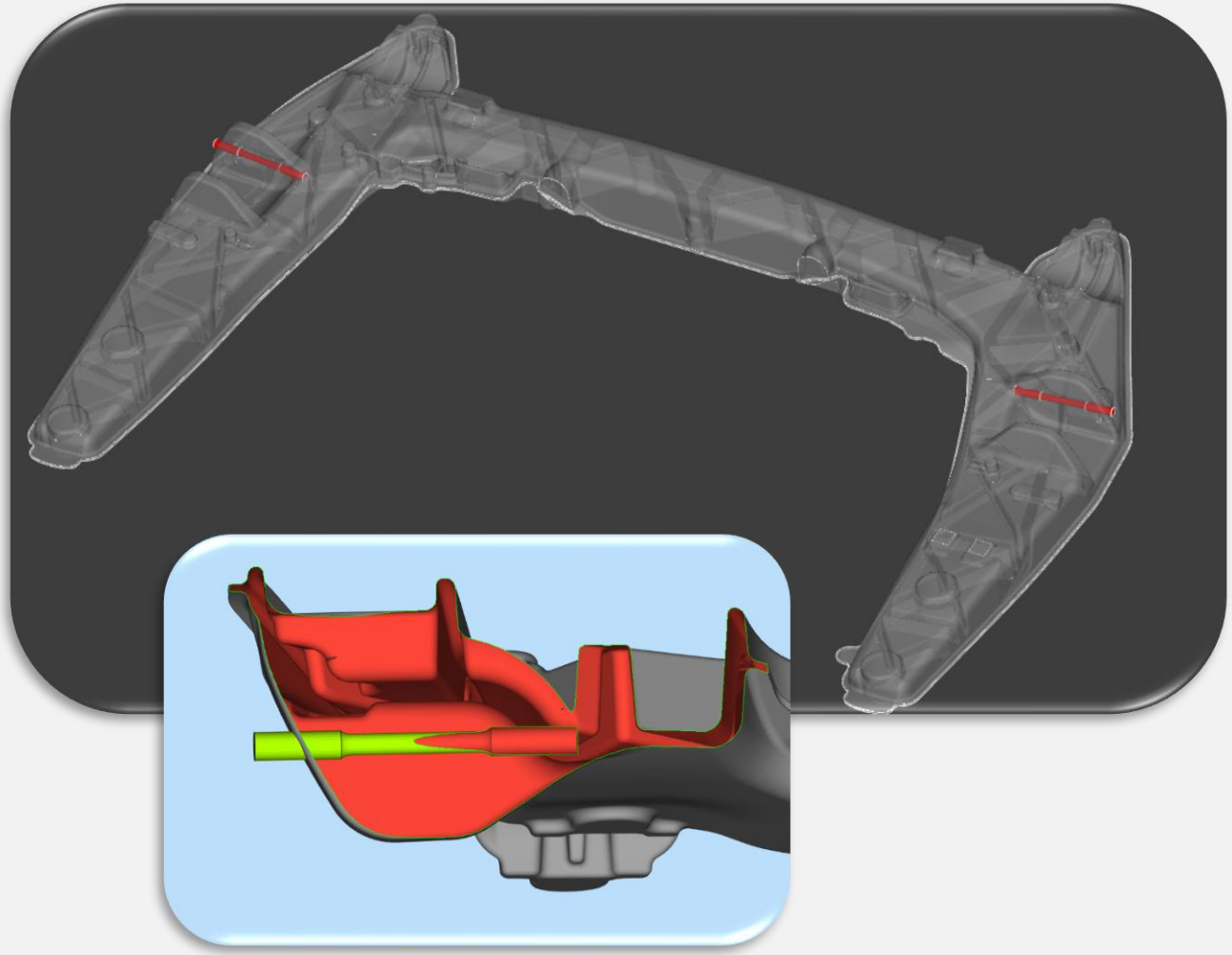
From measured real data and reverse engineering work

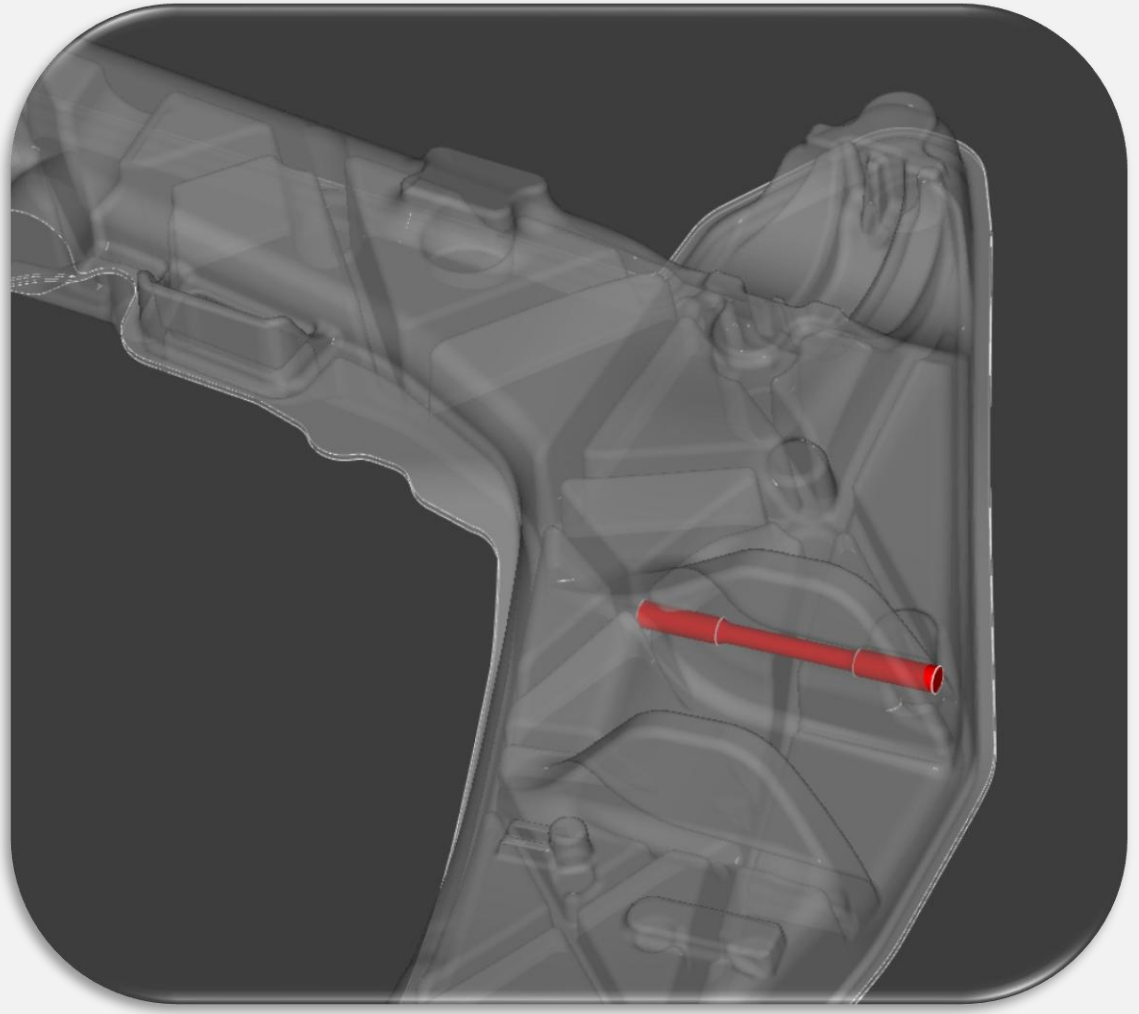
4

MECHANICAL PROPERTIES EVOLUTION THROUGH HEAT TREATMENT – REAL VS SIMULATION

4 Mechanical properties evolution through HT – Real vs Simulation

SPECIMEN POSITION

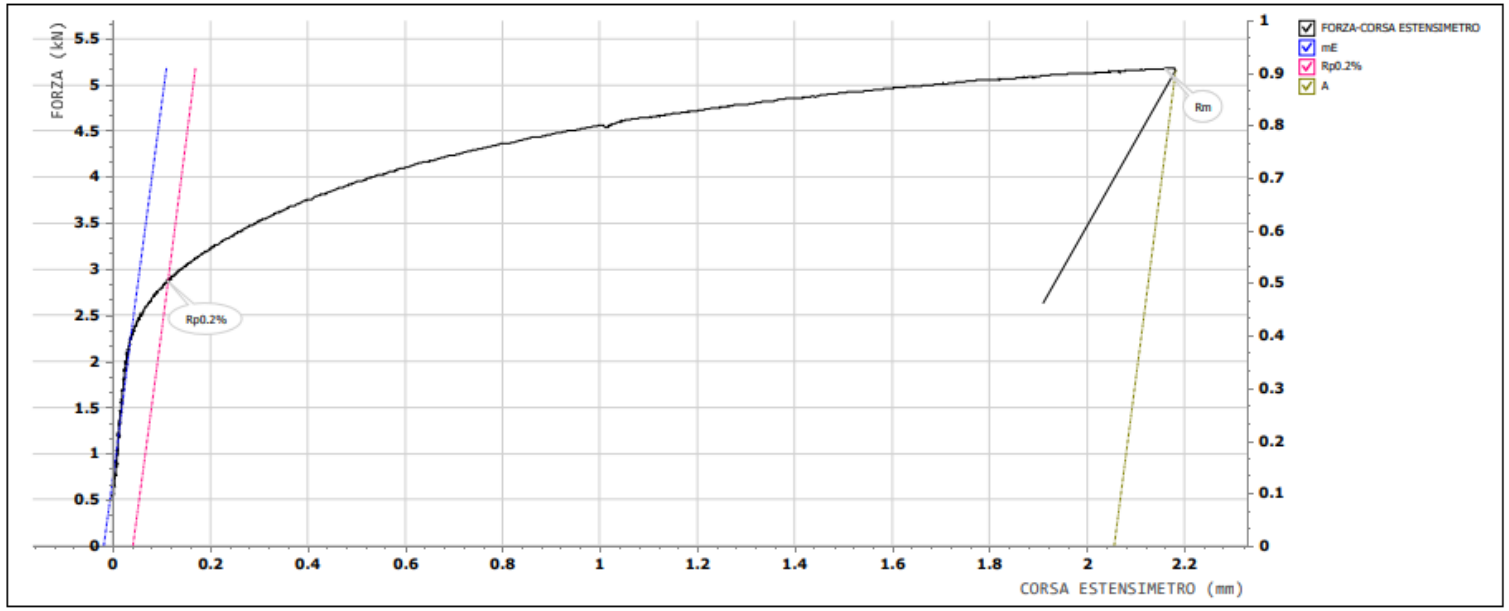




4 Mechanical properties evolution through HT – Real vs Simulation

EXAMPLE OF STRESS-STRAIN CURVE

d0	S0	Le	L0
6 mm	28.274 mm2	30 mm	30 mm



Risultato Test	Fm	Rm	Rp0.2%	A	Lu	E
Ok	5.180 kN	183.21 MPa	101.36 MPa	6.87 %	32.06 mm	43478 MPa

4 Mechanical properties evolution through HT – Real vs Simulation

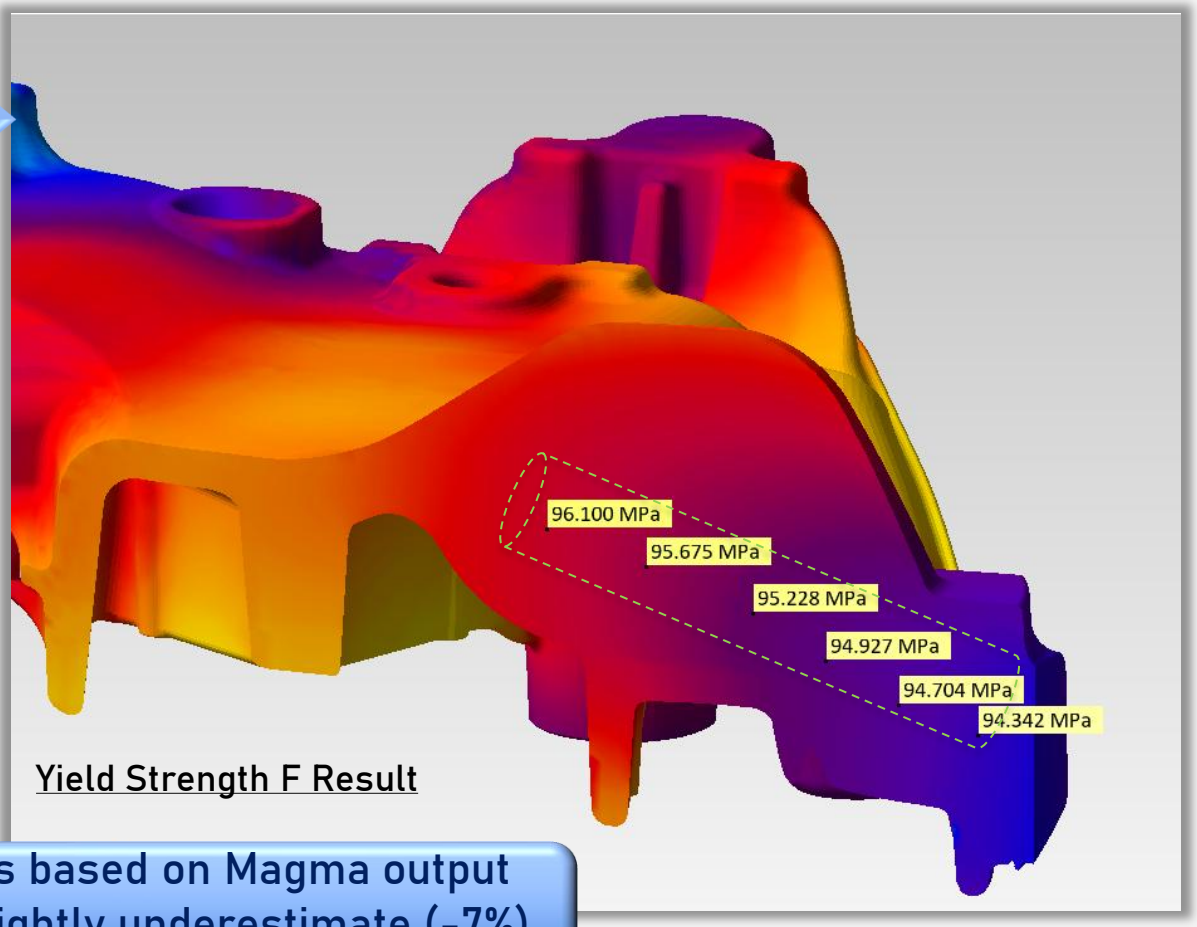
MECHANICAL PROPERTIES AS CAST

Measured values

PART	AREA	Rp 0.2
1	1	101,3
	2	106,8
2	1	101,5
	2	103,6
3	1	102,8
	2	102,4
Mean Values		103,1

YIELD STRENGTH AS CAST

Simulated values



Simulation results based on Magma output
Yield Strength F slightly underestimate (-7%) real values

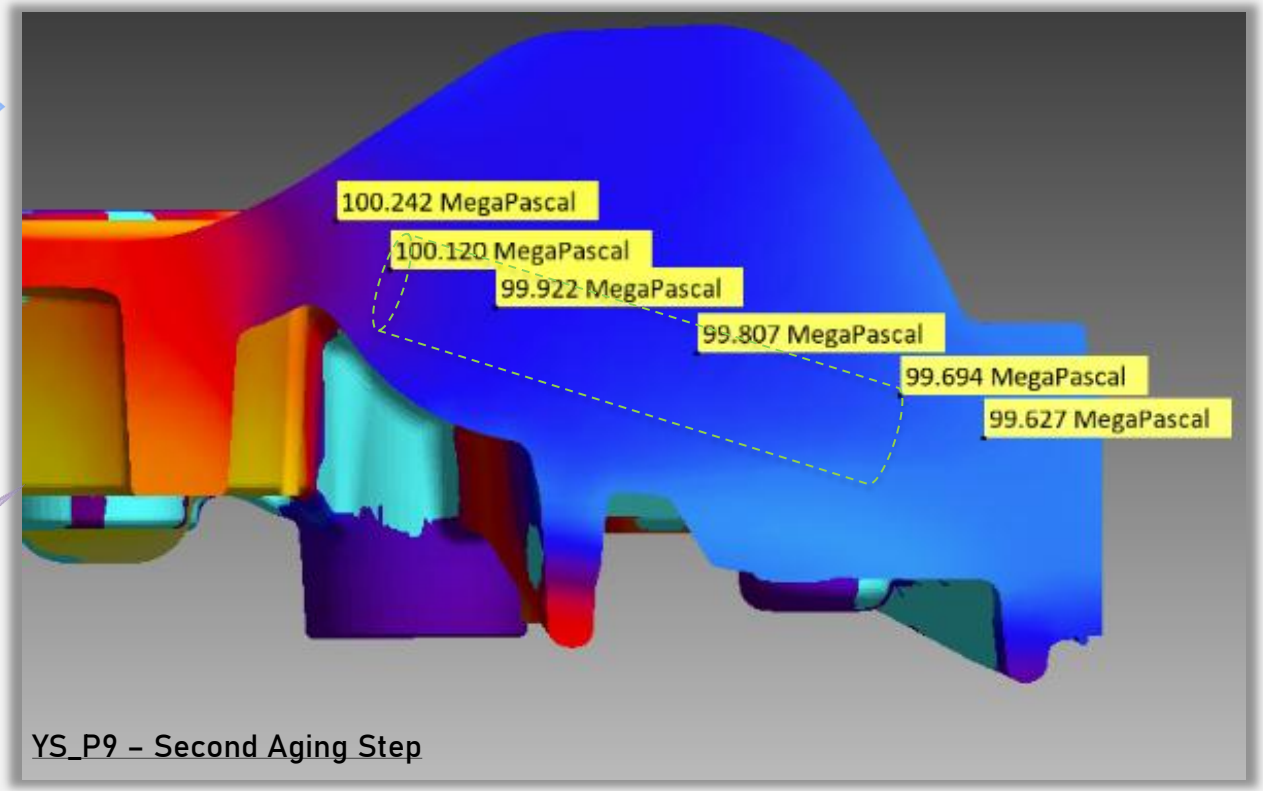
4 Measured and simulated mechanical properties comparison

MECHANICAL PROPERTIES AFTER QUENCH

Measured values

PART	AREA	Rp 0.2
1	1	121,6
	2	120,3
2	1	119,5
	2	120,2
3	1	116,7
	2	117
Mean Values		119,2

Simulated values



Beta 6.0.1 Release

YIELD STRENGTH AFTER QUENCH

Simulation ≈ -16% than specimen measures

4 Measured and simulated mechanical properties comparison

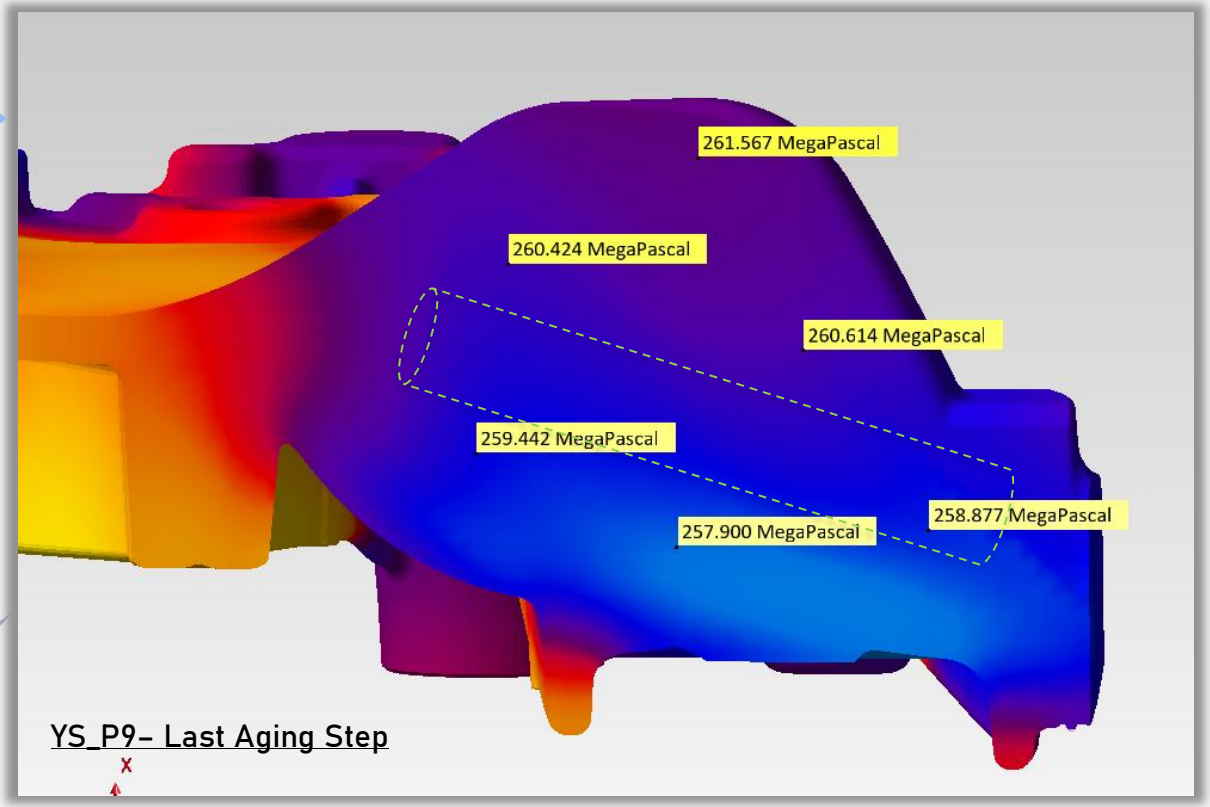
MECHANICAL PROPERTIES AFTER AGING

Measured values

PART	AREA	Rp 0.2
1	1	253,5
	2	250,3
2	1	266,1
	2	266,3
3	1	252,9
	2	252,1
Mean Values		256,9

YIELD STRENGTH AFTER AGING

Simulated values



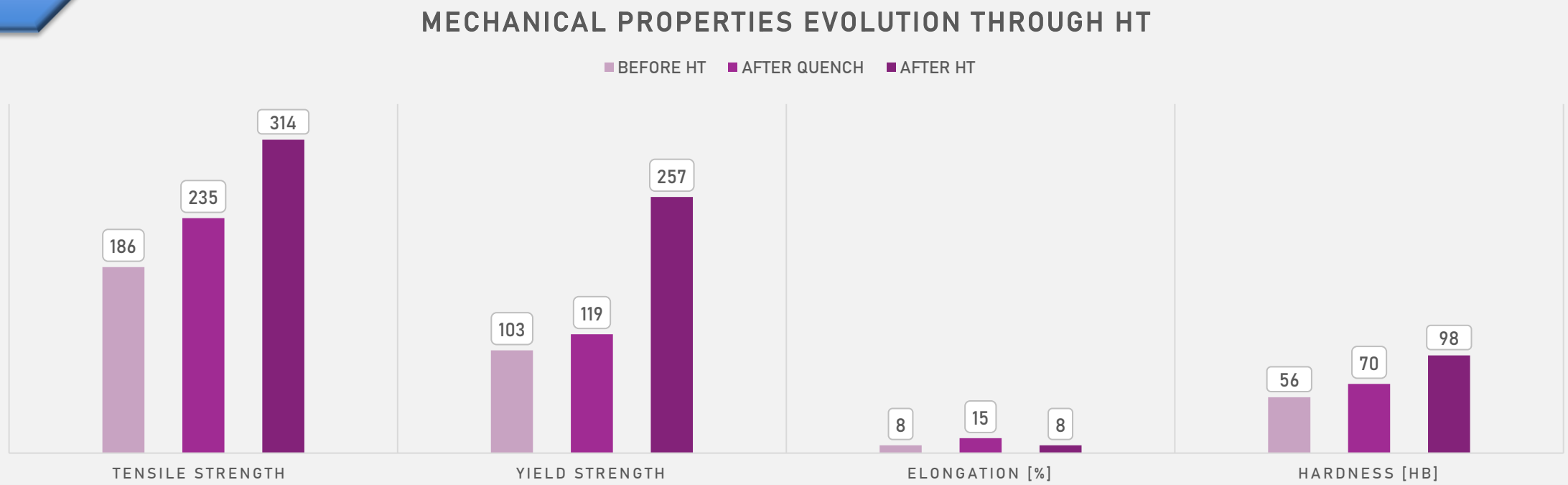
Beta 6.0.1 Release

Simulation comparable to real data

4 Measured and simulated mechanical properties comparison

Good matching simulation – reality

4 Mechanical properties evolution through T6 heat treatment



		Rm			Rp 0.2			A%			HB		
PART	AREA	Pre HT	Post Quench	Post HT	Pre HT	Post Quench	Post HT	Pre HT	Post Quench	Post HT	Pre HT	Post Quench	Post HT
1	1	183,2	230,2	312,5	101,3	121,6	253,5	6,8	10,7	7,6	55,5	68,6	95
	2	189,9	238,7	308,5	106,8	120,3	250,3	7,3	16,5	5,5			
2	1	185,3	233,4	320	101,5	119,5	266,1	8,2	12,5	8,3	56,8	70,6	101
	2	190,3	240,1	315,7	103,6	120,2	266,3	8,7	18,3	9,7			
3	1	181,2	236,1	313,5	102,8	116,7	252,9	7	15,1	6	55,5	68,8	98
	2	189,5	235,2	315,4	102,4	117	252,1	9,2	16,3	10,1			
Mean Values		**186,6**	**235,6**	**314,3**	**103,1**	**119,2**	**256,9**	**7,9**	**14,9**	**7,9**	**55,9**	**69,3**	**98,0**

Any questions?