TENSILE STRENGTH OF WELD SEAM IN EXPLOCLAD STEEL/Ti SHEETS

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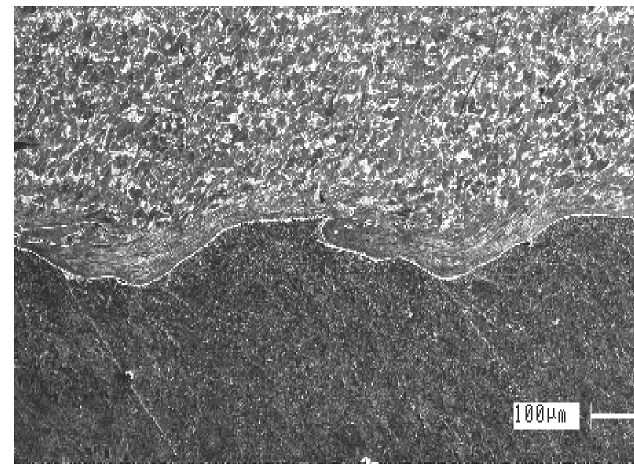

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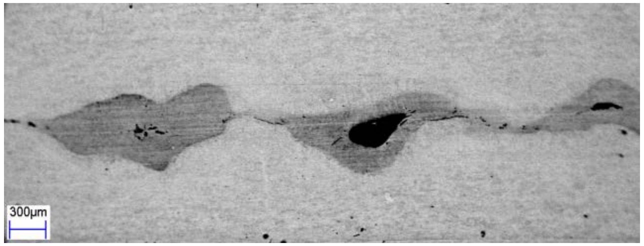
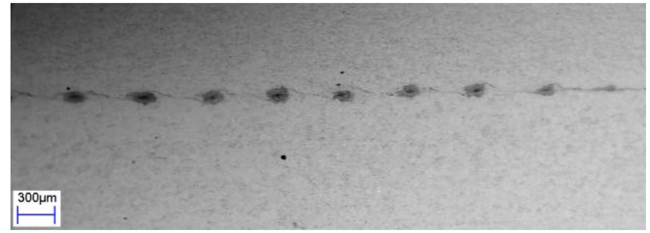
Microstructure vortex zones during explosion welding in various gases



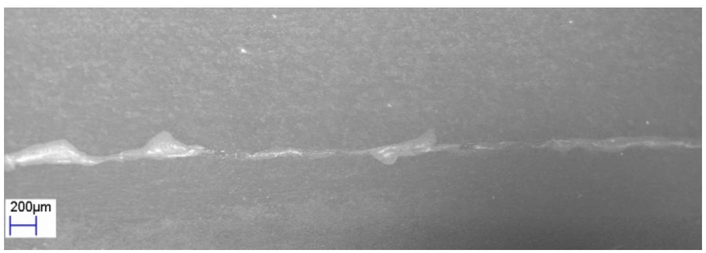
V_k=3980 m/s

Air

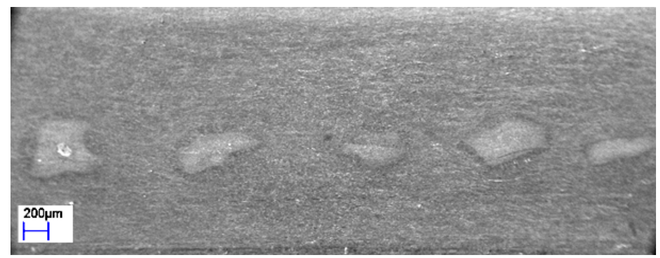


V_k=1880 m/s

Ti+Ti

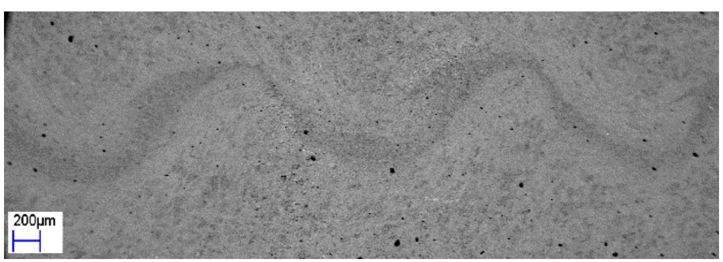


Oxygen

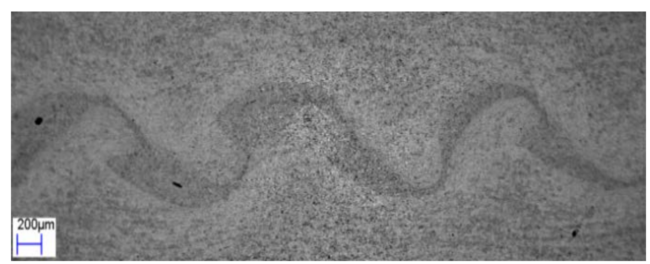


V_k =2690 m/s

Nitrogen



Argon



Helium

V_k =2690 m/s

Objective: **To study structure and properties changes in the bimetal at various distances from the initial point of the welding process along the length (the entire area) of the sheet and in the zone of defects.**

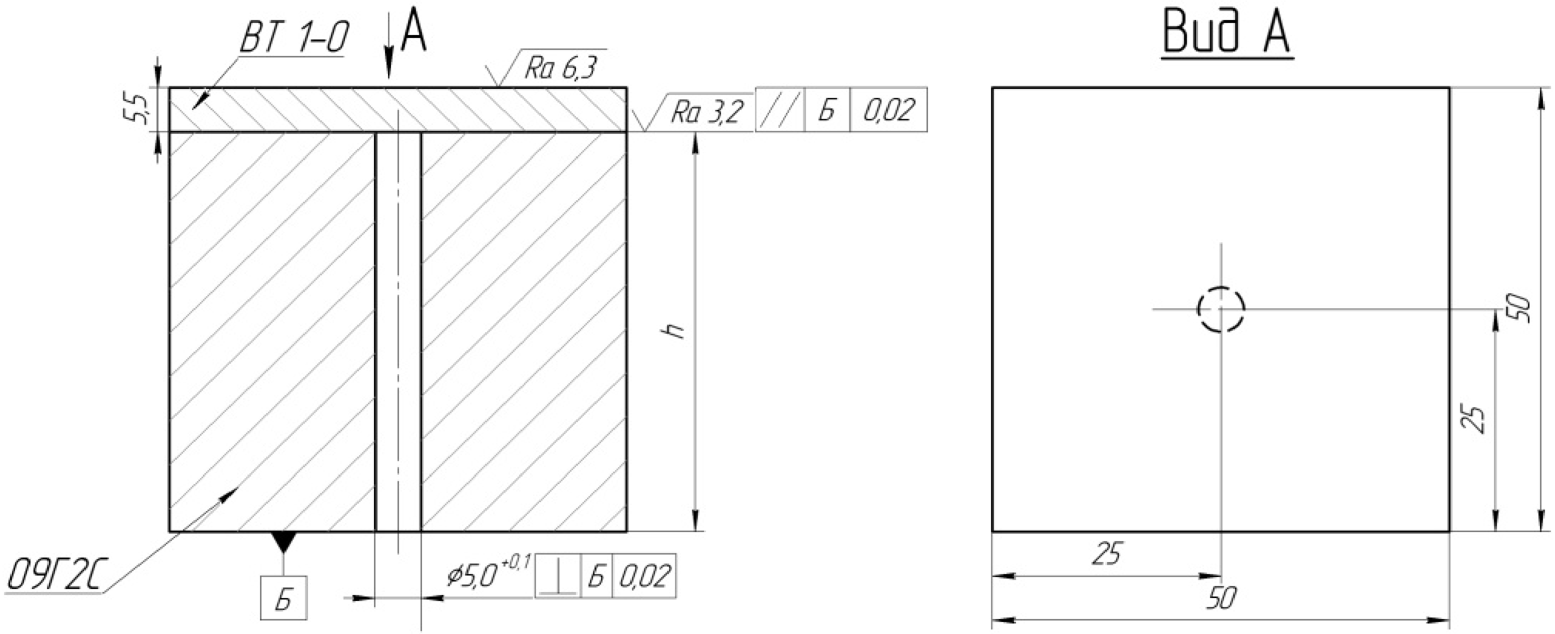
Two basic questions:

1. How is the bond strength distributed on the surface of a large bimetal sheet produced by explosion welding in shielding gases?

2. Is it possible to estimate the connection quality (including tensile strength) by using ultrasonic testing?

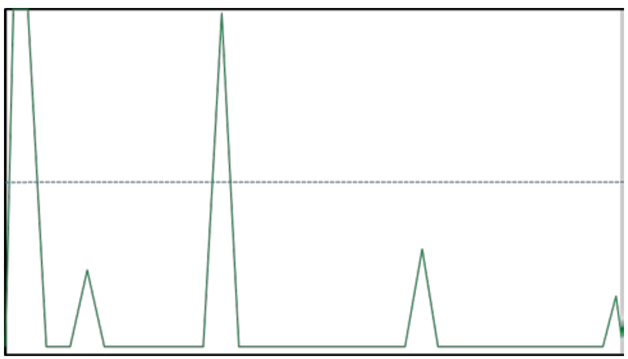
Research technique

1. Ultrasonic testing was carried out over the entire surface. The sensitivity of the device was up to the standard sample with flat-bottom drilling diameter 5 mm (20 mm^2) and 3.5 mm (10 mm^2).



2. In accordance with the results of ultrasonic examination we studied the bond structure and strength in different areas of the bimetallic sheet including the area adjacent to the discontinuity zones.

Ultrasonic indications at different sensitivity of the device



absence of defects at D5

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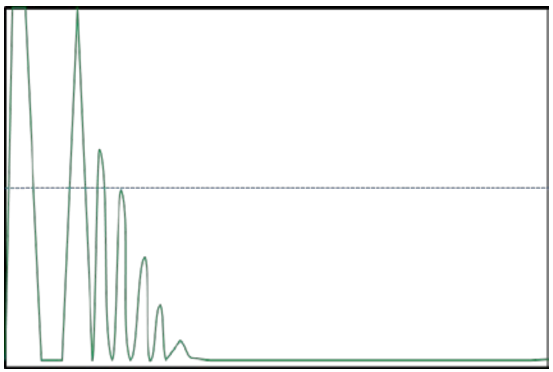
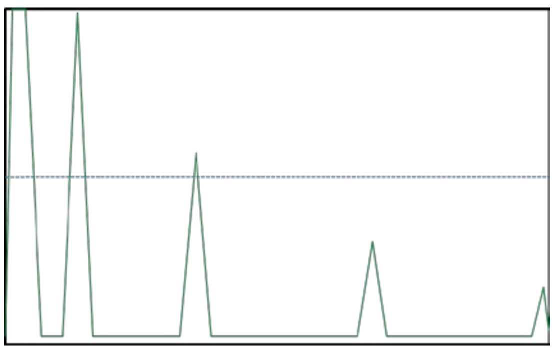


defects at D5

appearance of noise sensitivity at D5

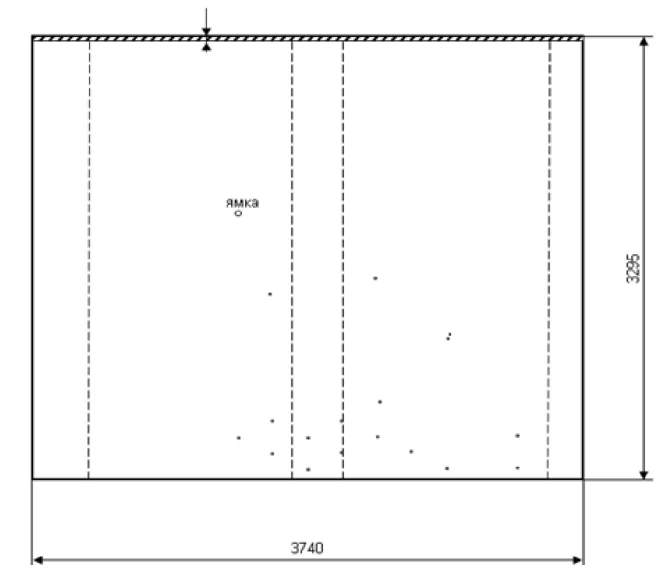


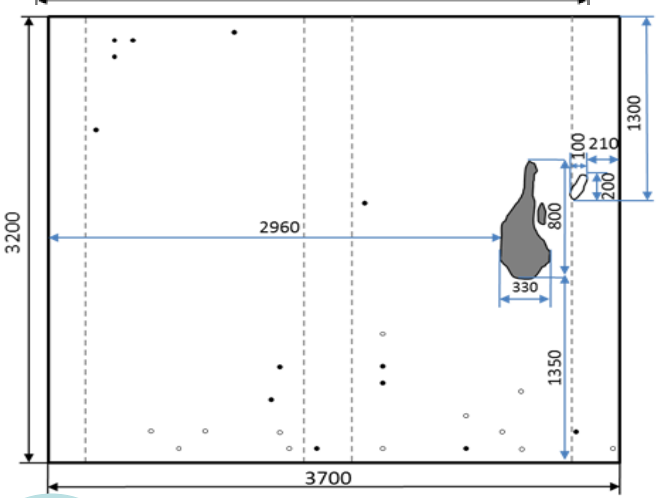
defects presence in the noise zone at D5 identified at D3,5

USI maps for bimetallic steel-titanium sheets

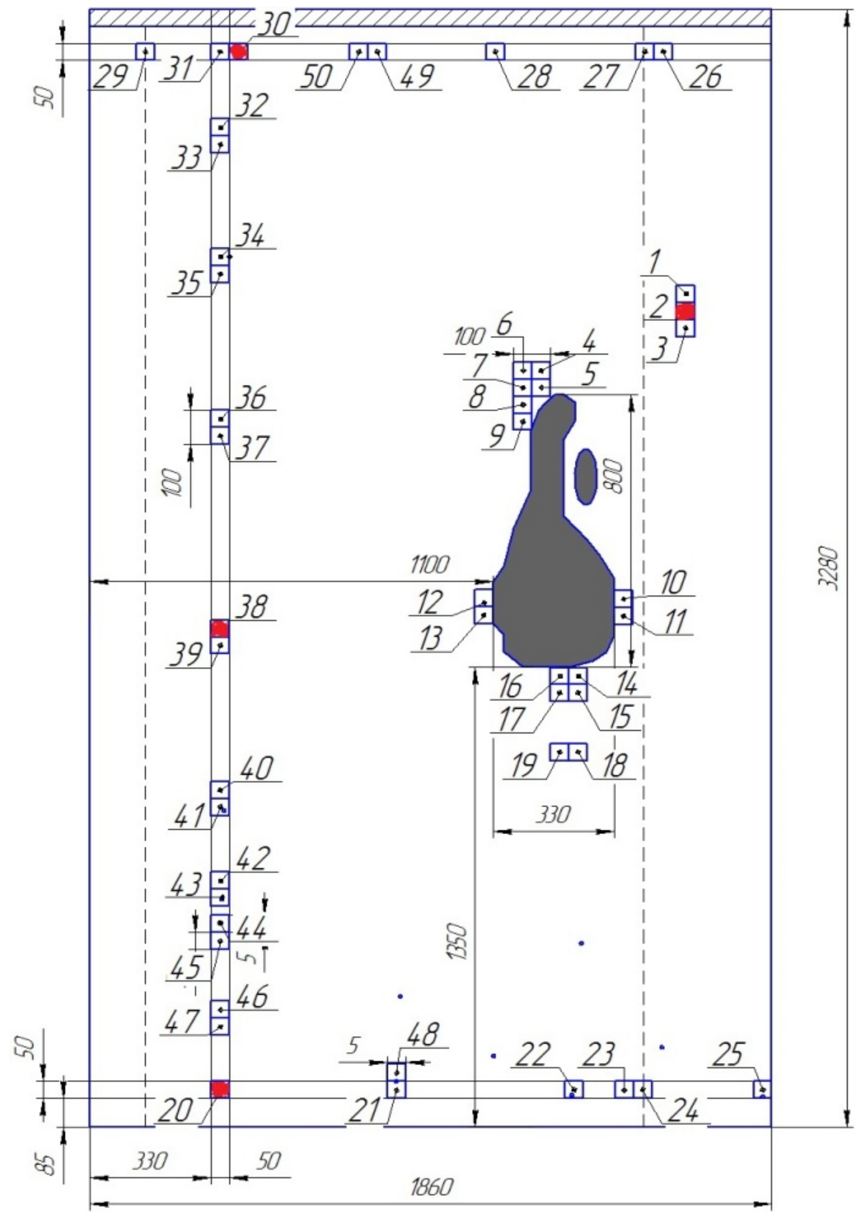
Cutting scheme for bimetallic model sample №260-2

Sheet №13

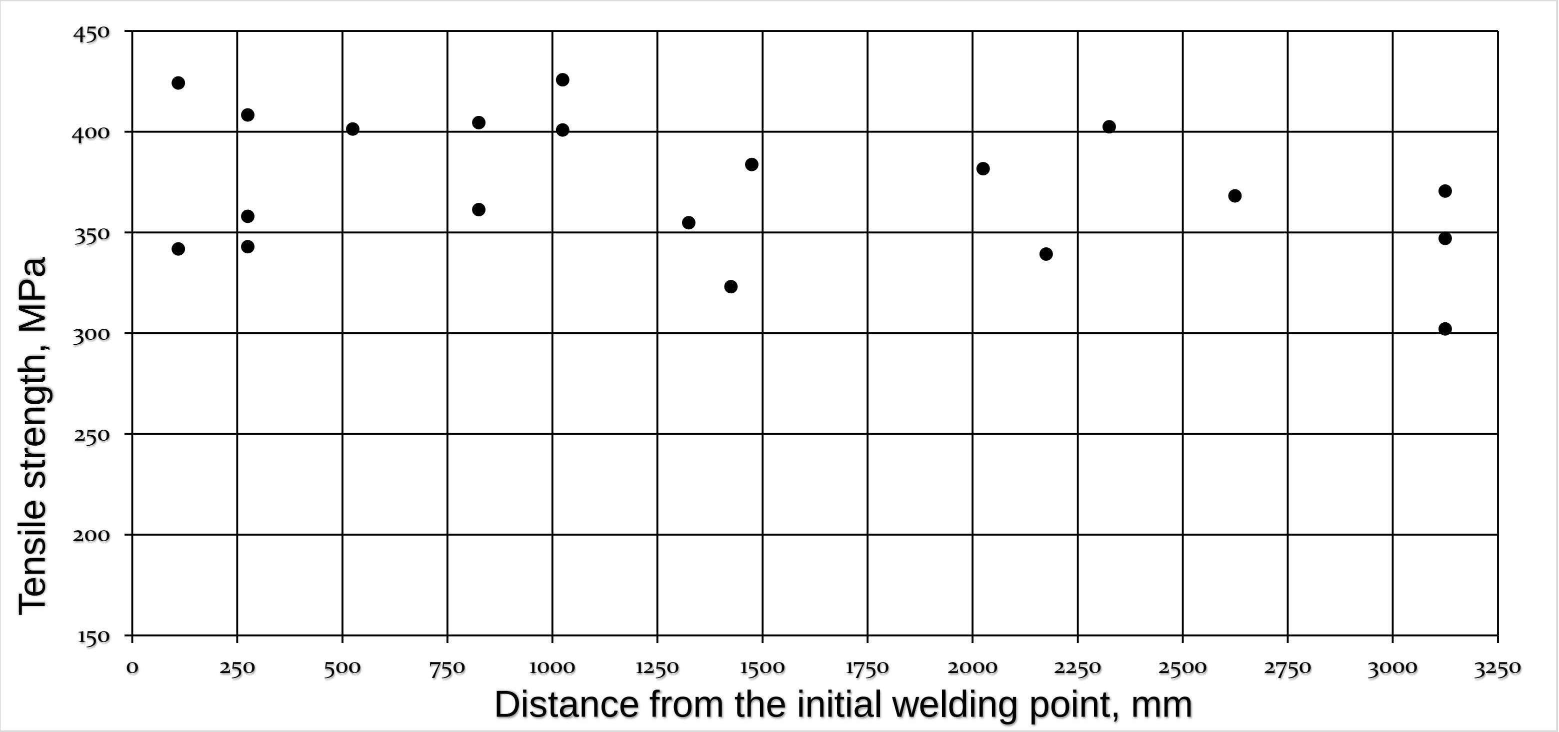




Sheet №260

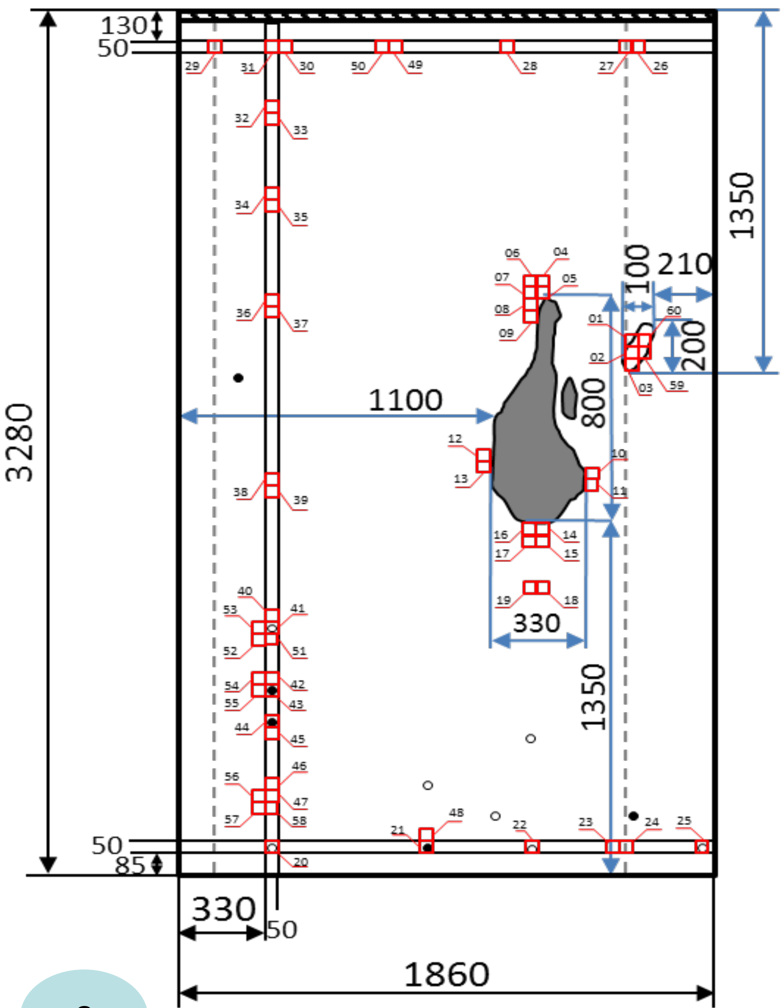


Change of tensile strength along the sheet length at 100% continuity quality (according to USI)



1. In areas without continuity defects (including point ones), σ = 302—424 MPa
2. In sections cut from the zones adjacent to the defect continuity, σ is not stable and varies from 65 MPa to 355 MPa.
3. In the continuity defect area (detected at scanning sensitivity level D3,5), $\sigma <$ 100 MPa

Cutting scheme for additional samples

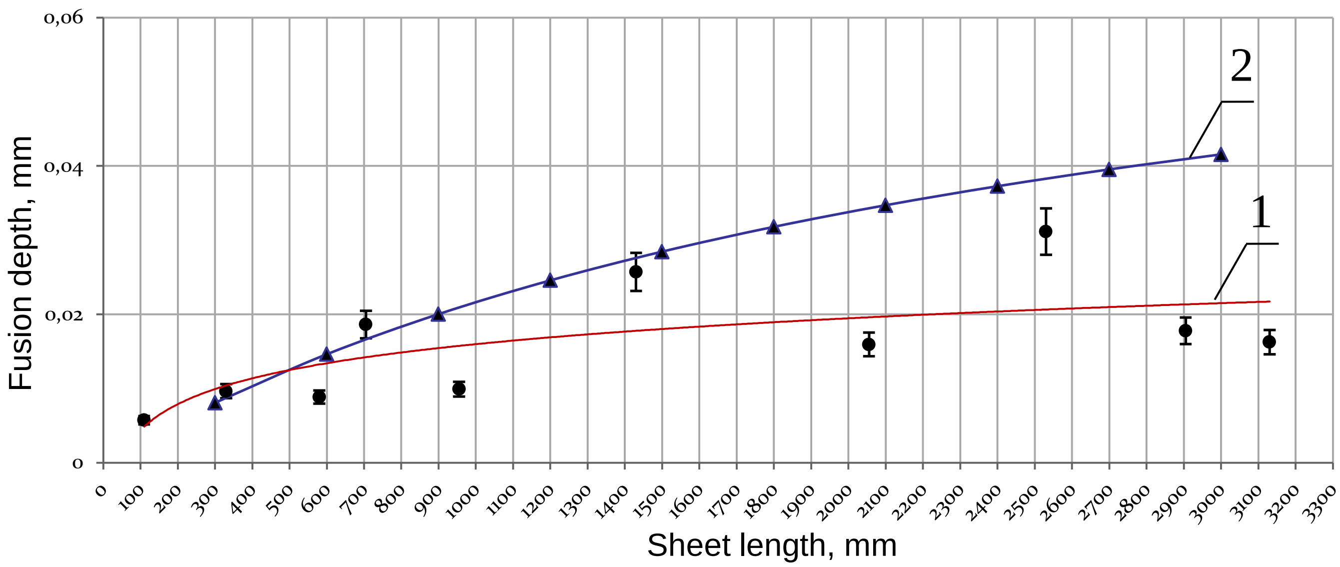


Tensile strength of the cladding layer

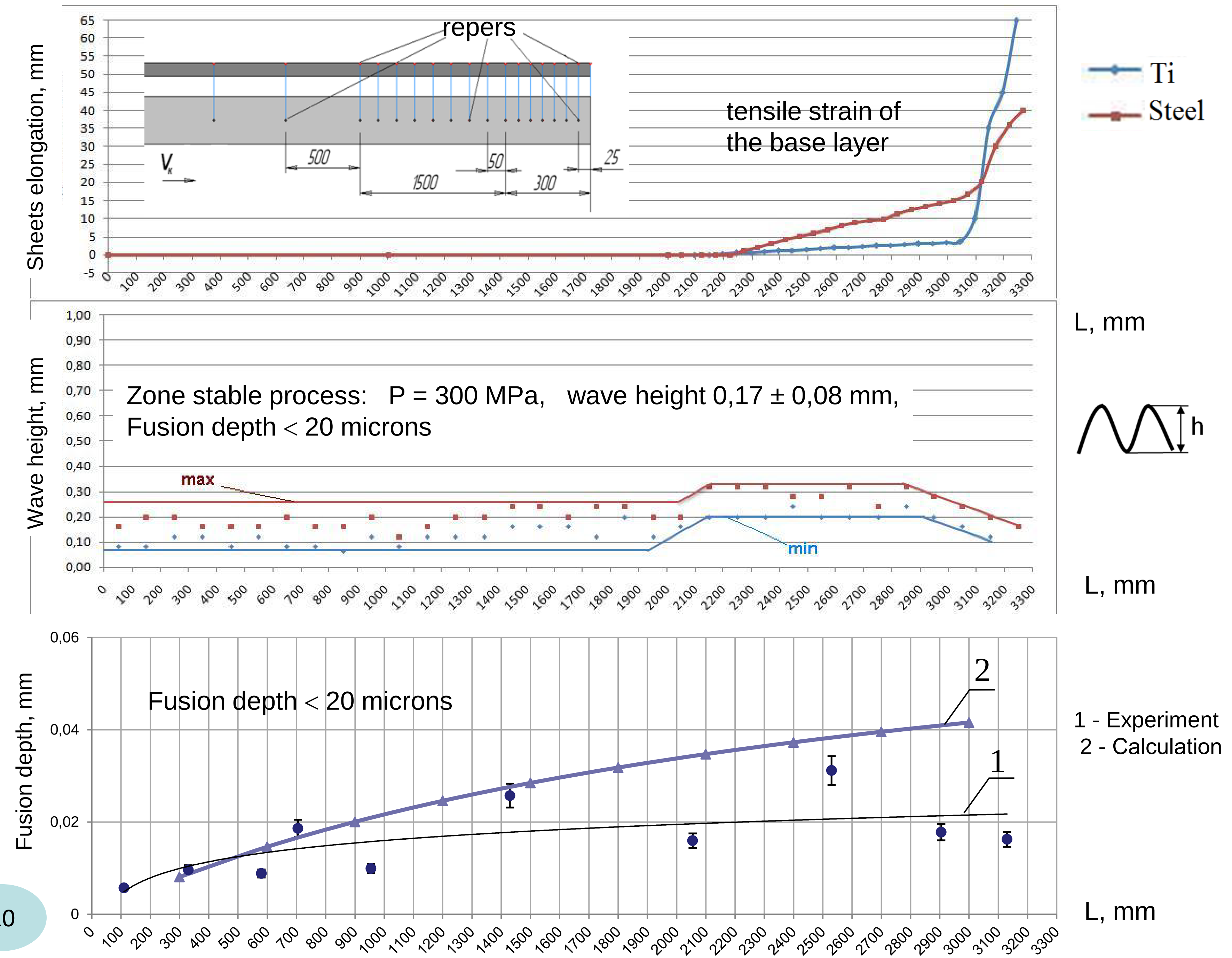
№	σ, MPa
51	218
52	426
53	401
54	361
55	404
56	408
57	358
58	343
60	51
59	Destroyed

Depth of fused layer

The surface of cast inclusions and wave parameters in the weld were measured. The ratio of the summarized square of cast inclusions to the length of the area was determined. The results were applied to a theoretical curve to determine the fusion depth in the joint zone.

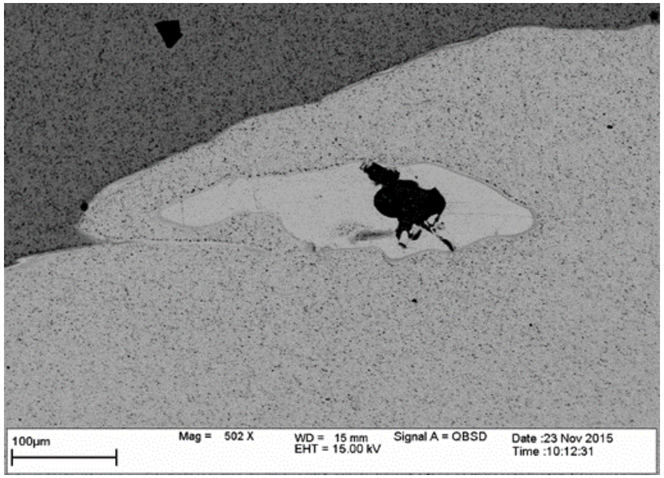


1 - Experimental data, 2 - Calculated data

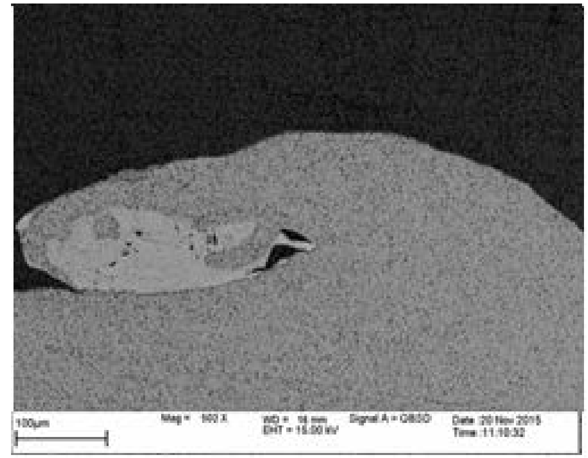


Sheets elongation, mm
repers
tensile strain of the base layer
Ti
Steel
500
1500
50
300
25
L, mm
Wave height, mm
Zone stable process: P = 300 MPa, wave height 0,17 ± 0,08 mm,
Fusion depth < 20 microns
max
min
h
L, mm
Fusion depth, mm
Fusion depth < 20 microns
2
1
1 - Experiment
2 - Calculation
L, mm

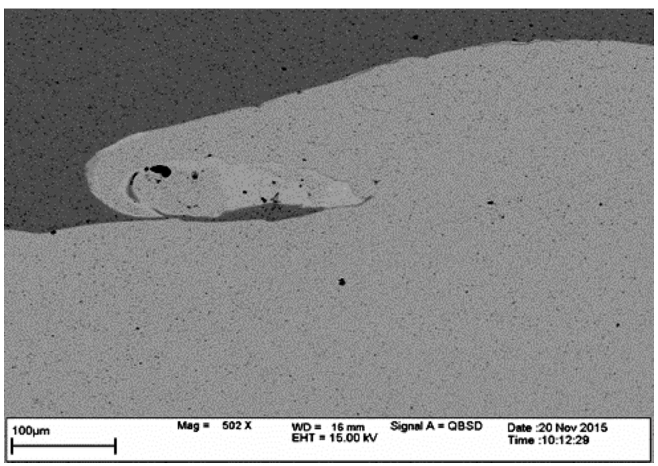
Microstructure of cast inclusions at different distances from the initial point of the process



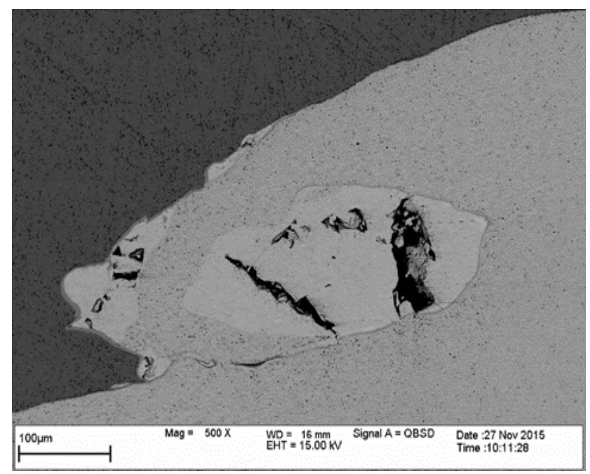
300 mm



1400 mm

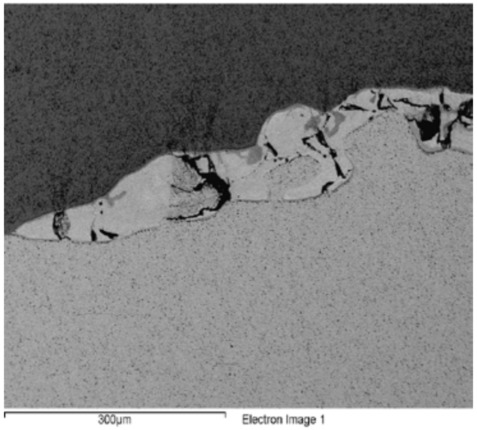


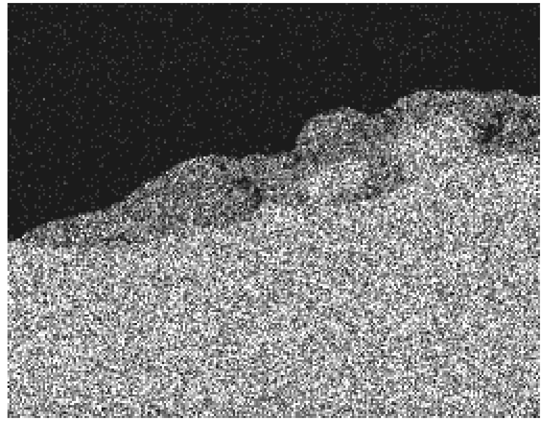
2100 mm



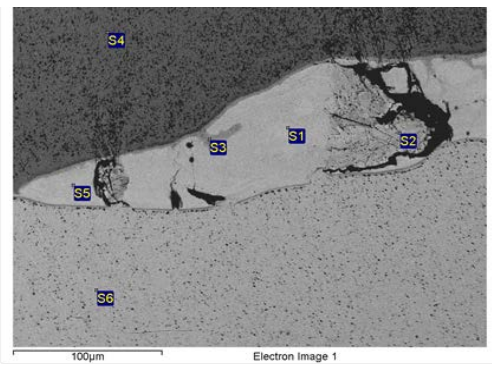
2900 mm

Defects presence in the noise zone at D5 identified at D3,5
Cast inclusions composition in the vortex zones

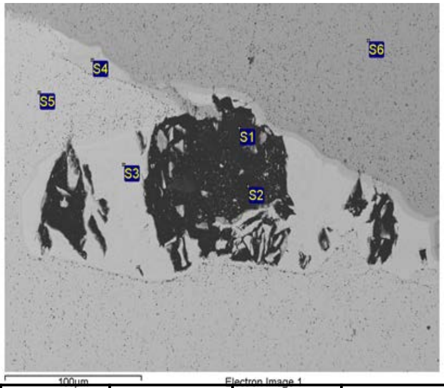



Fe Ka1

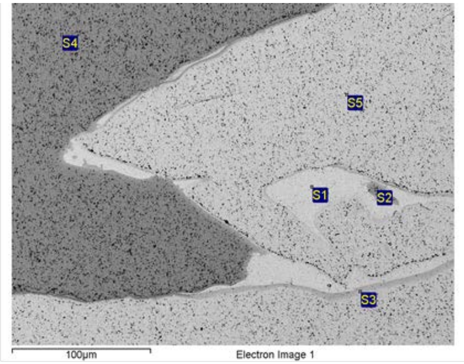

Ti Ka1



	Si	Ti	Mn	Fe
S1	**0.54**	**27.28**		**72.18**
S2	**0.52**	**32.64**		**66.84**
S3		25.31	0.99	73.70
S4		23.44	1.65	74.91
S5		96.09		3.91



	O	Si	Ti	Mn	Fe
S1		0.48	30.30	1.05	68.17
S2	**2.42**	**0.50**	**29.12**	**1.30**	**66.66**
S3	**2.71**		**56.93**		**40.36**
S4			100		
S5		0.58	33.85	0.97	64.60
S6		0.65		1.71	97.64



	Si	Ti	Cr	Mn	Fe
S1	0.81	17.87		1.67	6.66
S2	0.78		0.62	1.57	97.03
S3		**67.20**			**32.80**
S4		**86.91**			**13.09**
S5	0.86	20.39		1.23	77.52
S6	0.77			1.37	97.86
S7		100			

Conclusions

(1) Explosive welding in shielding gases of large size steel/Ti sheets provides the tensile strength of above 300 MPa all over the entire sheet surface, at good results of ultrasonic defectoscopy.

(2) The amount of fused inclusions is independent of *L*, slightly varies within narrow limits, and is close to a value theoretically estimated by the method based on registration of aerodynamic shock-compressed gas within the stand-off gap.

(3) The areas of incomplete fusion in the form of cast inclusions and intermetallics can be associated with formation of ply blisters