KOMERCIJALNO-TEHNIČKO PREDAVANJE / *COMMERCIAL-TECHNICAL PRESENTATIONS*

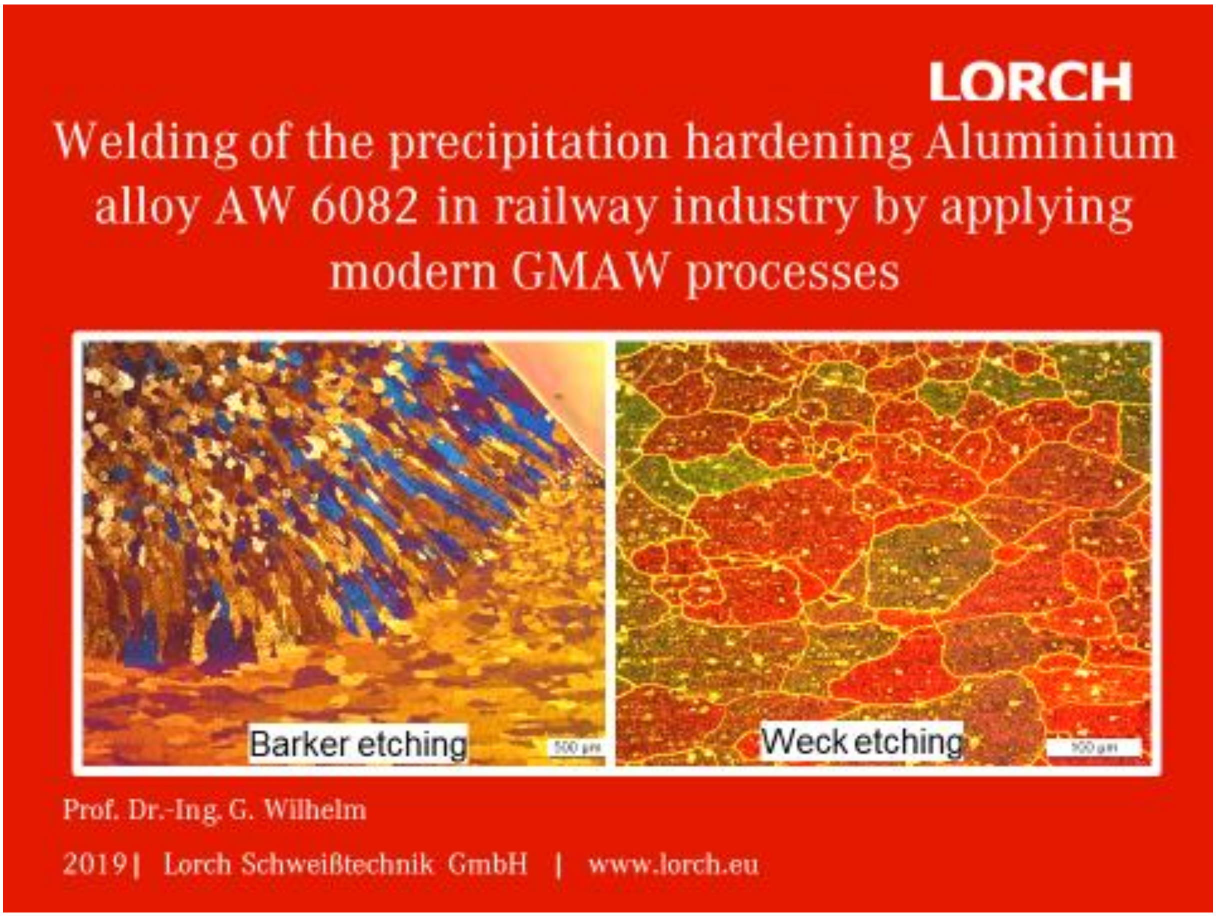
WELDING OF HARDENABLE ALUMINIUM ALLOYS AW 6082 WITH HIGHPERFORMANCE WELDING-PROCESSES

Wilhelm Gerald

Keywords: Modified GMAW processes, precipitation hardening Aluminium alloys, quality, microstructure, mechanical and technological properties

Abstract:

The GMAW process has been applied for many decades to join metals, especially different steel grades and various aluminium alloys. The demands for an increase in productivity combined with an increase in quality are constantly triggering the development of modified GMAW processes. Welding of the precipitation hardening Aluminium alloy AW 6082 leads to a significant decrease of the hardness and the yield strength in the heat affected zone. In addition the material percentage elongation after fracture is reduced. In this investigation the influence of various discontinuous energy regimes of different Lorch Speed Welding Processes on the microstructure, the mechanical and technological properties of the joints and on the performance of the welding process and is analysed. Based on several case studies the benefits of the Lorch Speed Welding Processes are carried out referring to the specifics of railway vehicles.



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Welding of the precipitation hardening Aluminium alloy AW 6082 in railway industry by applying modern GMAW processes

Prof. Dr.-Ing. G. Wilhelm

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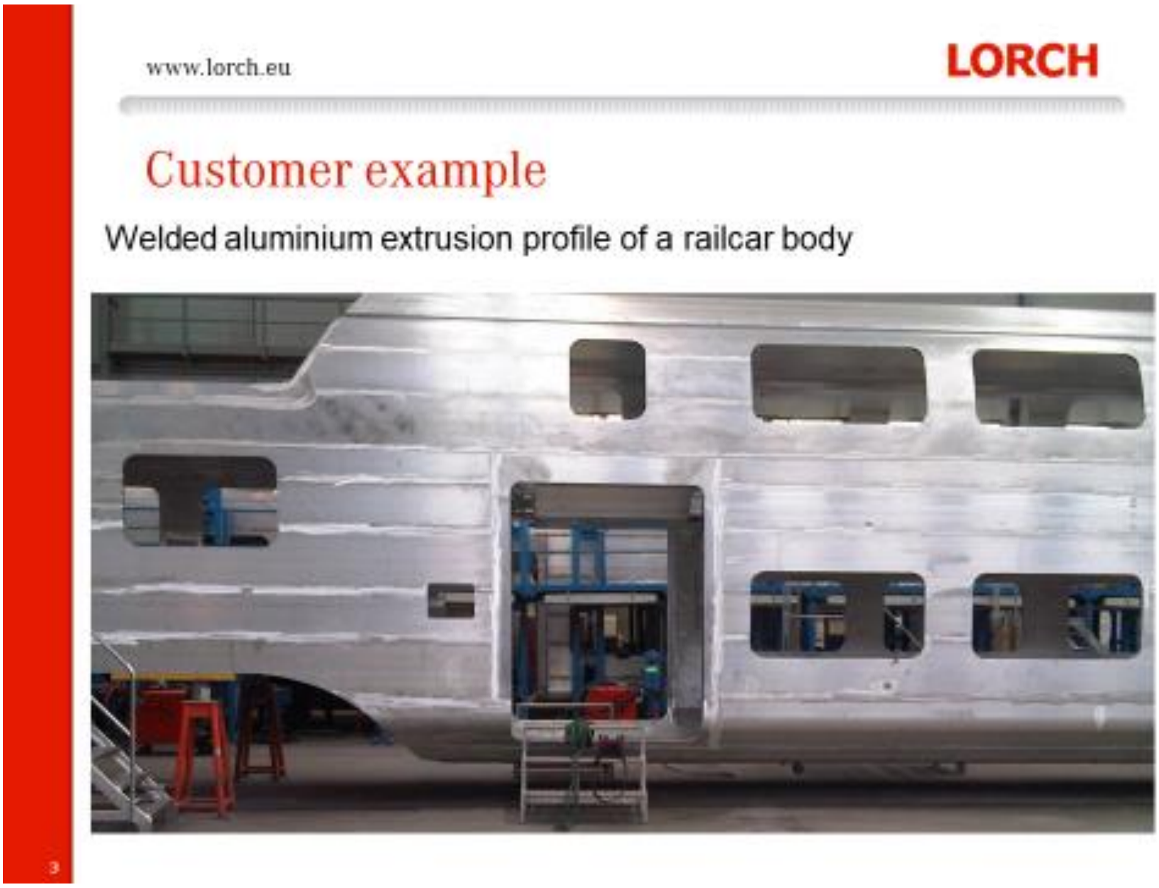
Structure

- Examples of welding constructions of precipitation hardening Aluminium in railway industry
- The advantages of the SpeedPulse process when welding AW 6082 T6
- The base material AW 6082 T6
- The filler metal AlMg4,5Mn
- The weld joint
- Objectives of the investigation
- Method of resolution
- Results
- Conclusions



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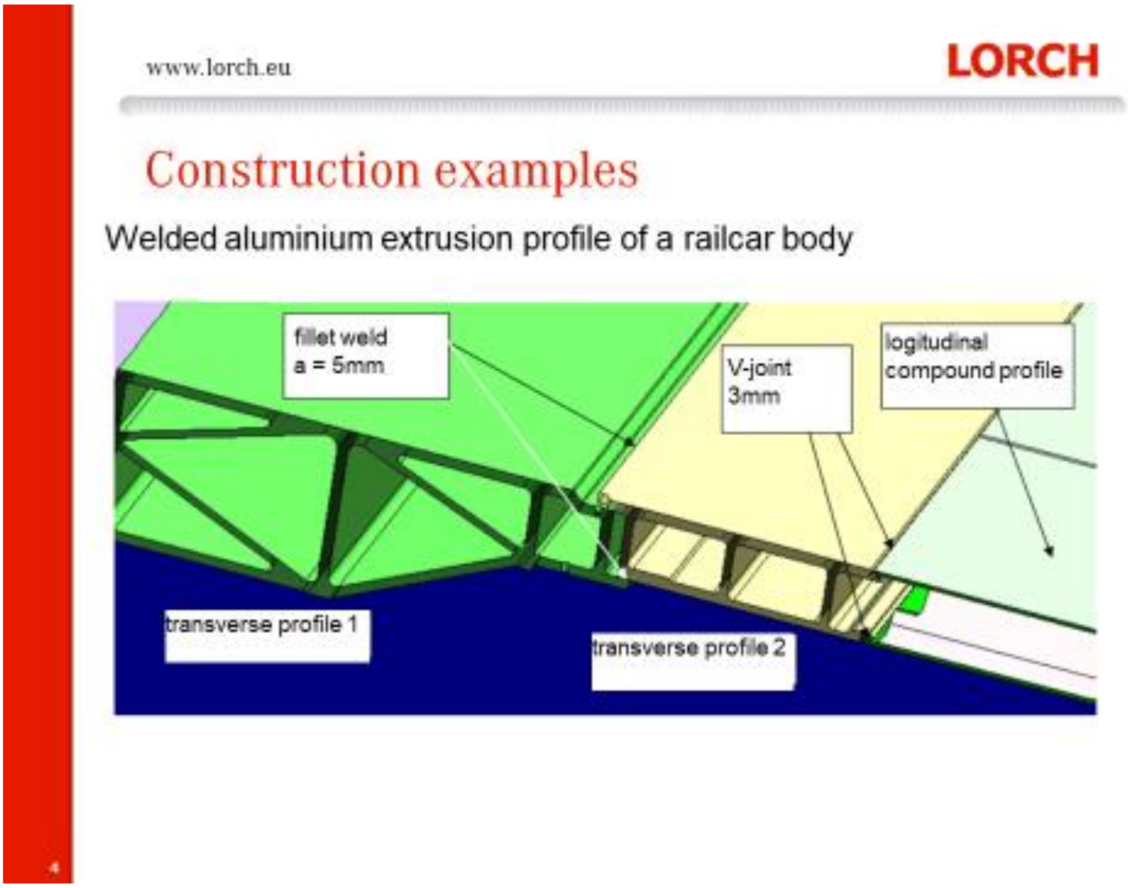
Customer example

Welded aluminium extrusion profile of a railcar body



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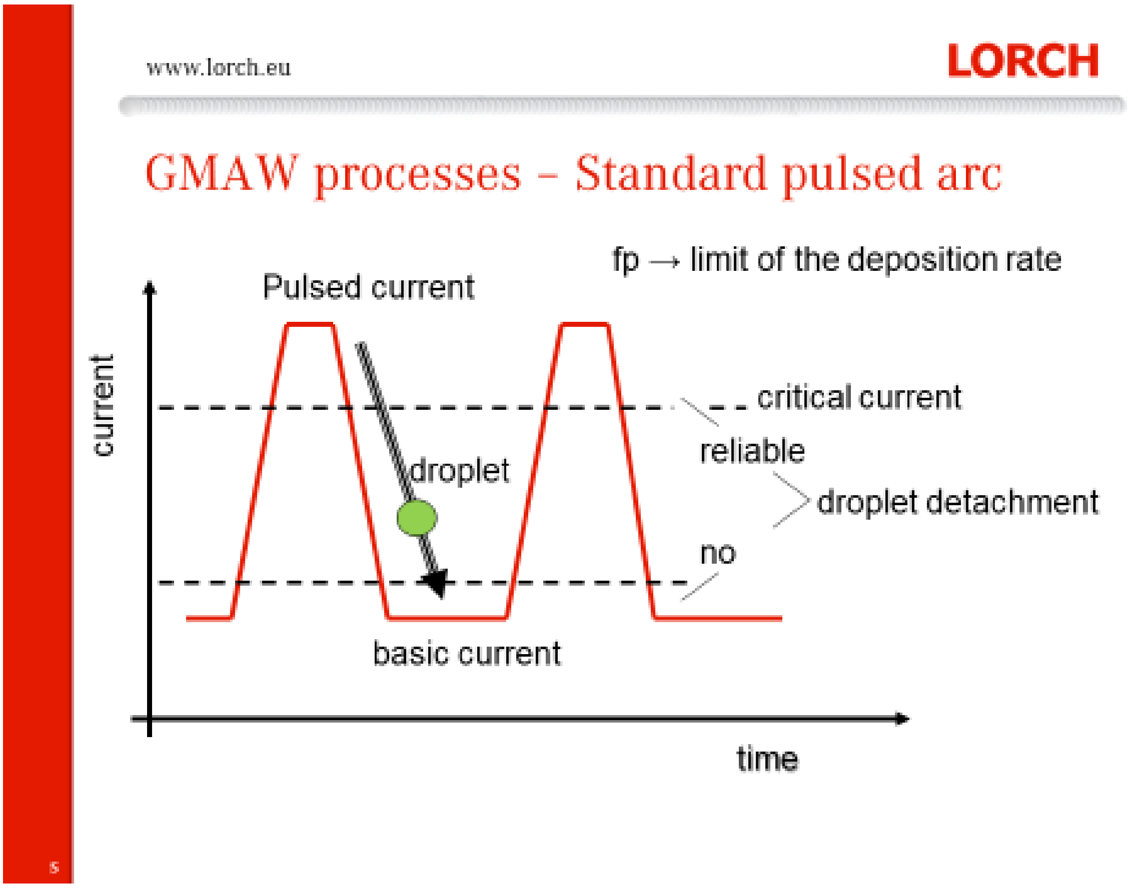
Construction examples

Welded aluminium extrusion profile of a railcar body



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GMAW processes – Standard pulsed arc

fp → limit of the deposition rate

Pulsed current

current

critical current

droplet

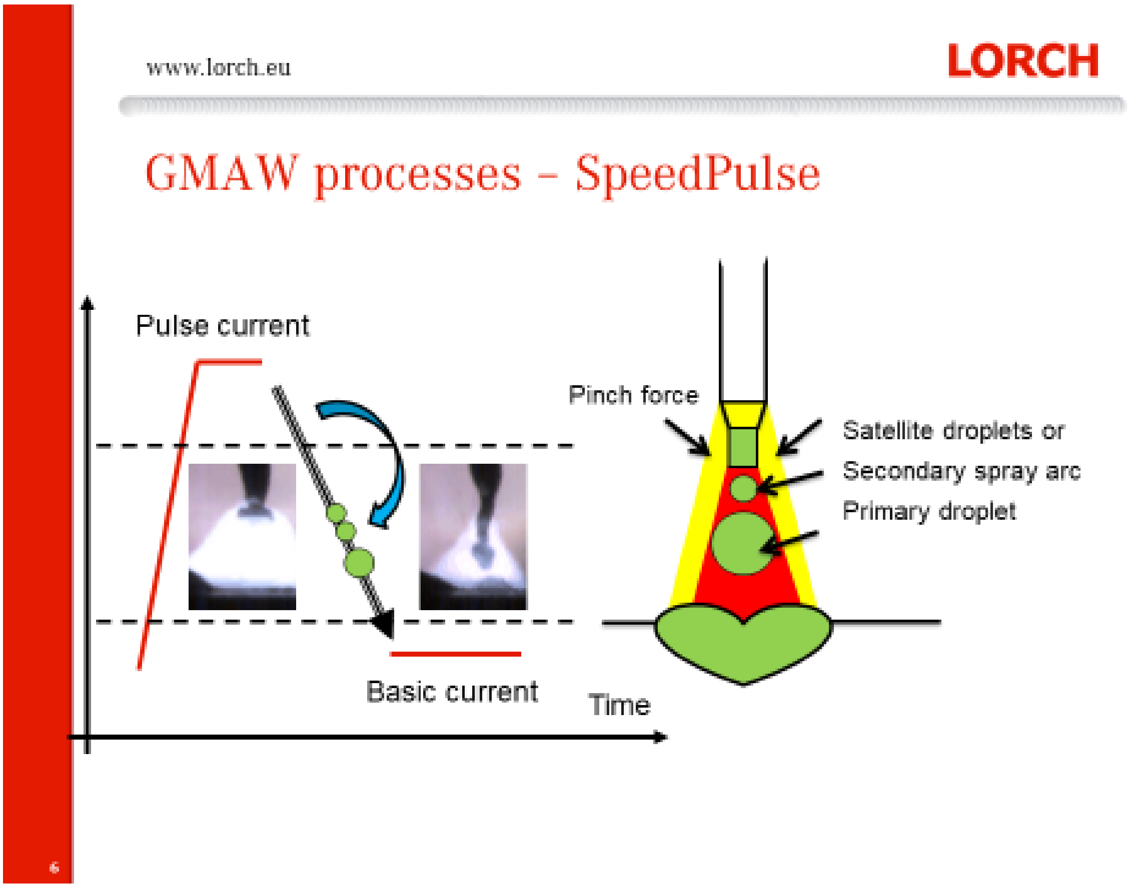
reliable

droplet detachment

no

basic current

time



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GMAW processes – SpeedPulse

Pulse current

Pinch force

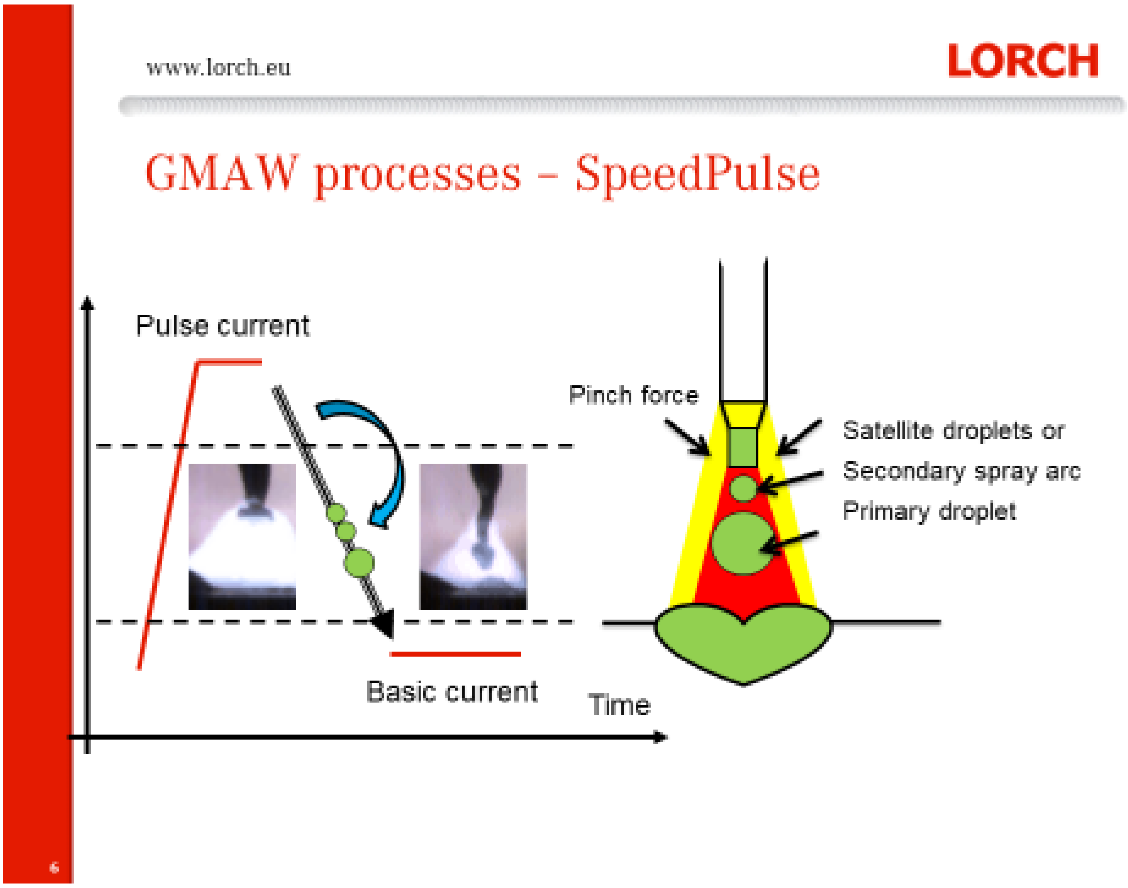
Satellite droplets or

Secondary spray arc

Primary droplet

Basic current

Time



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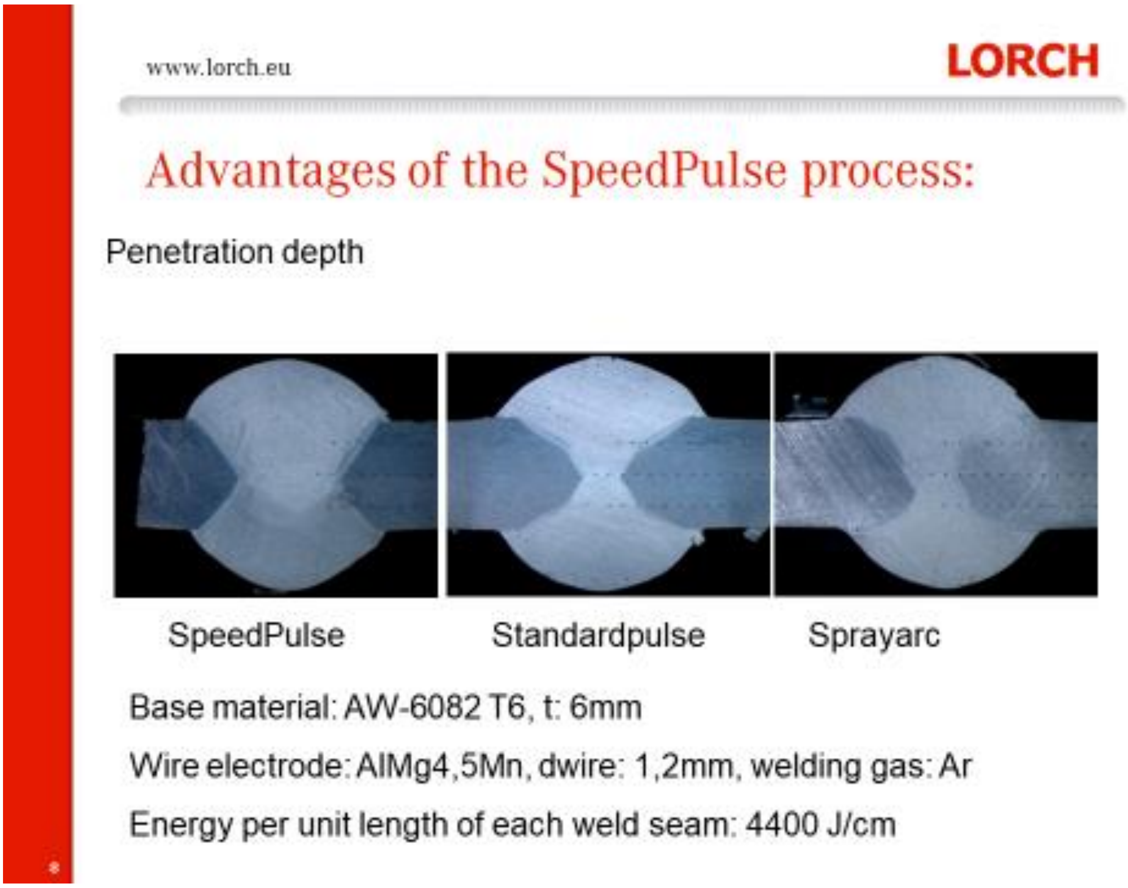

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Advantages of the SpeedPulse process:

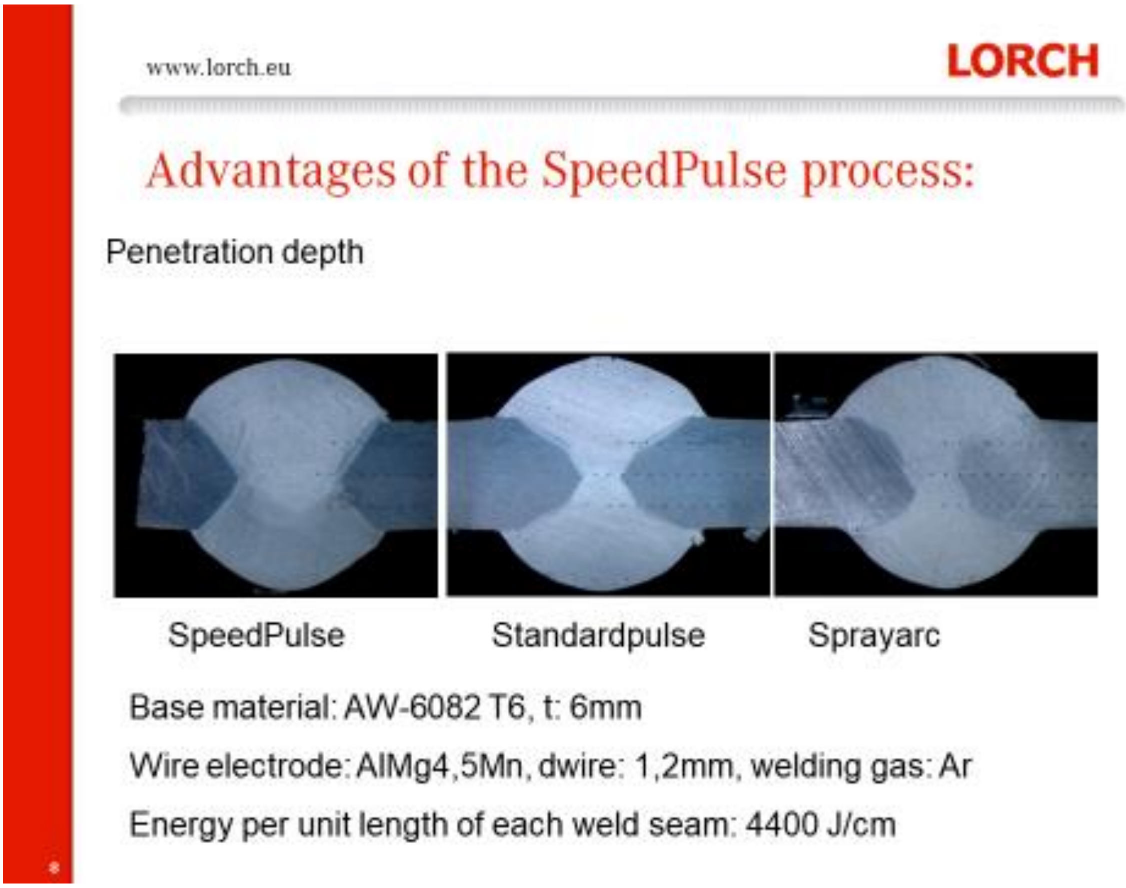
Penetration depth

SpeedPulse Standardpulse Sprayarc

Base material: AW-6082 T6, t: 6mm

Wire electrode: AlMg4,5Mn, dwire: 1,2mm, welding gas: Ar

Energy per unit length of each weld seam: 4400 J/cm



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Advantages of the SpeedPulse process:

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SpeedPulse | Standardpulse | Sprayarc

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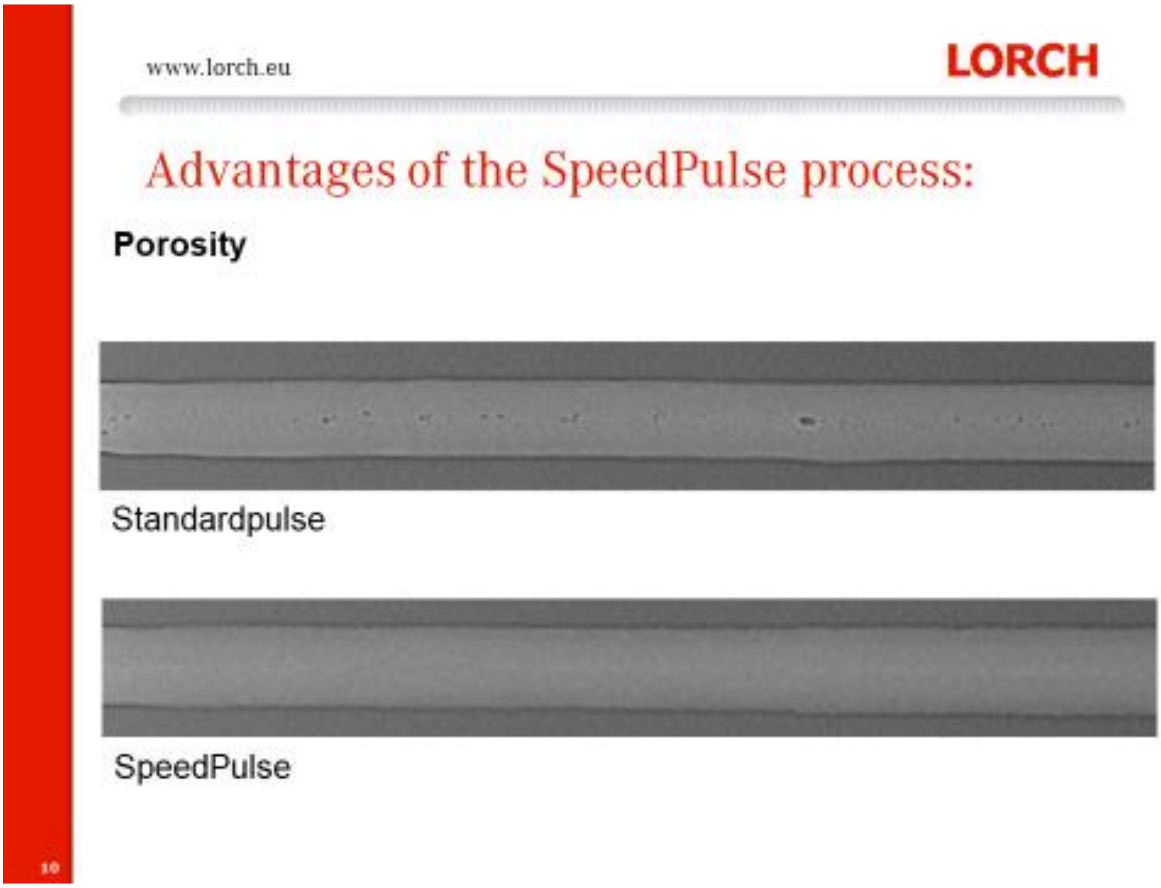
Advantages of the SpeedPulse process:

Base metal: AW-6082 T6:

Welding surface and porosity

Standardpulse with several pores

SpeedPulse without pores



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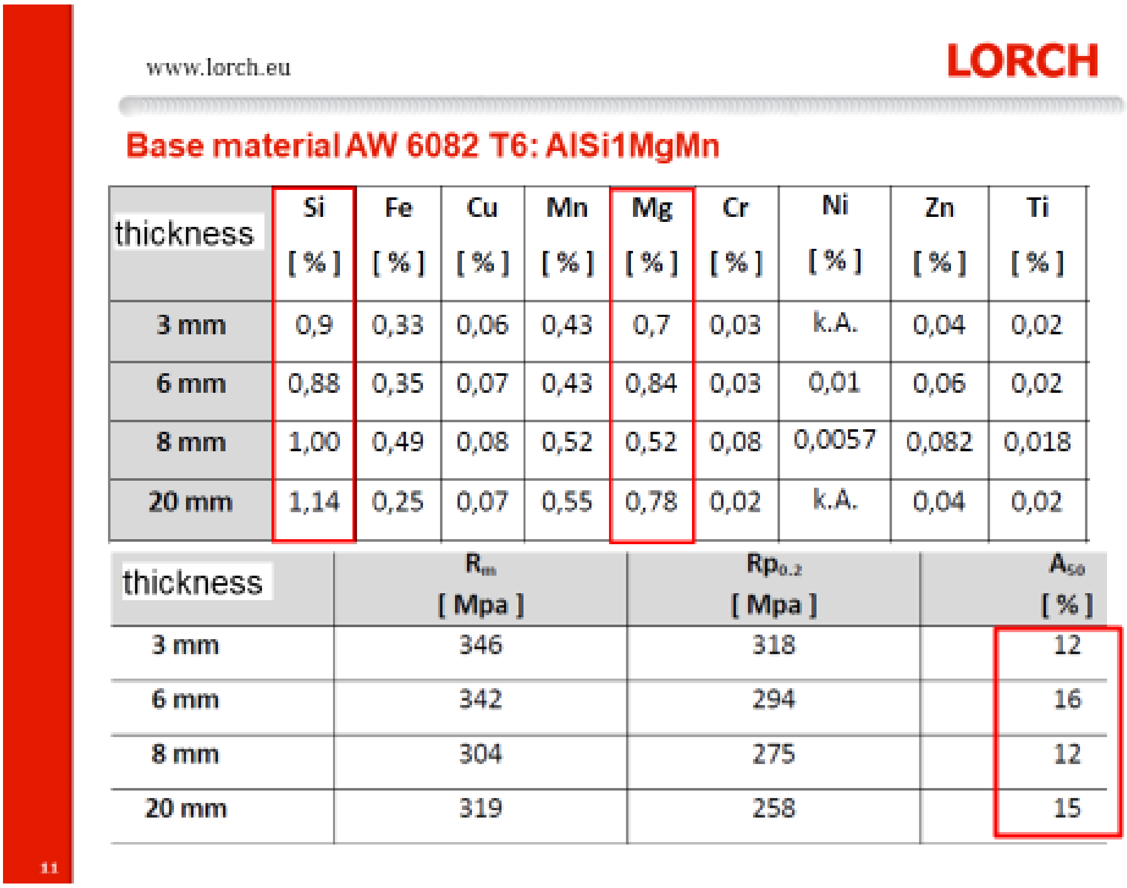
Advantages of the SpeedPulse process:

Porosity

Standardpulse

SpeedPulse



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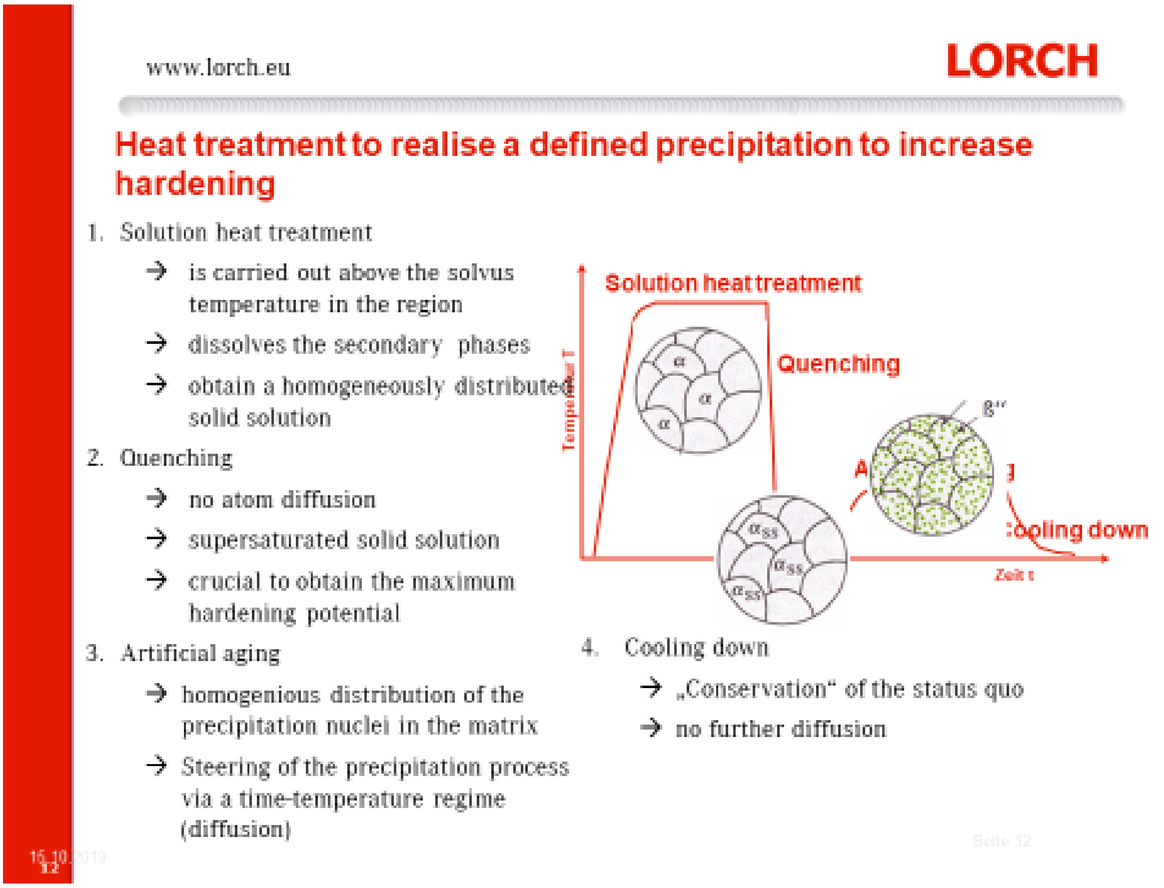
Base material AW 6082 T6: AlSi1MgMn

thickness	Si [%]	Fe [%]	Cu [%]	Mn [%]	Mg [%]	Cr [%]	Ni [%]	Zn [%]	Ti [%]
3 mm	0,9	0,33	0,06	0,43	0,7	0,03	k.A.	0,04	0,02
6 mm	0,88	0,35	0,07	0,43	0,84	0,03	0,01	0,06	0,02
8 mm	1,00	0,49	0,08	0,52	0,52	0,08	0,0057	0,082	0,018
20 mm	1,14	0,25	0,07	0,55	0,78	0,02	k.A.	0,04	0,02

thickness	R_m [Mpa]	$Rp_{0.2}$ [Mpa]	A_{50} [%]
3 mm	346	318	12
6 mm	342	294	16
8 mm	304	275	12
20 mm	319	258	15



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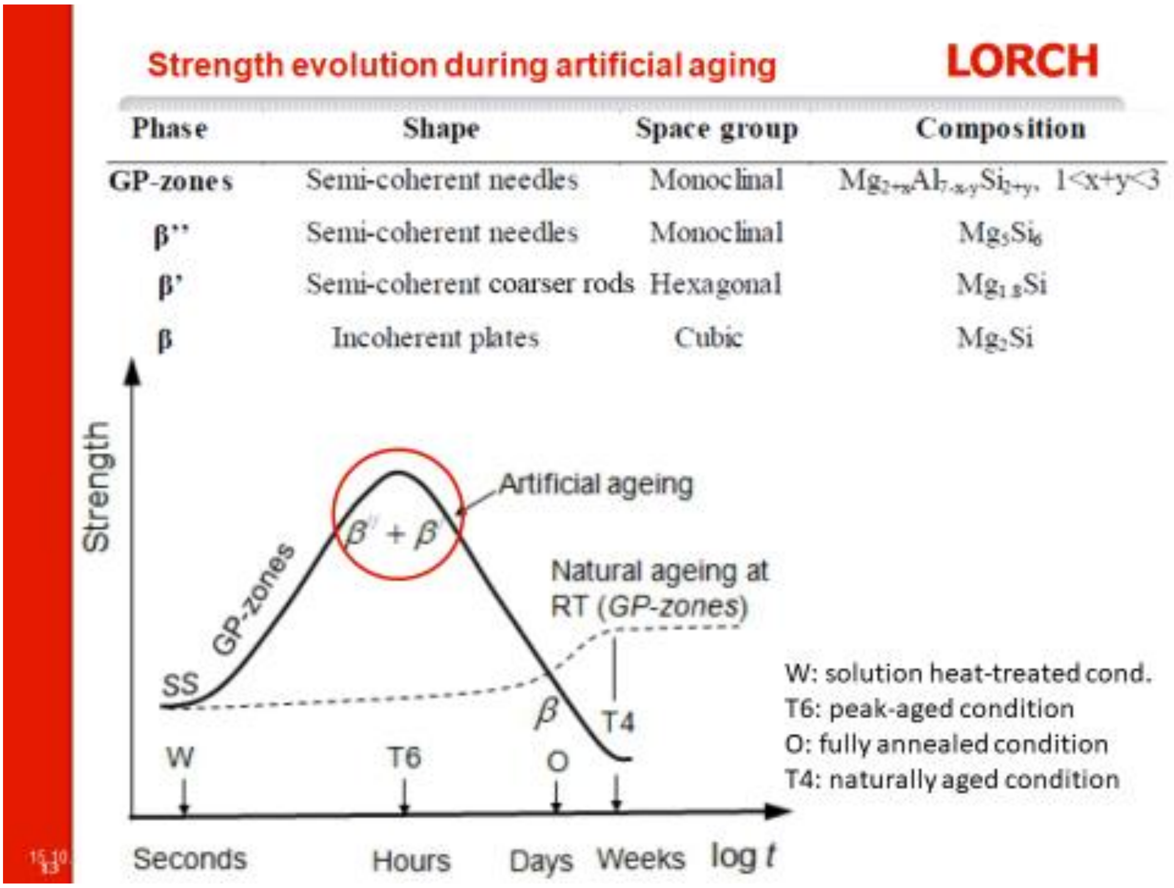
Heat treatment to realise a defined precipitation to increase hardening

1. Solution heat treatment
   - → is carried out above the solvus temperature in the region
   - → dissolves the secondary phases
   - → obtain a homogeneously distributed solid solution
2. Quenching
   - → no atom diffusion
   - → supersaturated solid solution
   - → crucial to obtain the maximum hardening potential
3. Artificial aging
   - → homogenious distribution of the precipitation nuclei in the matrix
   - → Steering of the precipitation process via a time-temperature regime (diffusion)
4. Cooling down
   - → „Conservation“ of the status quo
   - → no further diffusion



Strength evolution during artificial aging

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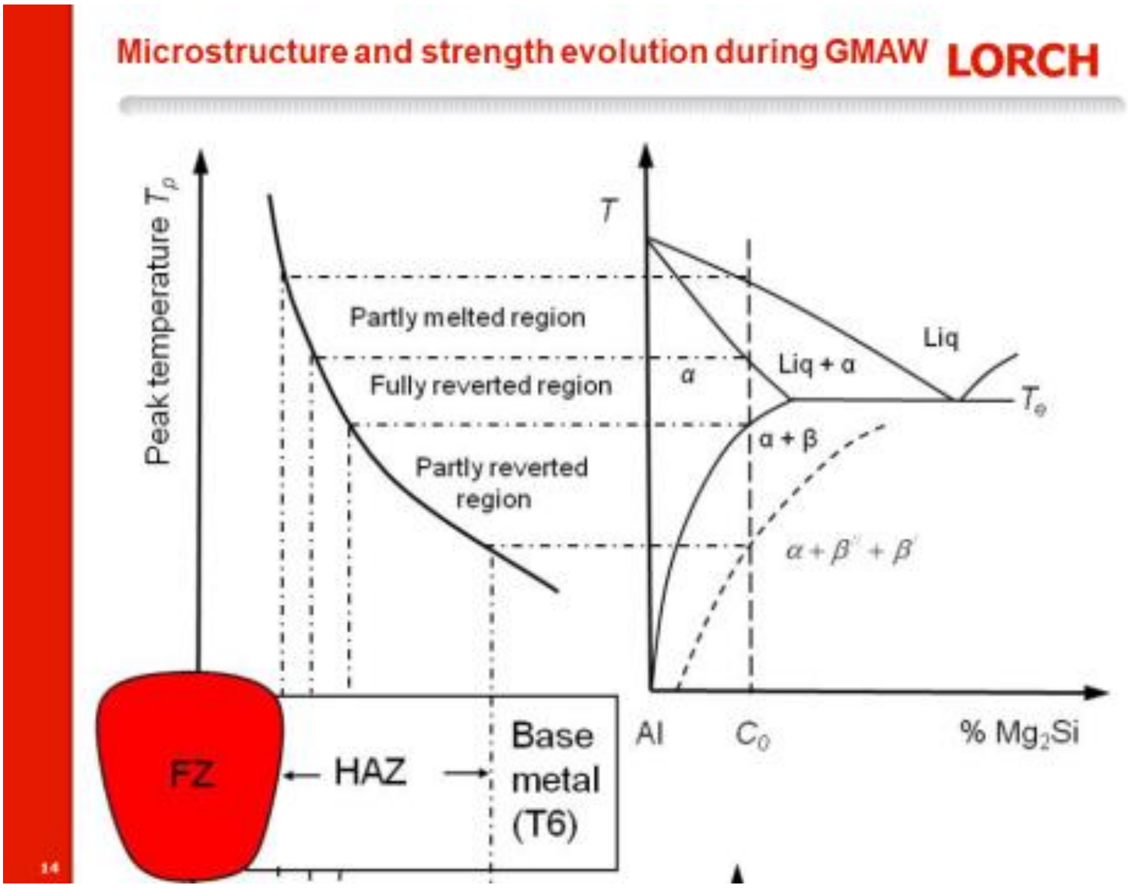
Phase	Shape	Space group	Composition
GP-zones	Semi-coherent needles	Monoclinal	$Mg_{2+x}Al_{7-x-y}Si_{2+y}$, 1<x+y<3
β''	Semi-coherent needles	Monoclinal	Mg_5Si_6
β'	Semi-coherent coarser rods	Hexagonal	$Mg_{1.8}Si$
β	Incoherent plates	Cubic	Mg_2Si

W: solution heat-treated cond.
T6: peak-aged condition
O: fully annealed condition
T4: naturally aged condition



Microstructure and strength evolution during GMAW

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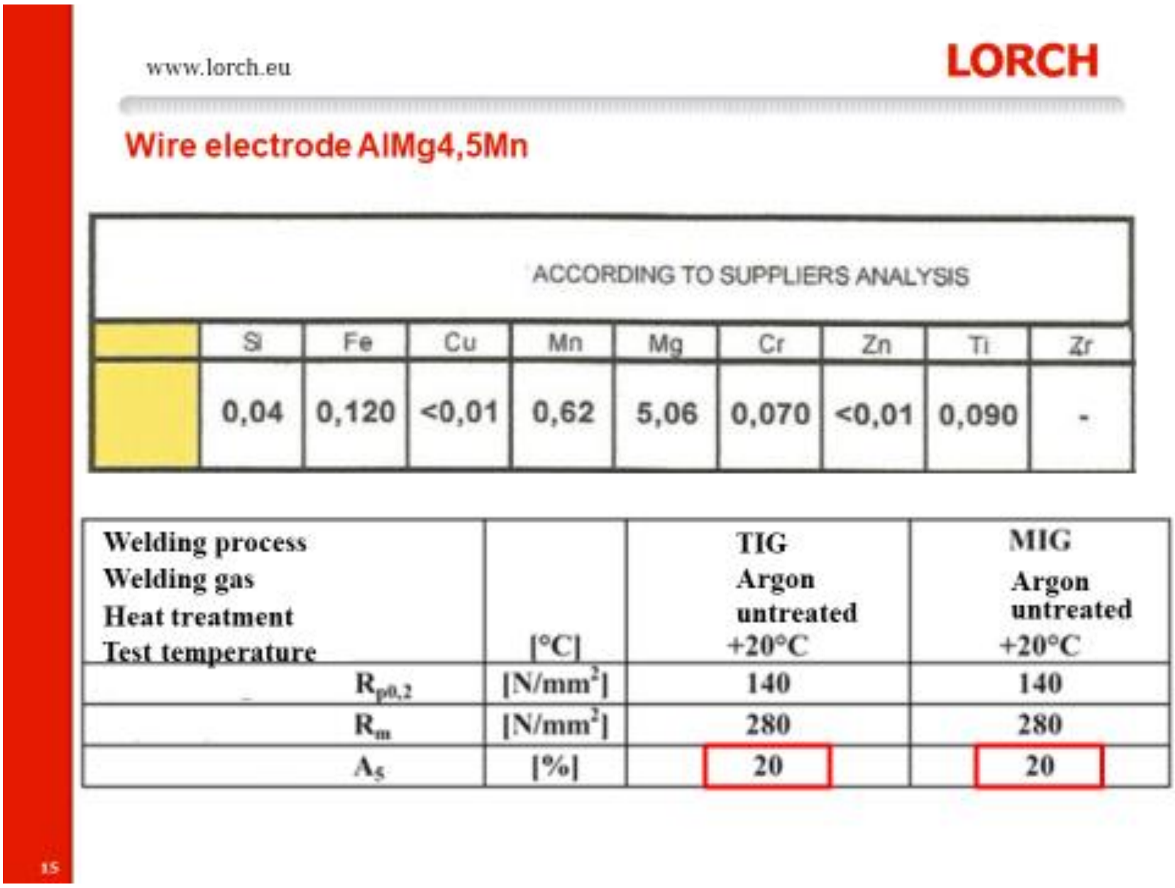

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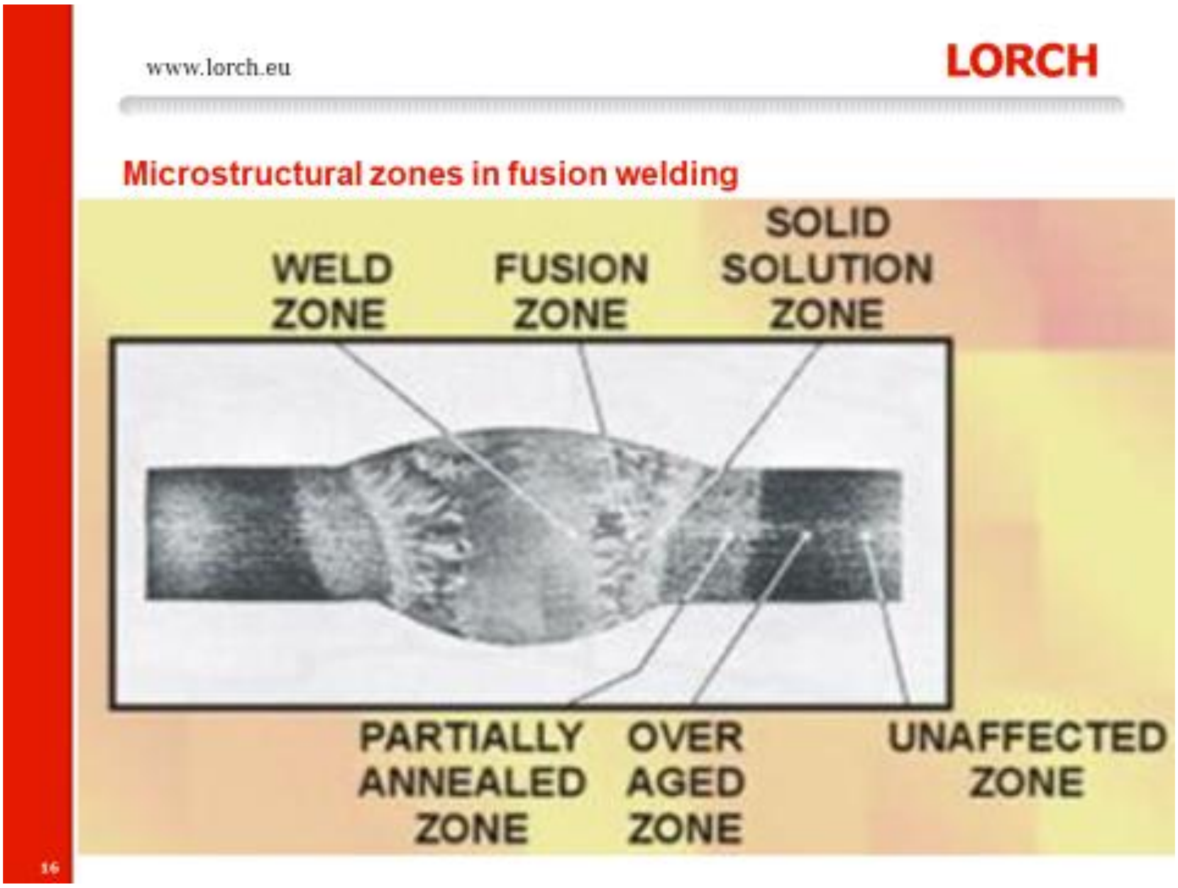
Wire electrode AlMg4,5Mn

ACCORDING TO SUPPLIERS ANALYSIS									
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
	0,04	0,120	<0,01	0,62	5,06	0,070	<0,01	0,090	-

Welding process **Welding gas** **Heat treatment** **Test temperature**	**[°C]**	**TIG** **Argon** **untreated** **+20°C**	**MIG** **Argon** **untreated** **+20°C**
$R_{p0,2}$	[N/mm^2]	140	140
R_m	[N/mm^2]	280	280
A_5	[%]	20	20



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Microstructural zones in fusion welding

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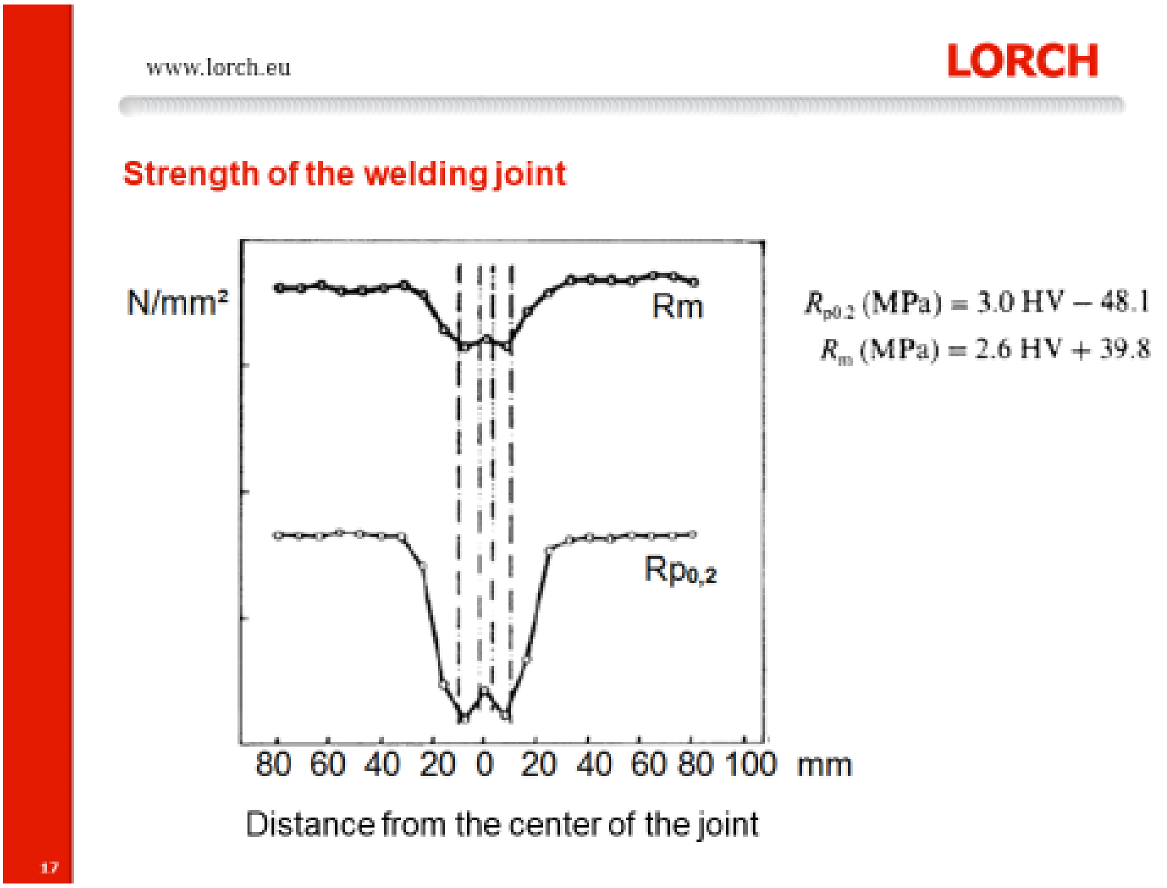

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Strength of the welding joint

$$R_{p0.2}\,(\mathrm{MPa}) = 3.0\,\mathrm{HV} - 48.1$$

$$R_m\,(\mathrm{MPa}) = 2.6\,\mathrm{HV} + 39.8$$

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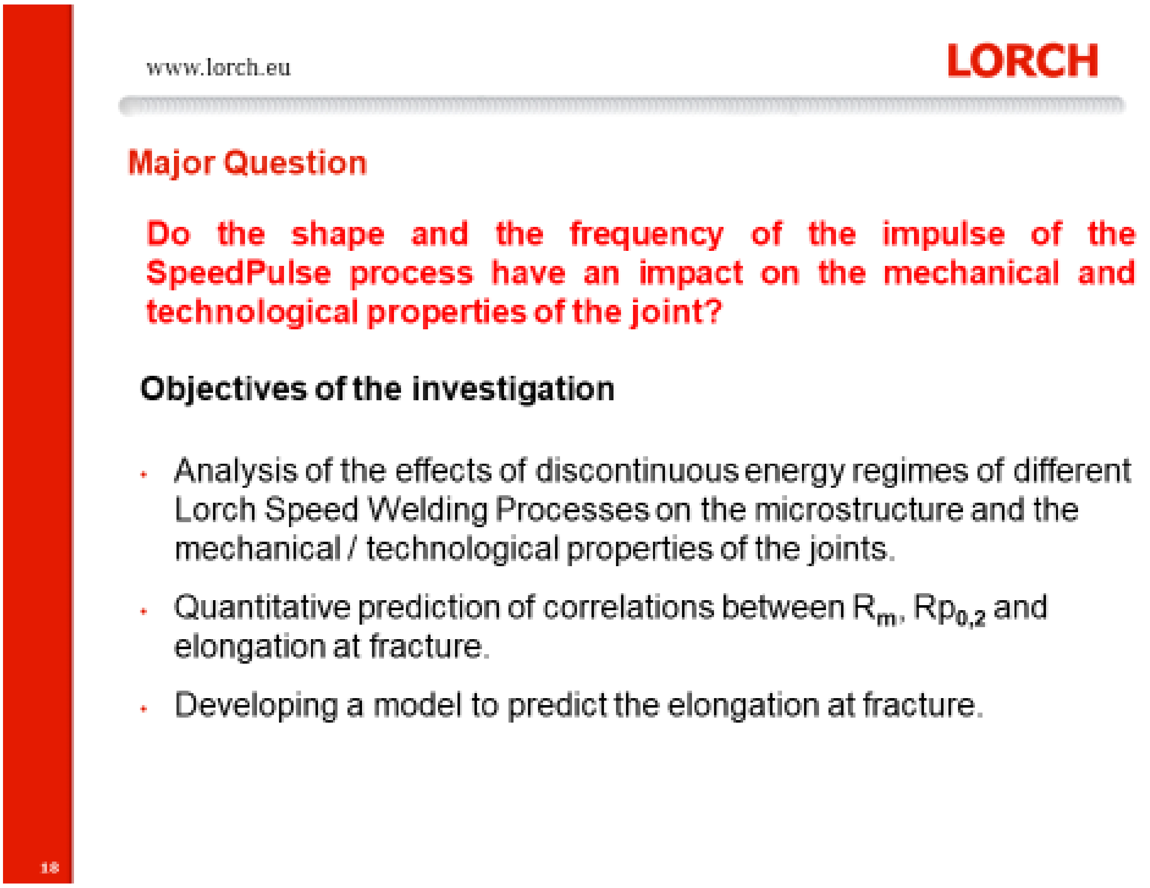

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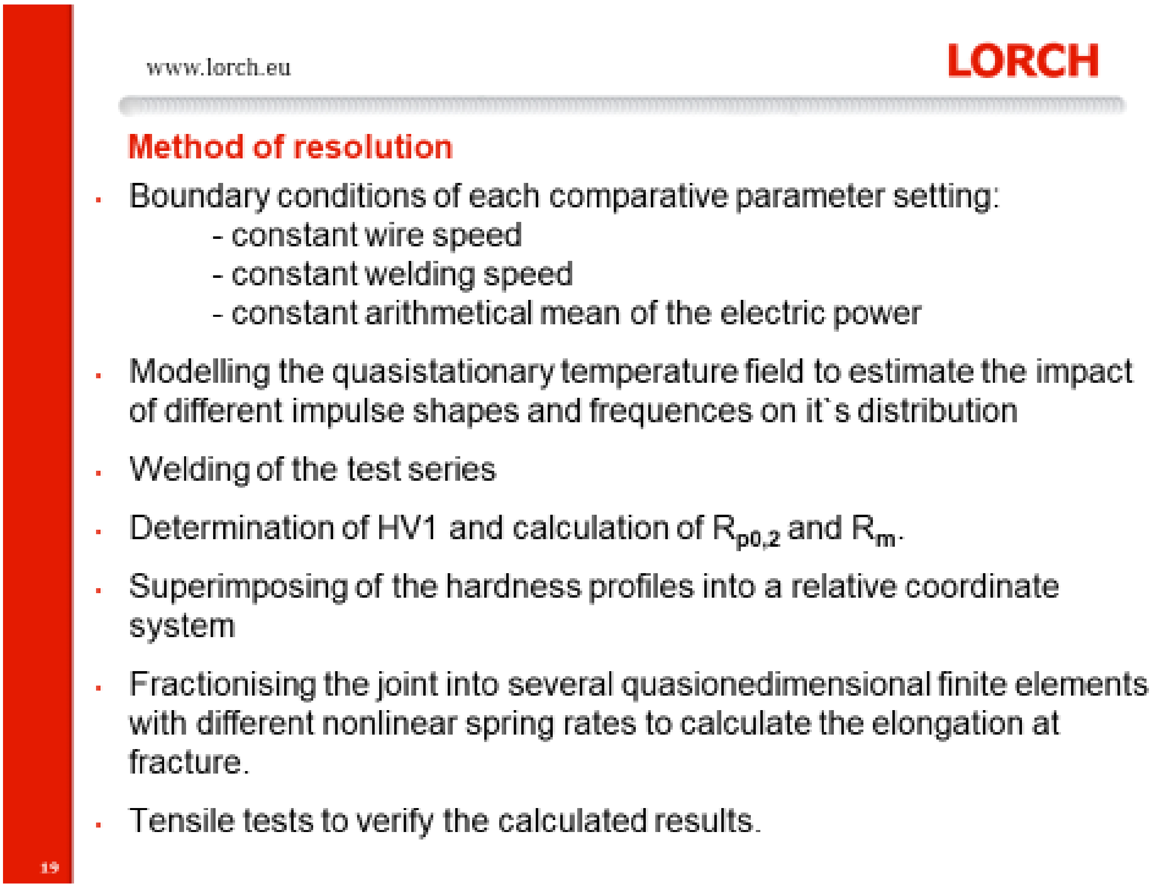
Major Question

Do the shape and the frequency of the impulse of the SpeedPulse process have an impact on the mechanical and technological properties of the joint?

Objectives of the investigation

- Analysis of the effects of discontinuous energy regimes of different Lorch Speed Welding Processes on the microstructure and the mechanical / technological properties of the joints.
- Quantitative prediction of correlations between R_m, $Rp_{0,2}$ and elongation at fracture.
- Developing a model to predict the elongation at fracture.



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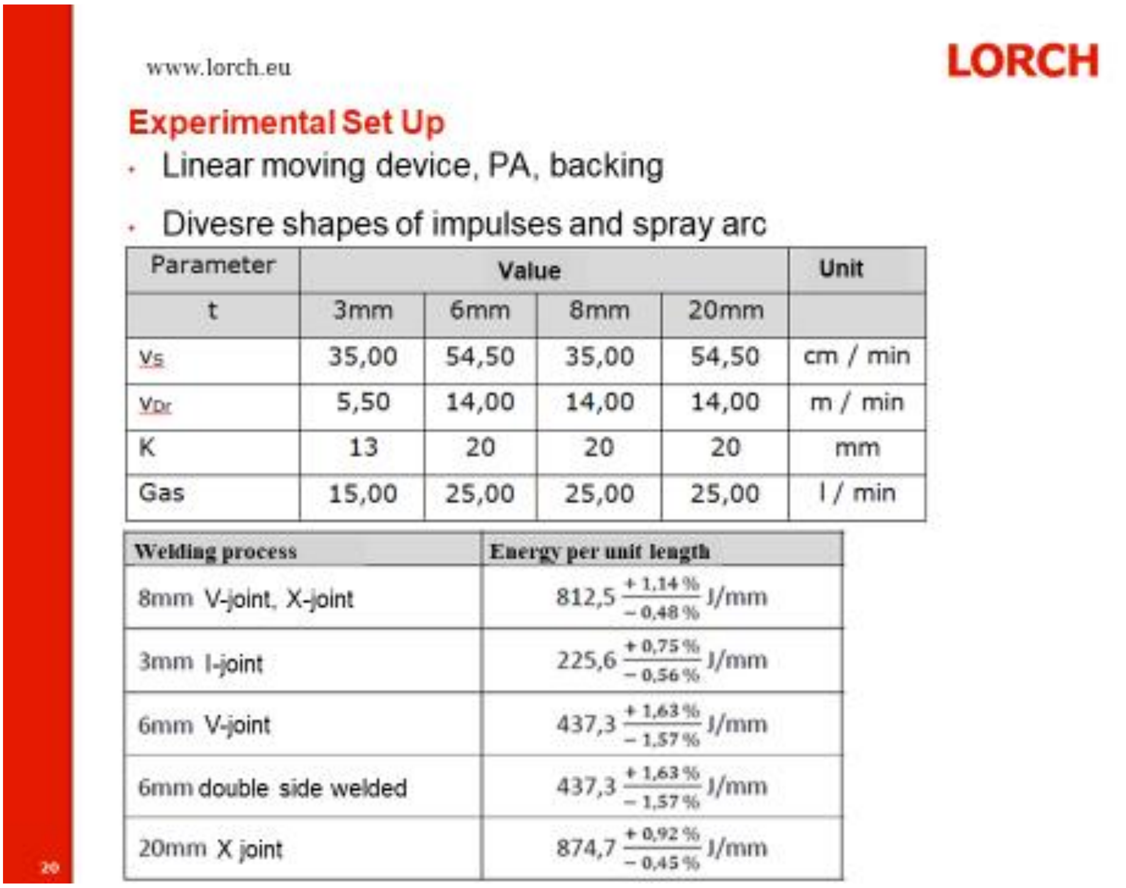
Method of resolution

- Boundary conditions of each comparative parameter setting:
  - constant wire speed
  - constant welding speed
  - constant arithmetical mean of the electric power
- Modelling the quasistationary temperature field to estimate the impact of different impulse shapes and frequences on it`s distribution
- Welding of the test series
- Determination of HV1 and calculation of $R_{p0,2}$ and R_m.
- Superimposing of the hardness profiles into a relative coordinate system
- Fractionising the joint into several quasionedimensional finite elements with different nonlinear spring rates to calculate the elongation at fracture.
- Tensile tests to verify the calculated results.



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Experimental Set Up

- Linear moving device, PA, backing
- Divesre shapes of impulses and spray arc

Parameter	Value				Unit
t	3mm	6mm	8mm	20mm	
V_S	35,00	54,50	35,00	54,50	cm / min
V_{Dr}	5,50	14,00	14,00	14,00	m / min
K	13	20	20	20	mm
Gas	15,00	25,00	25,00	25,00	l / min

Welding process	Energy per unit length
8mm V-joint, X-joint	$812{,}5\,\frac{+1{,}14\,\%}{-0{,}48\,\%}$ J/mm
3mm I-joint	$225{,}6\,\frac{+0{,}75\,\%}{-0{,}56\,\%}$ J/mm
6mm V-joint	$437{,}3\,\frac{+1{,}63\,\%}{-1{,}57\,\%}$ J/mm
6mm double side welded	$437{,}3\,\frac{+1{,}63\,\%}{-1{,}57\,\%}$ J/mm
20mm X joint	$874{,}7\,\frac{+0{,}92\,\%}{-0{,}45\,\%}$ J/mm

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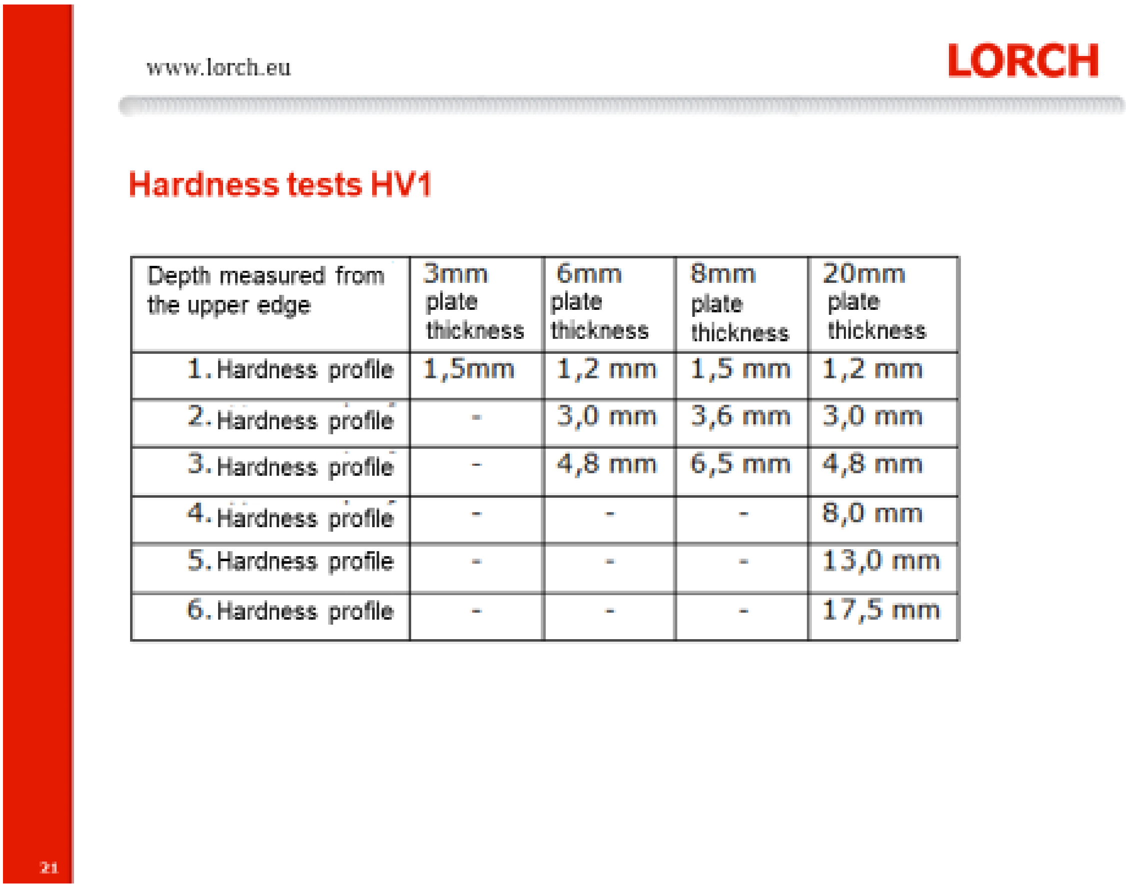

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Hardness tests HV1

Depth measured from the upper edge	3mm plate thickness	6mm plate thickness	8mm plate thickness	20mm plate thickness
1. Hardness profile	1,5mm	1,2 mm	1,5 mm	1,2 mm
2. Hardness profile	-	3,0 mm	3,6 mm	3,0 mm
3. Hardness profile	-	4,8 mm	6,5 mm	4,8 mm
4. Hardness profile	-	-	-	8,0 mm
5. Hardness profile	-	-	-	13,0 mm
6. Hardness profile	-	-	-	17,5 mm

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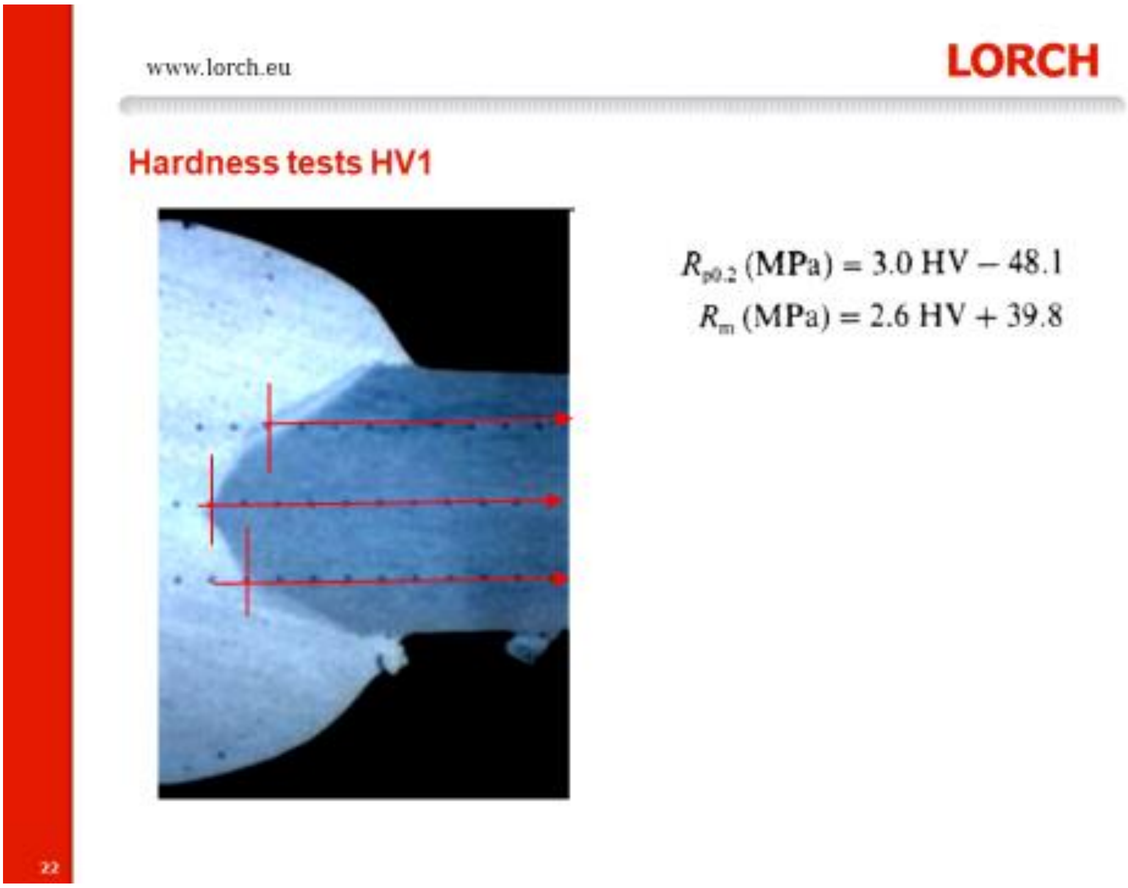

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Hardness tests HV1

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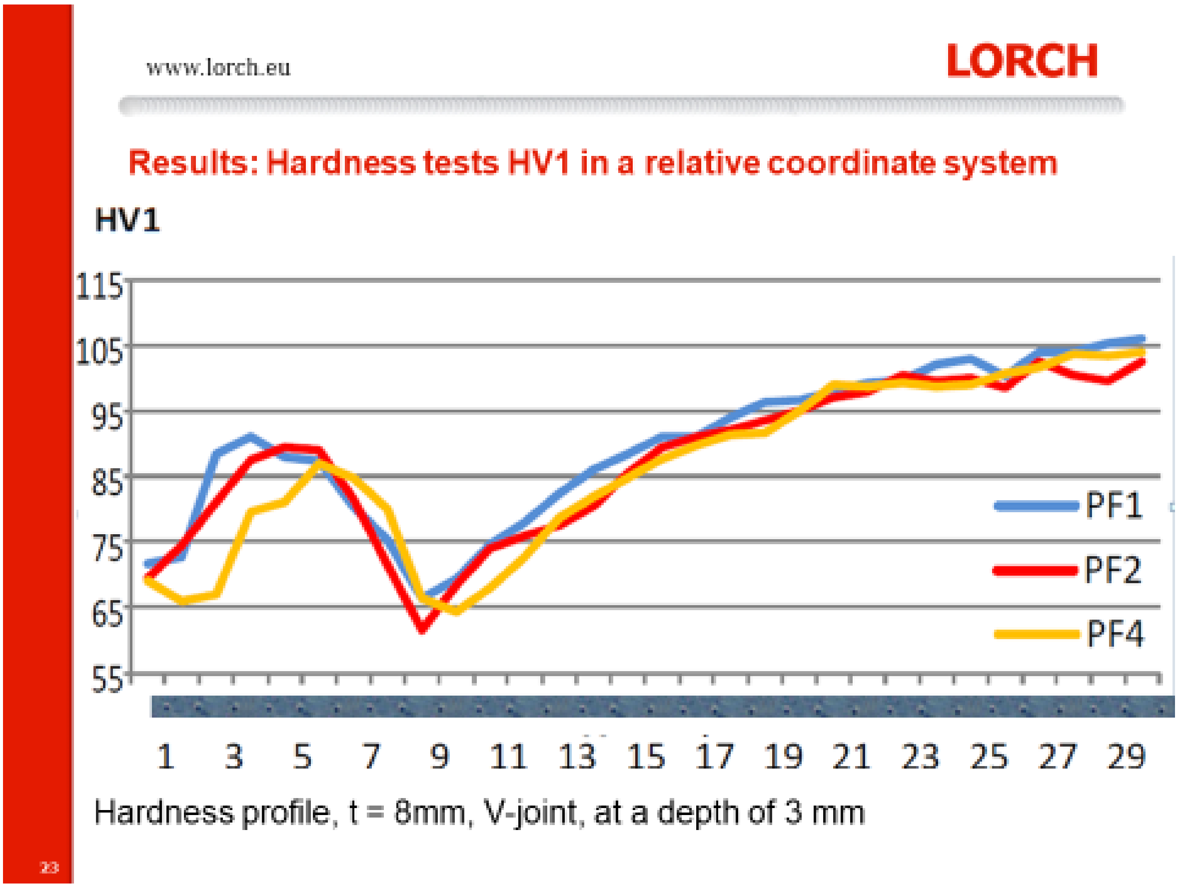

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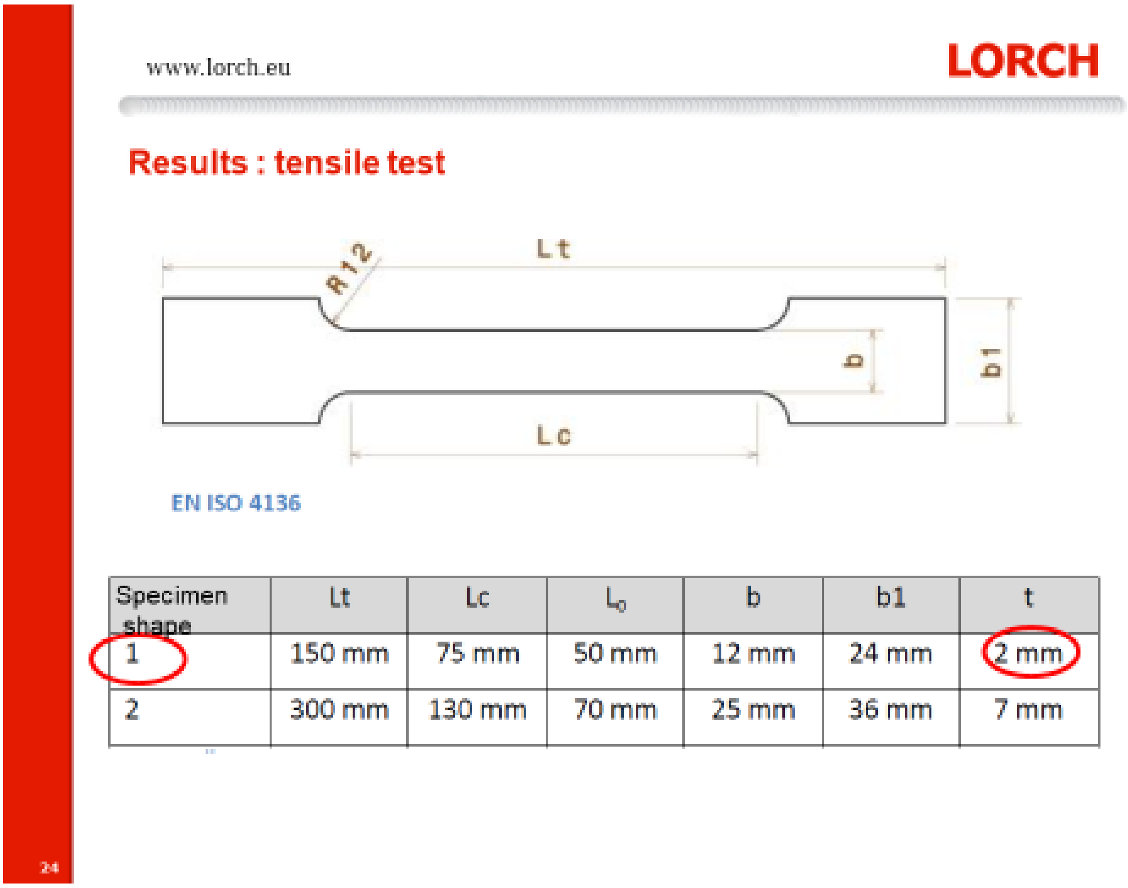
Results: Hardness tests HV1 in a relative coordinate system

Hardness profile, t = 8mm, V-joint, at a depth of 3 mm



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Results : tensile test

EN ISO 4136

Specimen shape	Lt	Lc	L_0	b	b1	t
1	150 mm	75 mm	50 mm	12 mm	24 mm	2 mm
2	300 mm	130 mm	70 mm	25 mm	36 mm	7 mm

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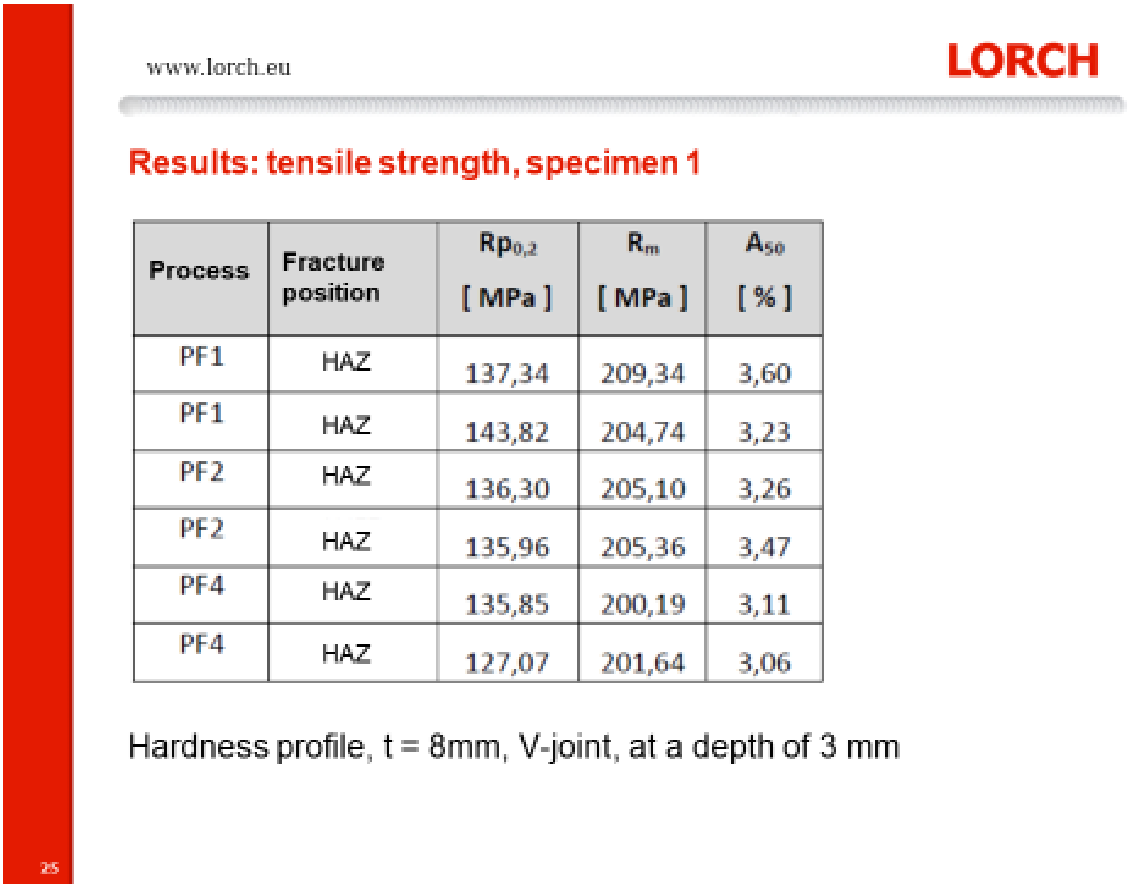

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Results: tensile strength, specimen 1

Process	Fracture position	$Rp_{0,2}$ [MPa]	R_m [MPa]	A_{50} [%]
PF1	HAZ	137,34	209,34	3,60
PF1	HAZ	143,82	204,74	3,23
PF2	HAZ	136,30	205,10	3,26
PF2	HAZ	135,96	205,36	3,47
PF4	HAZ	135,85	200,19	3,11
PF4	HAZ	127,07	201,64	3,06

Hardness profile, t = 8mm, V-joint, at a depth of 3 mm

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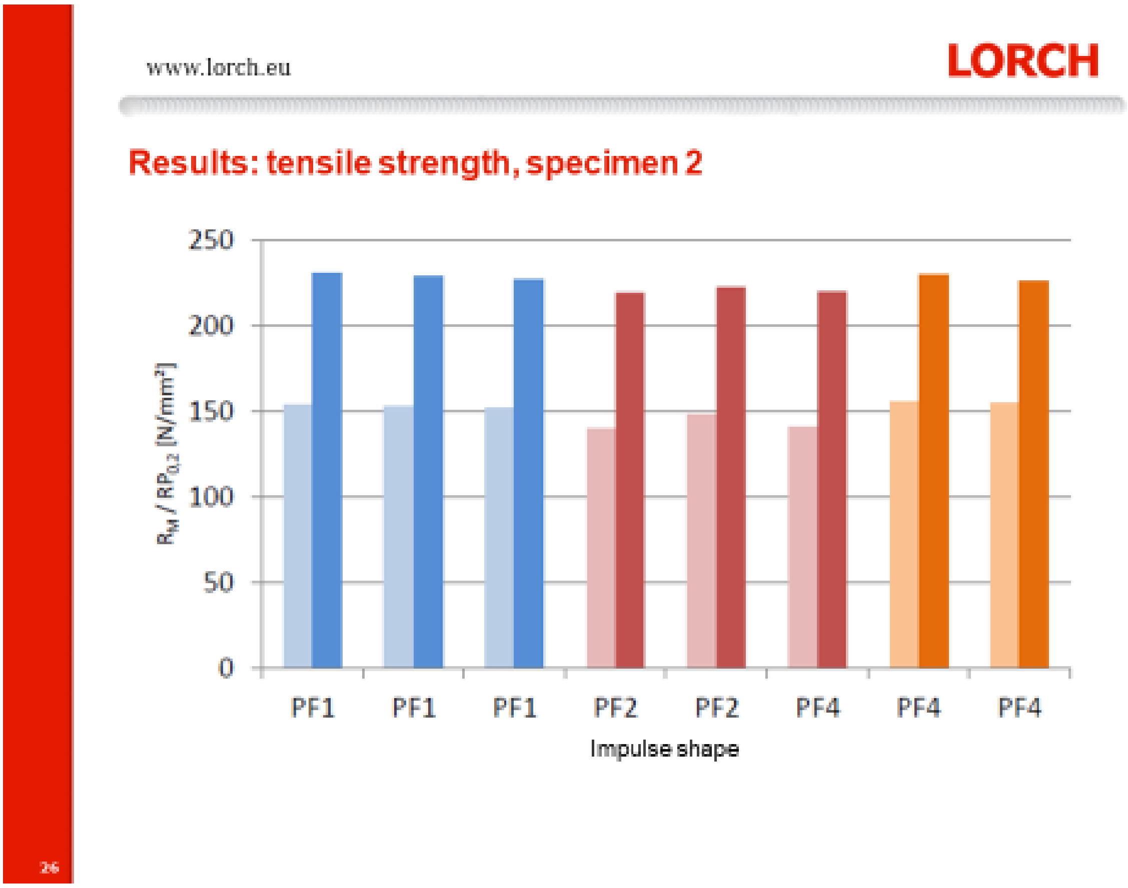

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Results: tensile strength, specimen 2

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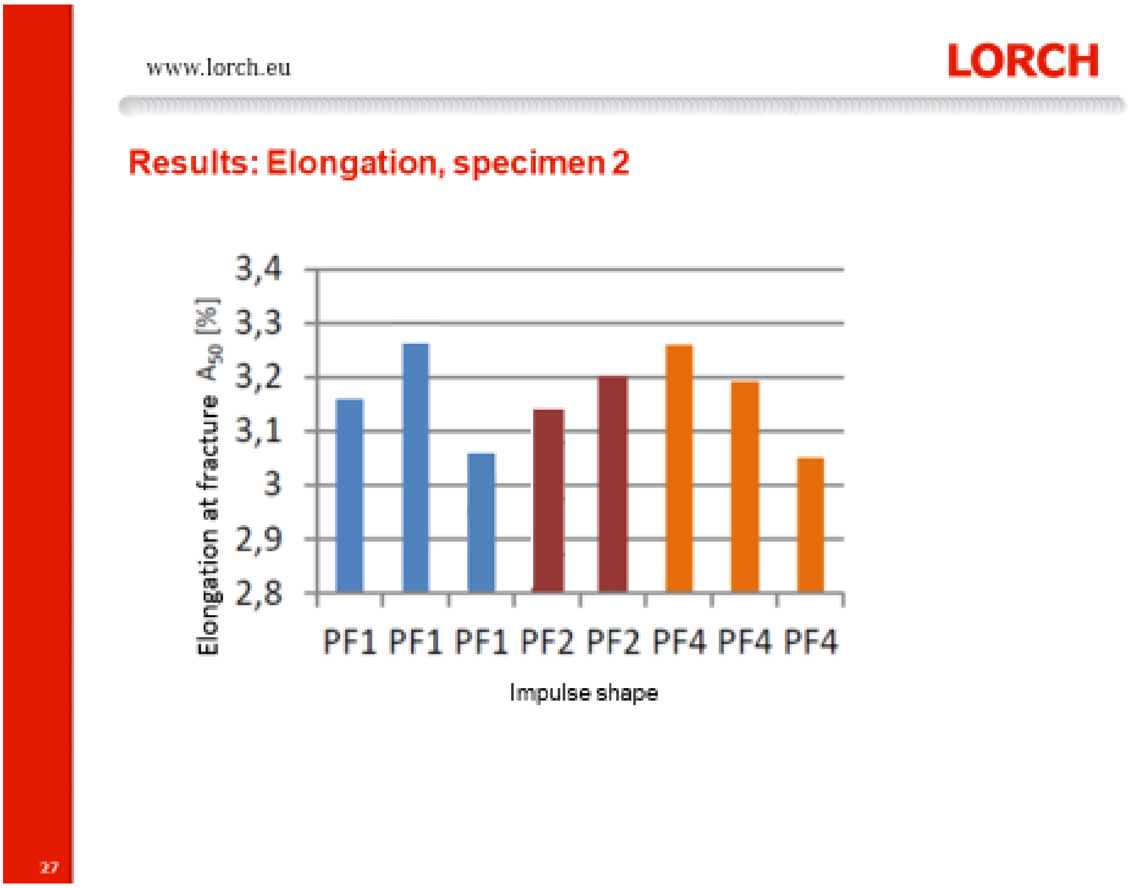

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Results: Elongation, specimen 2

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Conclusions

1. Advantages of the SpeedPulse process
   - Higher deposition rate
   - less porosity
   - deeper penetration

2. The hardness, the tensile strenght and the elongation do not significantly depend on the shape and the frequency of the impulse

3. Onedimensional modelling of the elongation at fracture is still in progress

The advantages of the SpeedPulse process can be applied without any metallurgical disadvantages.

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Thank you for your attention

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