Laser texturing to improve the mechanical strength of steel to aluminium dissimilar joints

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Outline

- Goal and objectives
- Introduction
- Methodology
- Results
- Conclusions

Goal & Objectives

- Goal

Increase the maximum tensile shear load of laser dissimilar spot welds of steel (Fe) to aluminium (Al).

- Objectives

Investigate how different textures at the steel surface can influence the IMC (Intermetallic compound) formation and mechanical properties of dissimilar laser spot welds of Fe to Al.

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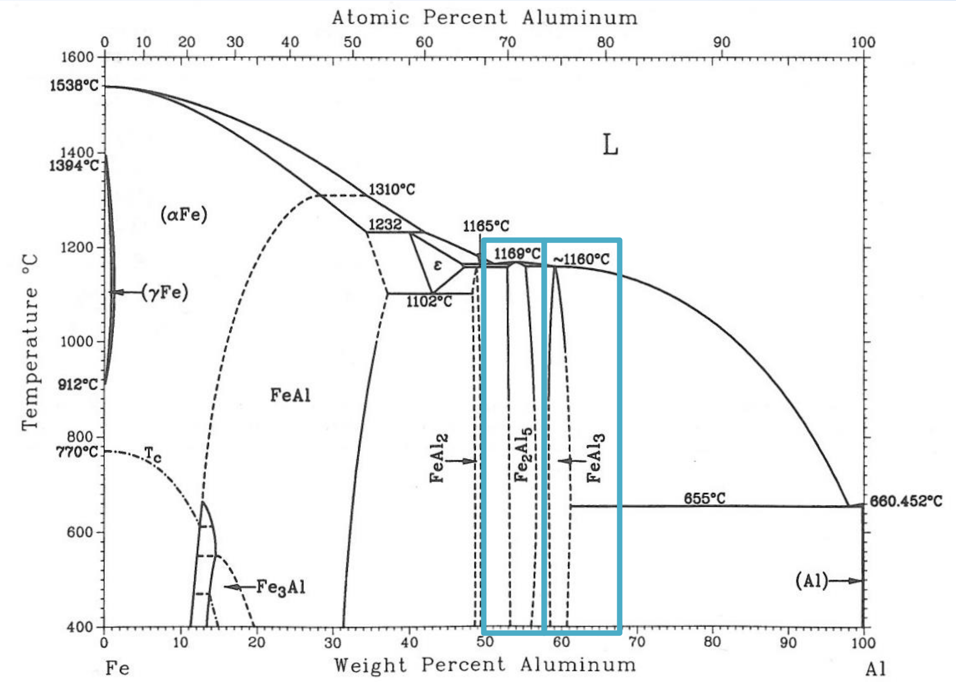
Introduction

Fe – Al dissimilar joints:

Fe and Al are metallurgically highly dissimilar and form brittle IMC (intermetallic compounds) when fused together.

The IMC formation in controlled by reaction/diffusion of both metal with each other.

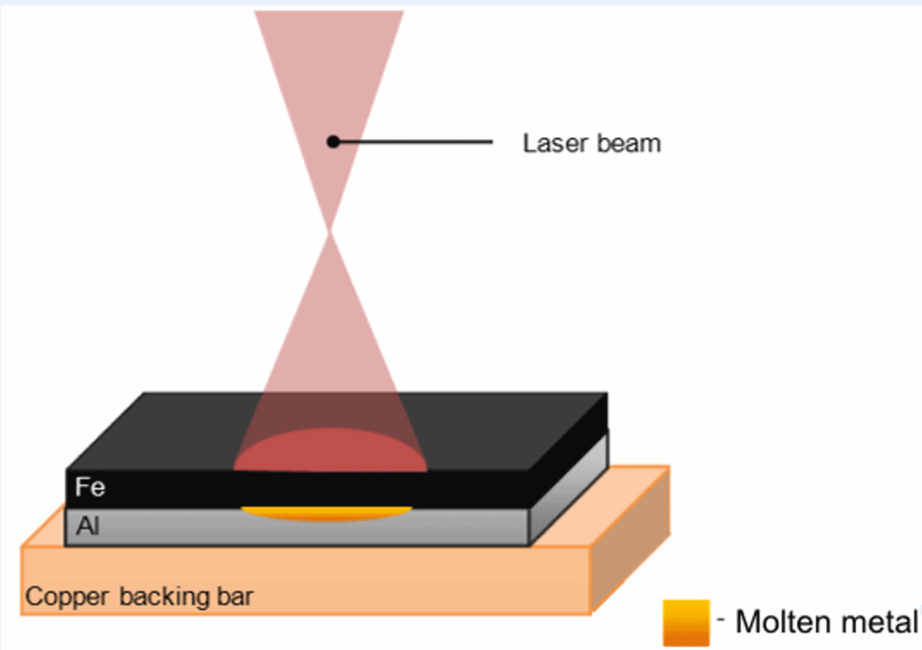
However this metallic combination is very desirable for the automotive industry in particular



IMC	Micro Hardness (HV)
Fe_2Al_5	1000-1100
$FeAl_3$	820-980

Introduction (cont.)

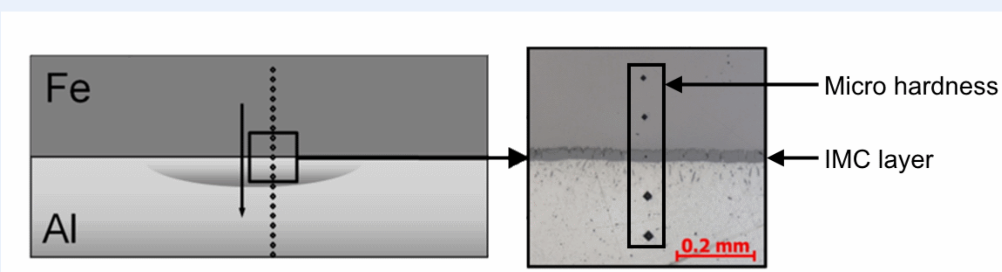
To decrease the diffusion/reaction laser spot welding in conduction mode was used.



The laser is used in conduction mode to melt the Al while the Fe remains in the solid state.

Liquid Al to solid Fe interface.

Spot welding was chosen because it is already applied by the automotive industry.



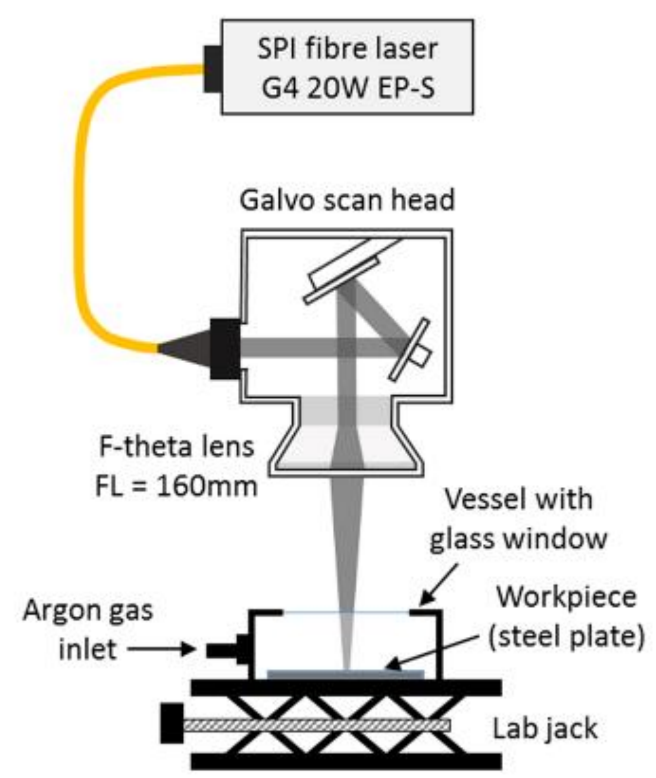
Typical IMC formation for Fe-Al laser spot welding.

Methodology

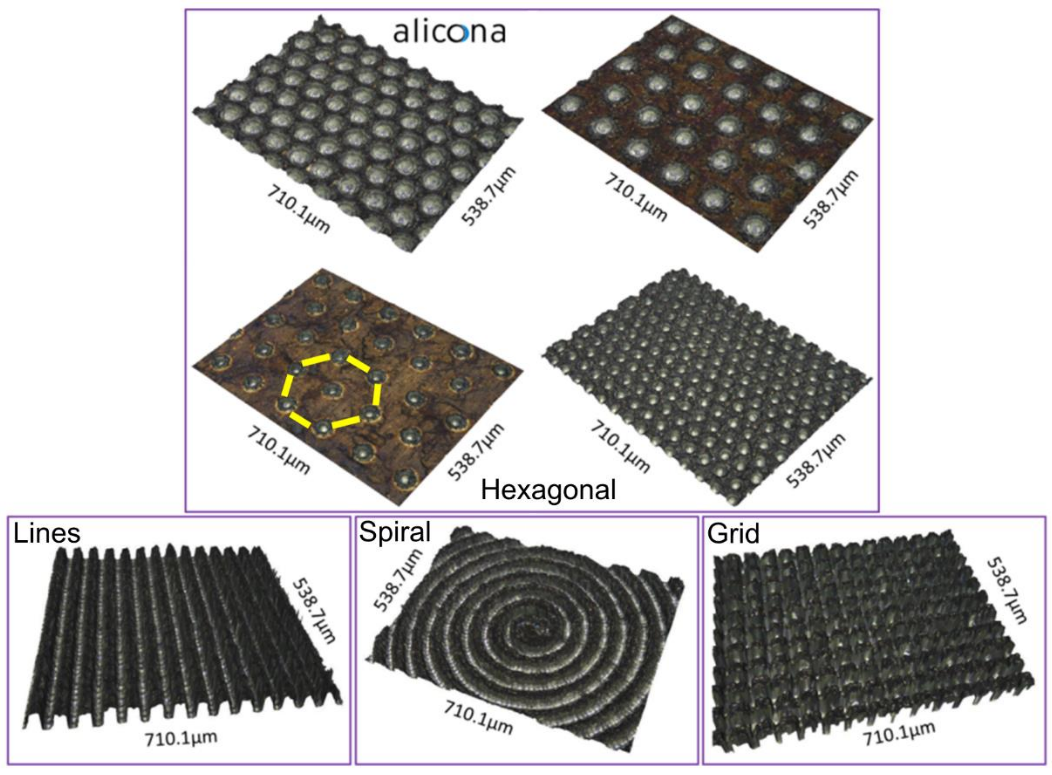
Fe interface remains solid and only the Al is molten a textures can be printed in the Fe surface to improve the wettability of Al in Fe.

This was done at Herriot-Watt using a SPI ns pulsed laser with 20 W.

Experimental setup



Textures



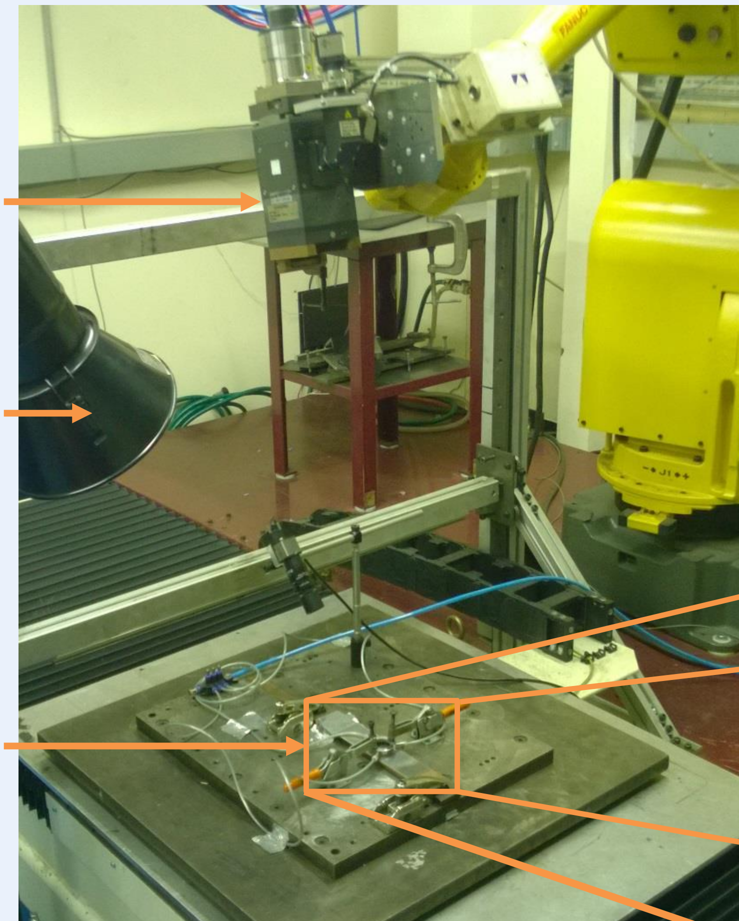
Methodology (cont.)

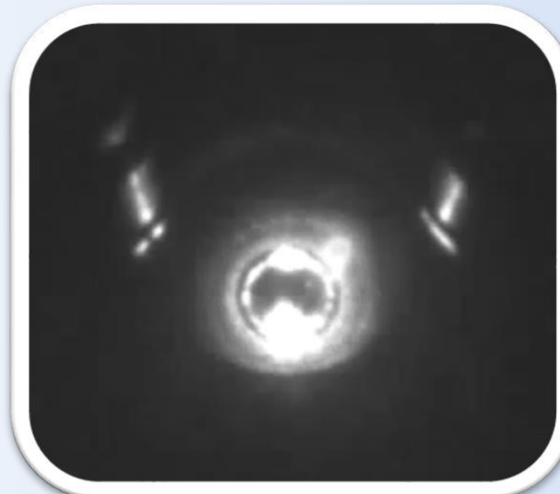
Textures sizes:

<table>
<tr><th>Texture</th><th>Pattern</th><th>Depth (µm)</th><th>Diameter (µm)</th><th>Distance (µm)</th></tr>
<tr><td>A</td><td rowspan="4">Hexagonal</td><td rowspan="7">30</td><td rowspan="2">65</td><td>80</td></tr>
<tr><td>B</td><td rowspan="2">125</td></tr>
<tr><td>C</td><td rowspan="5">40</td></tr>
<tr><td>D</td><td rowspan="3">50</td></tr>
<tr><td>E</td><td>Lines</td></tr>
<tr><td>F</td><td>Spiral</td></tr>
<tr><td>G</td><td>Grid</td></tr>
</table>

Methodology (cont.)

The textured samples were then laser spot welded at Cranfield University using an IPG 8kW CW laser.





Methodology (cont.)

Welding experiments:

Beam diameter (mm)	Power (kW)	Interaction time (s)	Power density (µm)	Specific point energy (µm)
13	2	3	15.1	6.0
		4		8.0
		5		10.0
		6		12.0
	2.25	2	17.0	6.8
	2.67	3	20.1	8.0
		4		10.7
		5		13.4
	3	3	22.7	9.0
	3.67		27.6	11.0
	4		30.1	12

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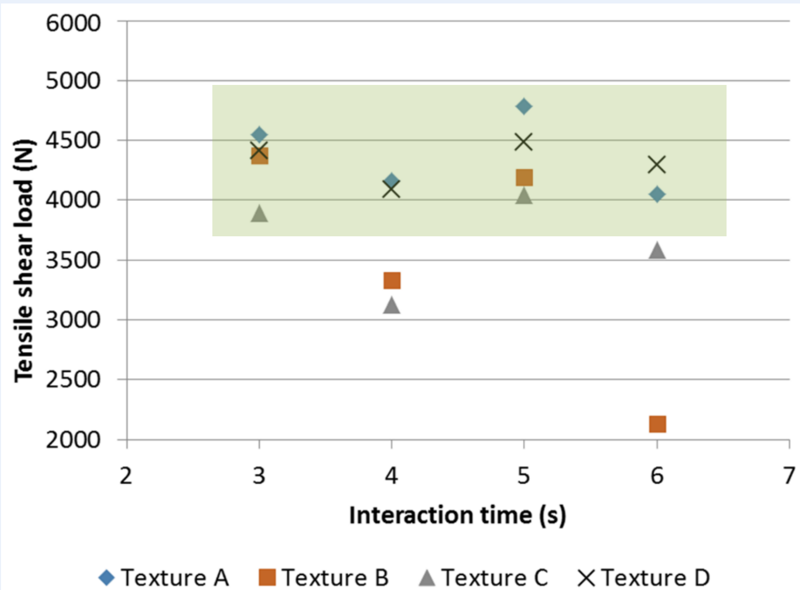
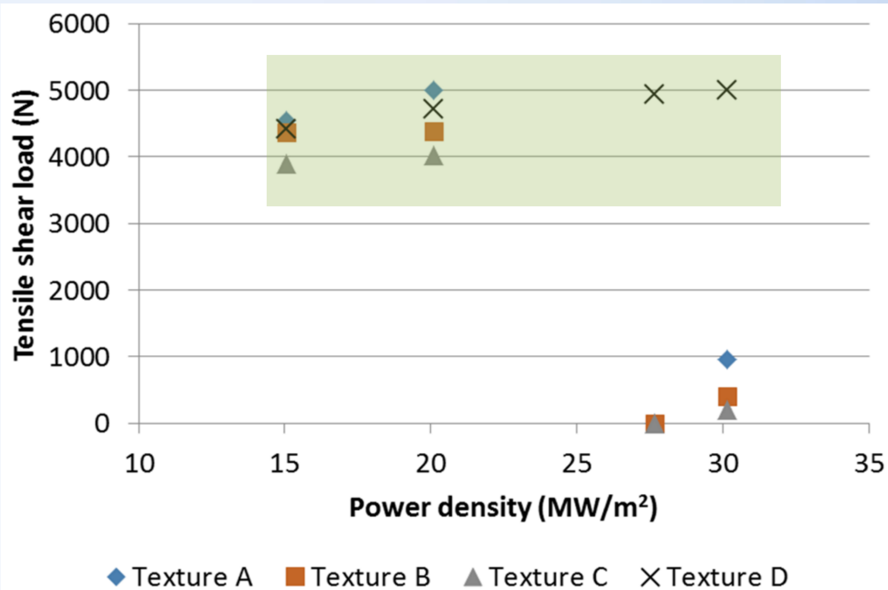
Results

Hexagonal patterns:





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<tr><td>B</td><td rowspan="2">125</td></tr>
<tr><td>C</td><td rowspan="2">40</td></tr>
<tr><td>D</td><td>50</td></tr>
</table>

Textures A and D have the best mechanical properties for any interaction time.

Only texture D has good mechanical properties for higher values of power density.

The dimensions of texture D were selected to evaluate the different geometrical patterns.

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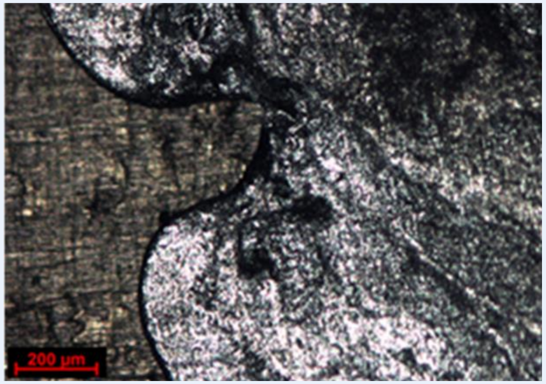
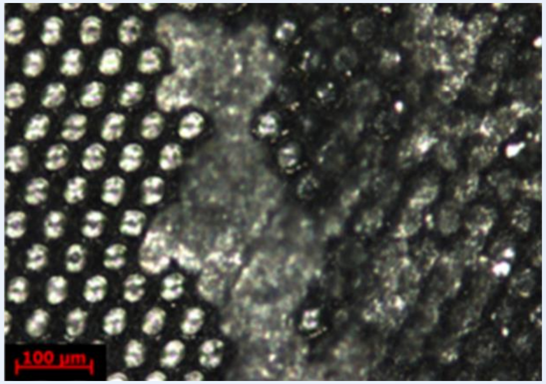
Results (cont.)

Geometrical patterns - interface microscopy:

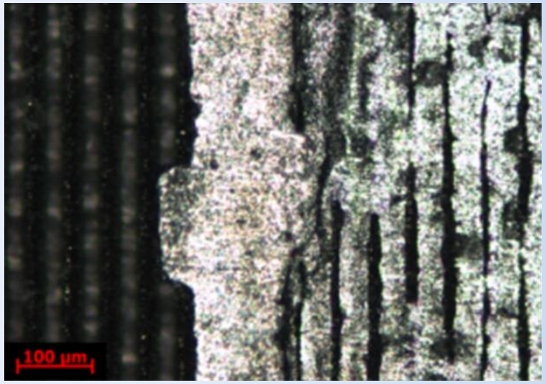
Non textured



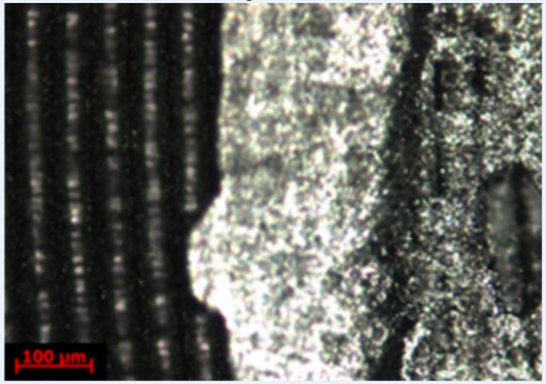
Hexagonal



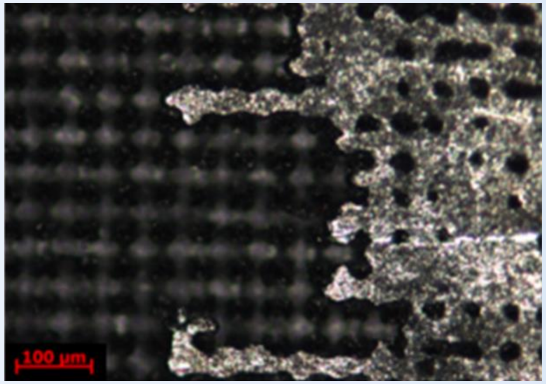
Lines



Spiral



Grid



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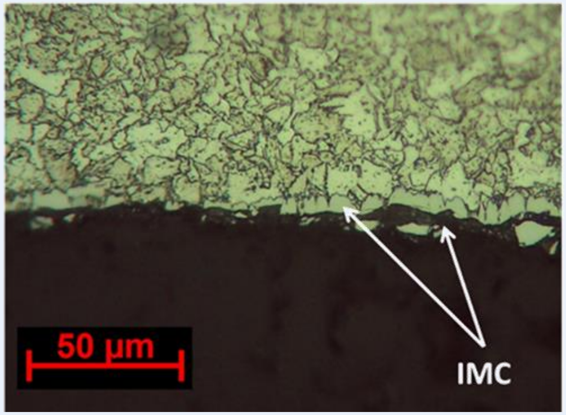
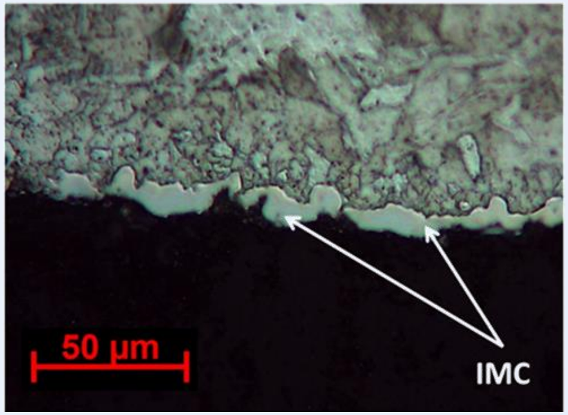
Results (cont.)

Geometrical patterns - interface microscopy (cont.):

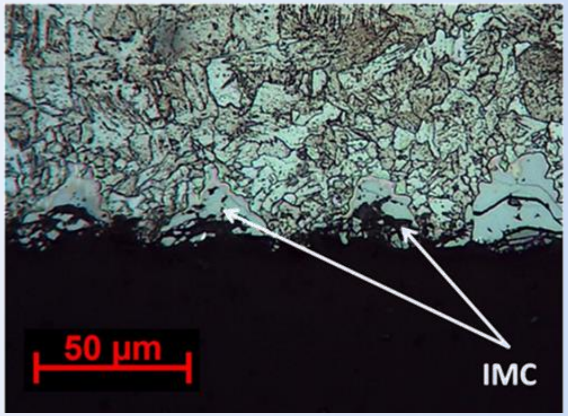
Non textured



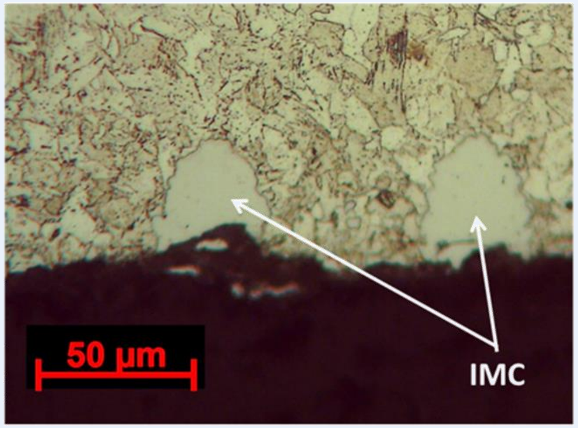
Hexagonal



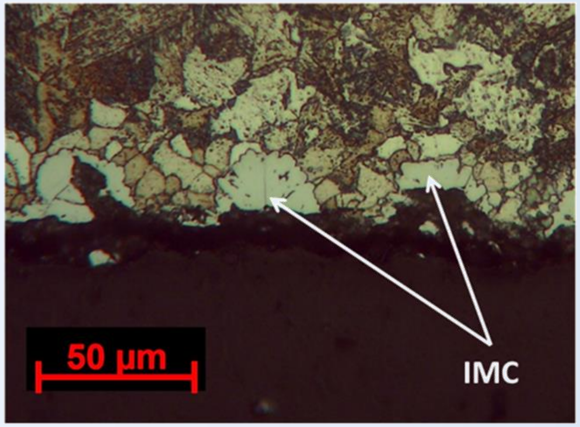
Lines



Spiral

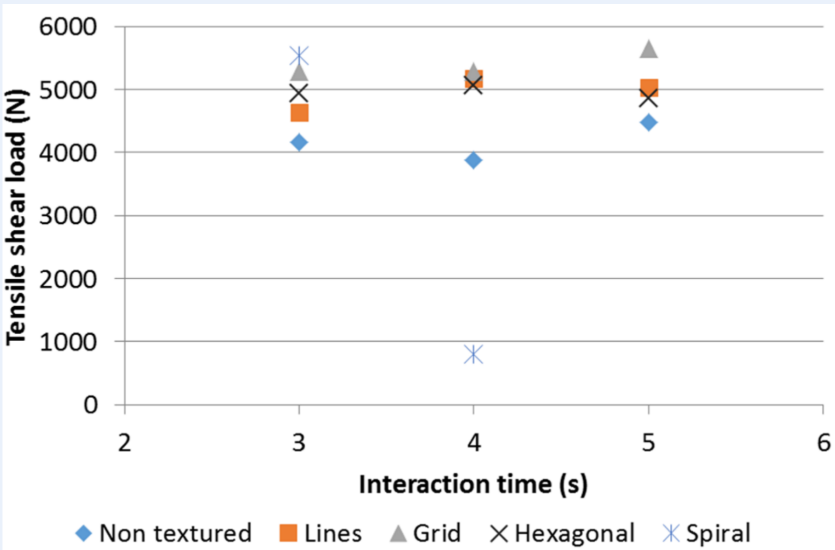


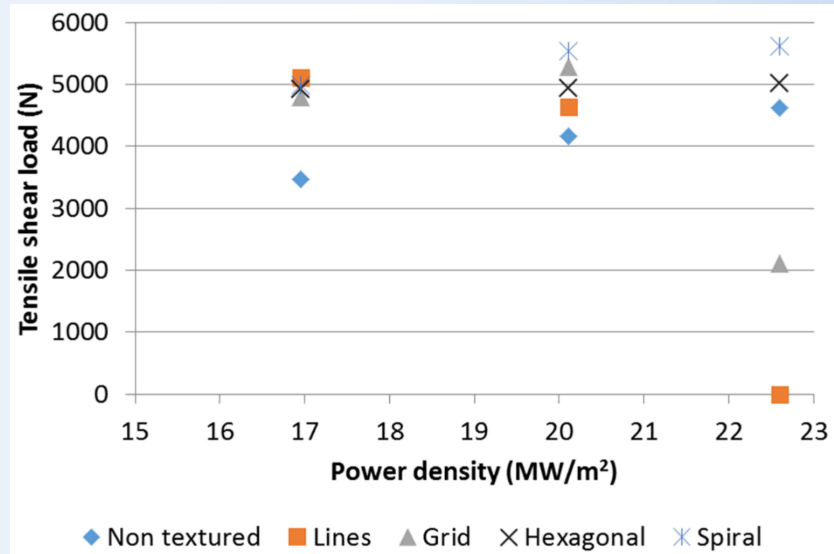
Grid



Results (cont.)

Geometrical patterns:





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<tr><td>F</td><td>Grid</td></tr>
<tr><td>G</td><td>Spiral</td></tr>
</table>

Lines, grid and hexagonal have better mechanical properties than the non textured samples for any interaction time.

The same is valid for the power density with exception of grid and lines for the higher value of power density.

Conclusions

- Defect free Fe-Al joints were produced by laser spot welding using laser-textured steel.
- Patterns laser marked in the steel plates affected the Al flow at the interface and the IMC formation.
- The maximum tensile shear load of textured samples increased up to 25% when compared to non-textured steel samples.

Thank you for listening

- Any questions?