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INFLUENCE OF CONNECTION TYPE ON THE FATIGUE LIFE OF WELDED

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1. Introduction

The technology of welding materials together is one of the most widespread methods of inseparable joining. The predominant majority of the mechanical industry uses this joining method to build new constructions and as well as to regenerate damaged objects.

There has been invented many different methods of making joints characterized by the thermal energy input, the way of creating the protected atmosphere, etc. There can be distinguished a few basic types of Welded joints (Fig.1):

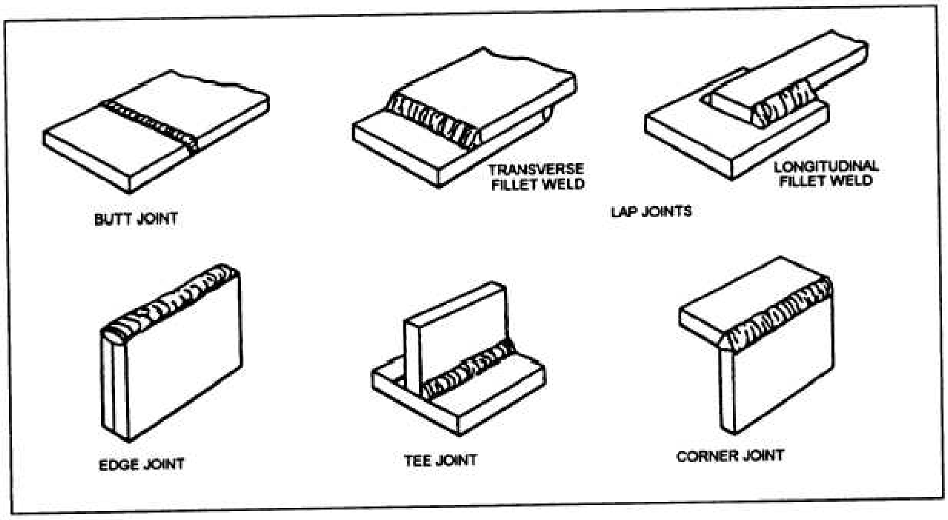


Fig. 1. Welded joints

Each of the welding methods and the type of weld has many various advantages in the form of: the possibility of joining different kinds of materials, easy process automation, the possibility of welding in unfavorable environments (e.g. underwater), tightness of the joint and many more. Nevertheless, despite the many advantages the welding process has a number of drawbacks, which oftentimes prevent employing this method entirely [1]. The most detrimental of them are: the material structural change in the heat affected zone and the thermal deformations, which are caused by the distribution of condensed thermal energy in huge amounts. The structural change of the material has an obvious impact on the tensile and fatigue strength. After-welding deformations cause a large amount of stresses in the weld itself, in the heat affected zone, but also in the whole constructions in specific cases. By employing various welding methods we can reduce the degree of stresses, but they can never be fully eliminated. In the case of an inappropriately designed construction there is a possibility of a huge accumulation of stresses, which is shown in Fig. 2. It is vitally important to appropriately design the routes and types of the welds used [4]. The scope of the experiment encompassed testing four types of samples in a environment of static and variable loads.

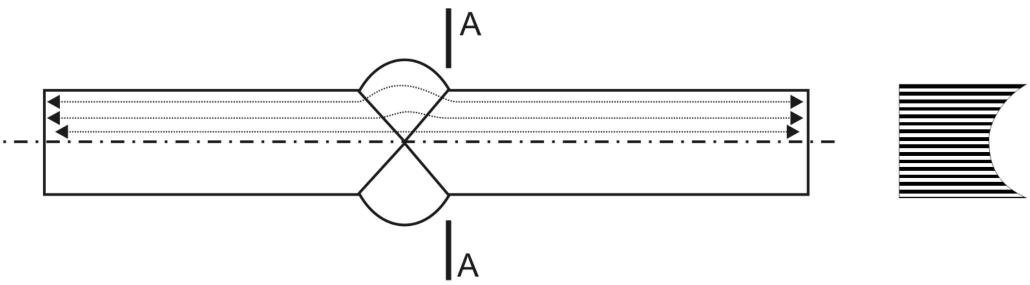


Fig. 3. Stress acculumation in the weld

In welds there can be found stress accumulation resulting from:

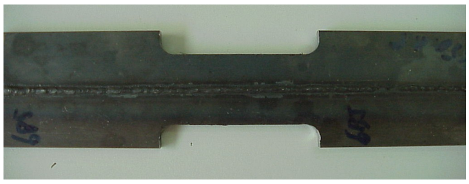
- mechanical notch (local change of the object's shape)
- structural notch (local change of the material's structure)
- welding defects
- additional welding stresses

2. Test samples

The experiment was conducted according to norms PN-EN ISO 6892-1:2009 and PN-74/H-04327- Fatigue Testing of Metals. The static elongation test was carried out in the room temperature. Four types of test samples were used out of steel grades 650 (6) and 700 (7). The shape of the samples is shown in Fig. 3.

a)

b)



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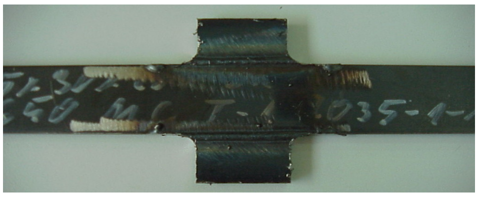

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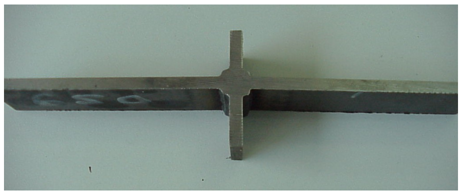


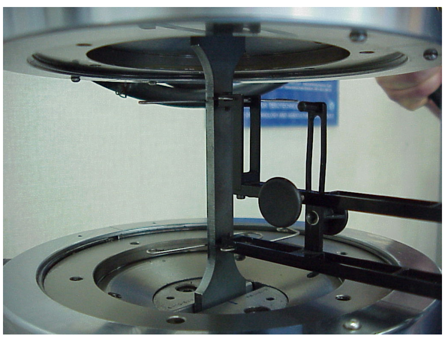
Fig. 3. Test samples: a) uniform sample (type A) , b) with a longitudinal weld (type B), c) with longitudianl welds (type C), d) cross joint (type D)

3. Experiment methodology

3.1. Static tests

Fatigue tests were preceded by static tests [2]. Static elongation tests were conducted using the Instron 8501 tester machine equipped with a force gauge head of the ±100 kN measuring range. Elongation values were taken using an extensometer for static tests with the measuring base of 50mm secured on the measured part of the sample. The experiment composed of subjecting the test samples to loads which increased with the speed of the piston feed of the tester machine equaled 0.05 mm/s. Fig.4 shows the samples secured in clamps of the tester machine.

a)



b)

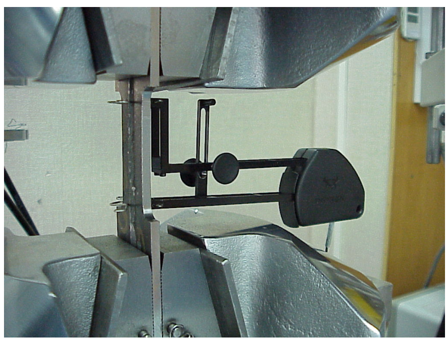


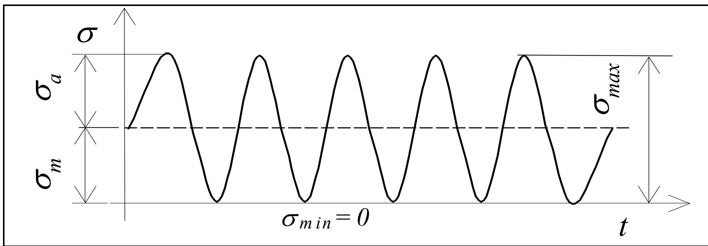
Fig. 4. Samples in the clamps of the tester machine: a) samples with a weld (type A), b) sample with the longitudinal weld (type B)

The experiment was conducted at the temperature of 21°C. The tests were being conducted up to the point of the sample split within the measuring range of the extensometer. During the test the temporary values of load force affecting the sample were registered and its elongation.

3.2. Fatigue tests

The test samples were subjected to sinusoidal elogation loading (Tab. 1) [3]. Load levels were determined after an analysis of the static elongation tests' results. The variable load parameters are shown in Table 1.

Table 1. Variable load parameters used during the experiment



level	Stress, MPa			
	σ_{max}	σ_{min}	σ_a	$\Delta\sigma_a$
1	70	0	35	70
2	80	0	40	80
3	90	0	45	90

Fatigue tests were ended at the point of the sample split. Fig 5 shows the samples already prepared for the fatigue tests.

a) b)

Fig. 5. The samples during the fatigue tests: a) with longitudinal welds (type c), b) cross-type sample (type D)

4. Results and analysis

4.1.Static tests

The form of the sample's damage was interconnected with the type of the sample. In the case of the sample with the weld (type A) and the sample with the longitudinal weld the crack always appeared in the sample measured area (Fig. 6 a, b). This applied to both steel grades. As for the two remaining sample types the crack always appeared in the vicinity of the weld. An exception here is the cross-joint sample where the welded joint always broke in the weld area. The cracks of type samples C and D are shown in Fig. 6c i 6d.

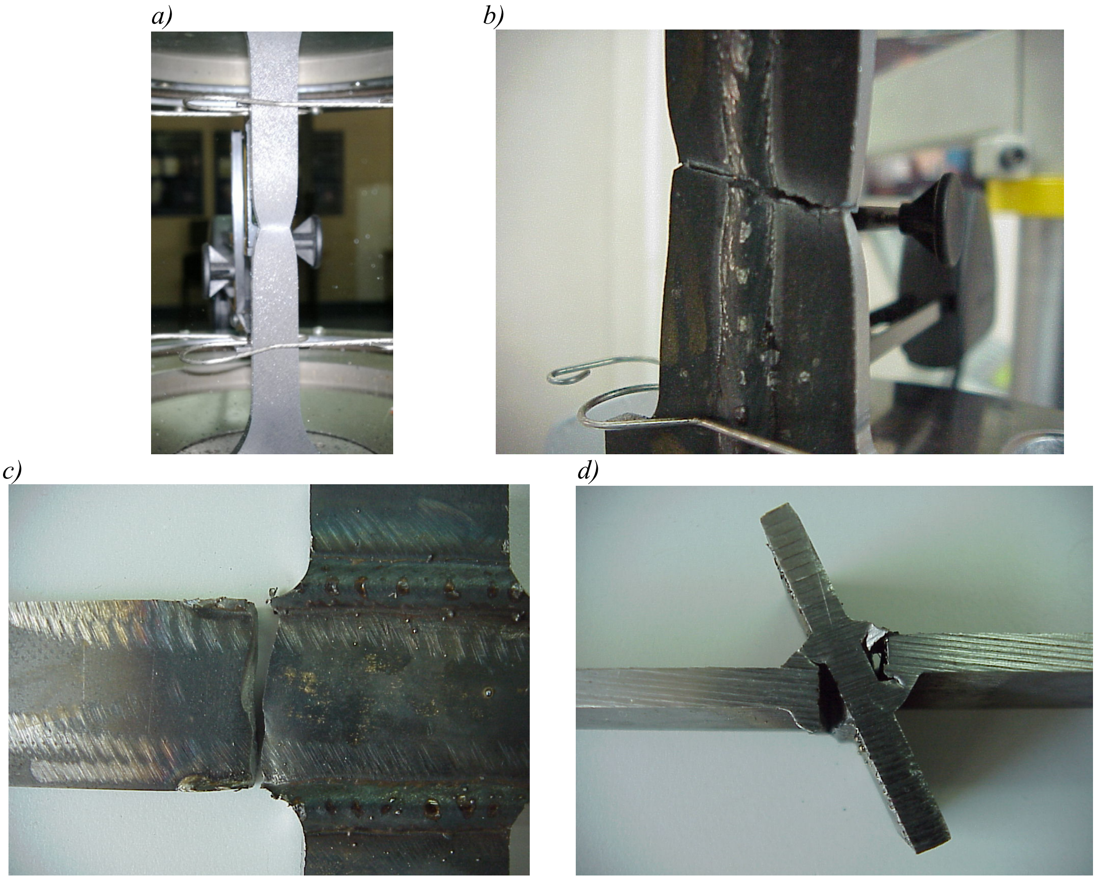


Fig. 6. Forms of the damage during the static tests: a) damage of the type A sample, b) damage of the type B sample, c) damage of the type C sample, d) damage of the type D sample

The static elongation test are shown in the form of graphs on the coordinate system: test sample elongation – stress. The stresses in the test sample subjected to tensile load were calculated dividing the temporary values of load force by the initial cross-sectional area of the sample. As the initial cross-sectional area of the sample the following was assumed:

- for type A sample – section determined by crosswise dimensions of the sample;
- for type B sample – section determined by crosswise dimensions of the sample outside the weld;
- for type C sample – section determined by crosswise dimensions of the sample outside the weld;
- for type D sample – section determined by crosswise dimensions of the sample outside the weld.

The graphs depicting elongation can be found in Fig 8.

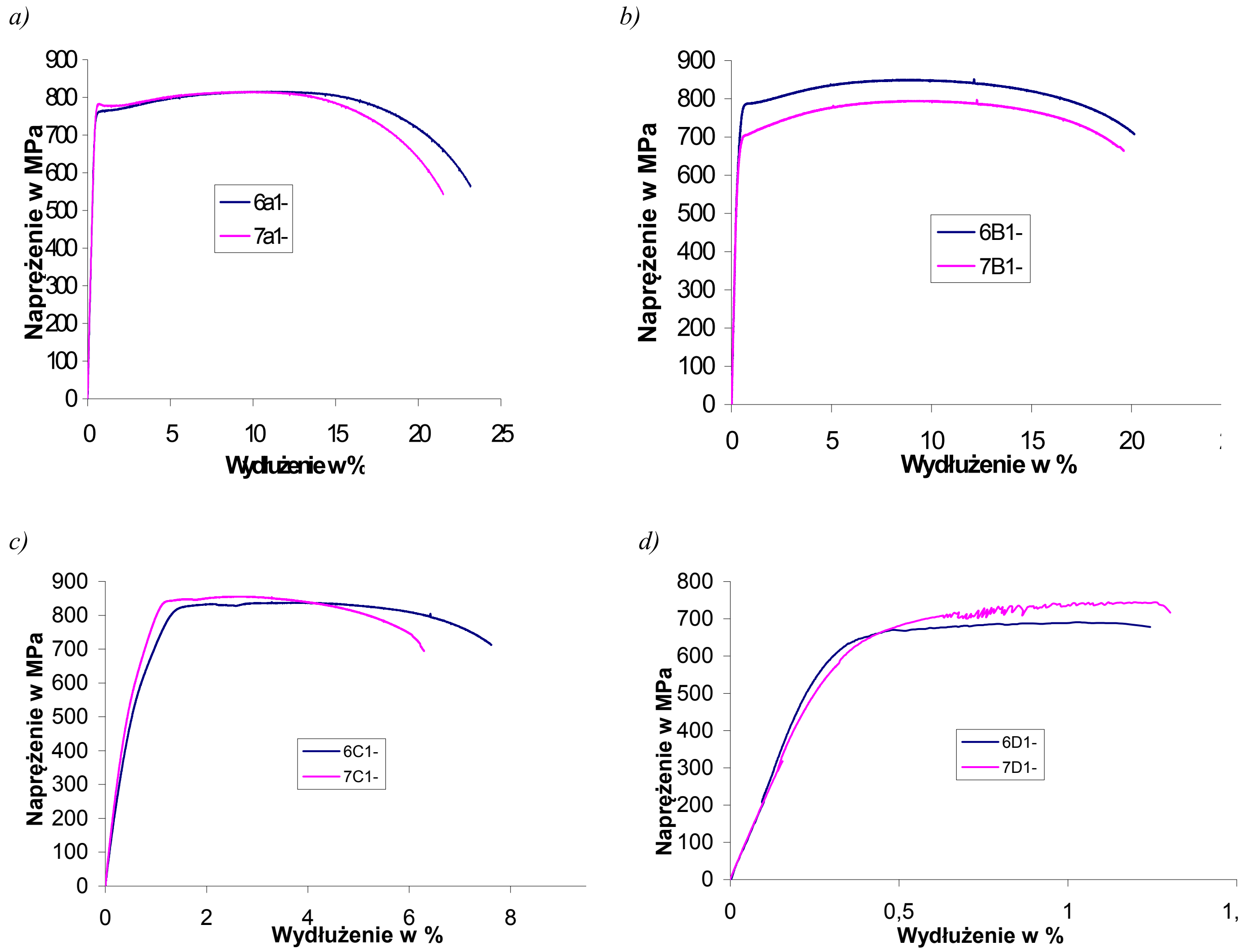


Fig. 8. Static elongation graphs: a) sample with the weld Type A, b) Type B, c) Type C, d) Type D

The graphs analyzed in detail. The results are grouped in Table 2.

Table 2. Resulst of the static elongation graphs' analysis

No.	Sample type	Steel grade 650			Steel grade 700		
		R_m	R_e	A	R_m	R_e	A
1	A	815	754	22,66	814	779	21,51
2	B	850	766	21,12	797	695	20,68
			$R_{p0.2}$			$R_{p0.2}$	
3	C	855	594	8,02	872	664	6,67
4	D	691	668	1,25	744	689	1,3

Fig. 8 shows the most common forms of damage during the fatigue tests.

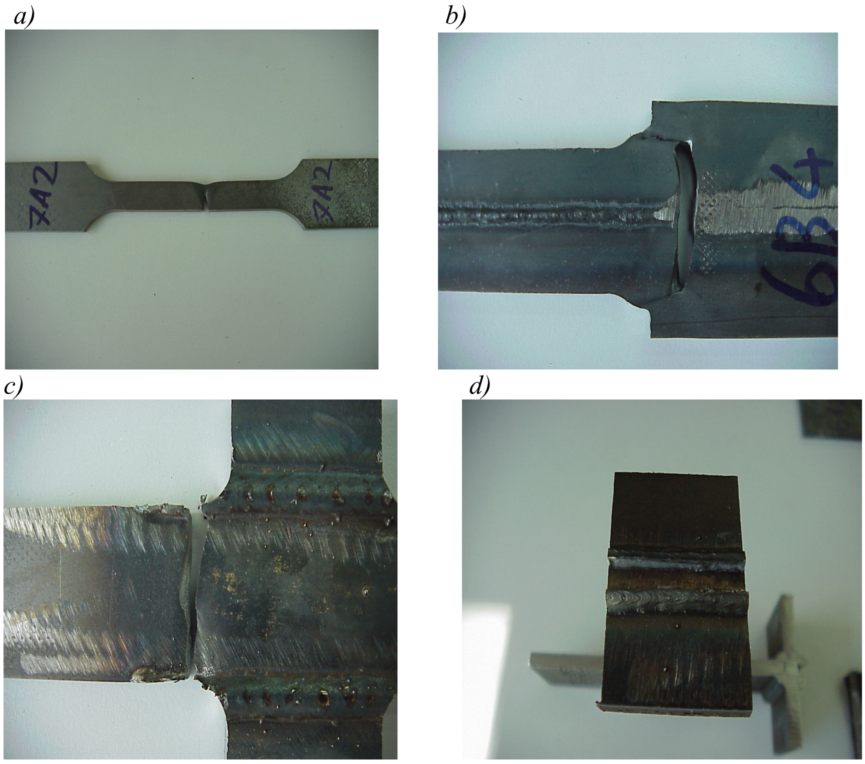


Fig. 8. Forms of damage during the fatigue tests: a) type A, b) type B, c) type D, d) type D

The results obtained during the fatigue tests are shown in Fig. 10 and 11 in the forms of fatigue graphs on the coordinate system: cycle number till the point of break N – stress σ_{max}. The fatigue graphs in the bilogarithmic form were approximated using the following equation:

$$\log \sigma_{\max} = a \log N + b, \tag{1}$$

where:

a- gradient of the graph,

b- the intercept of the regression graph.

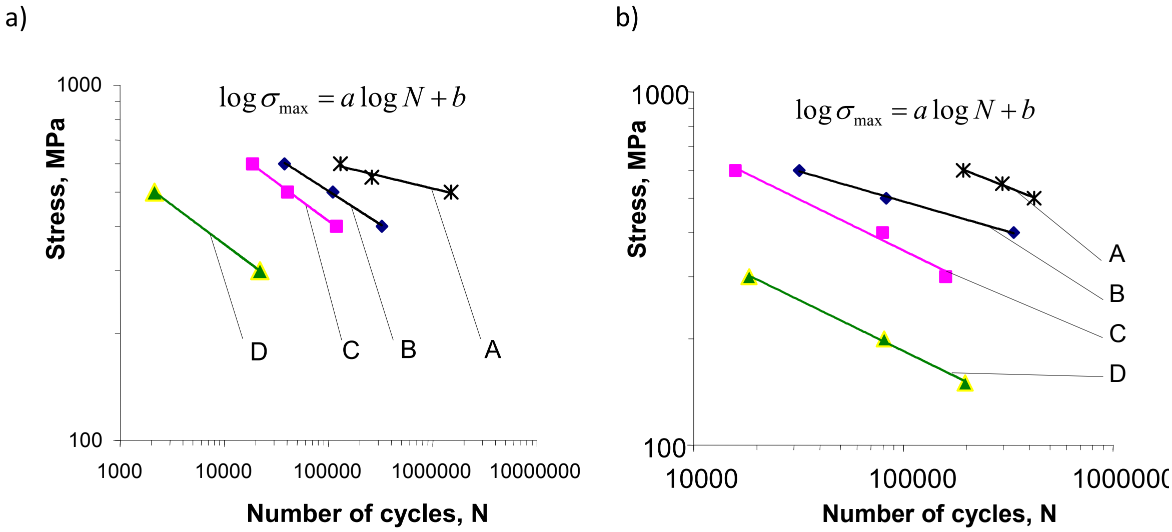


Fig. 9. Fatigue graphs: a) steel grade 650, b) steel grade 700

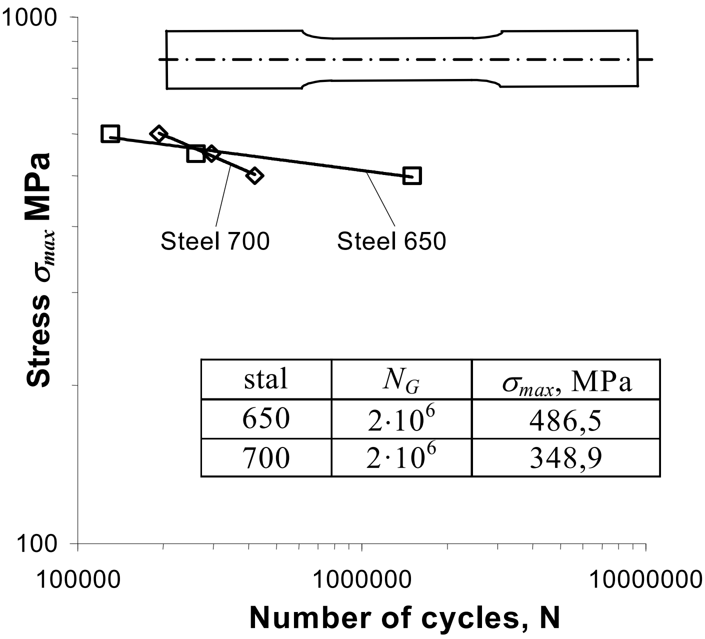
From the fatigue graph equation the values of stresses were calculated corresponding to the base number of cycles: N_G=10^6, N_G=$2 \cdot 10^6$ and N_G=10^7. The obtained results are listed in Table 3 and in Fig. 10.

Table 3. Fatigue graph parameters for the test sample from steel 650 and 700

Sample type	Steel	Equation	*a*	*b*	σ_{max} for N_G=$2 \cdot 10^6$
A	650	$\sigma_{max}=a\ \log N+b$	-0,0706	1355	486,5042
	700		-0,2333	10300	348,9851
B	650		-0,1885	4403,9	285,8204
	700		-0,1712	3518	293,4672
C	650		-0,2177	5079	215,7963
	700		-0,2914	10189	148,5975
D	650		-0,2903	5226,6	77,45158
	700		-0,2526	3576,2	91,57599

For the comparison of the fatigue life results of the same type samples made from steel 650 and 700 fatigue graphs in Fig. 9 were plotted.

a)



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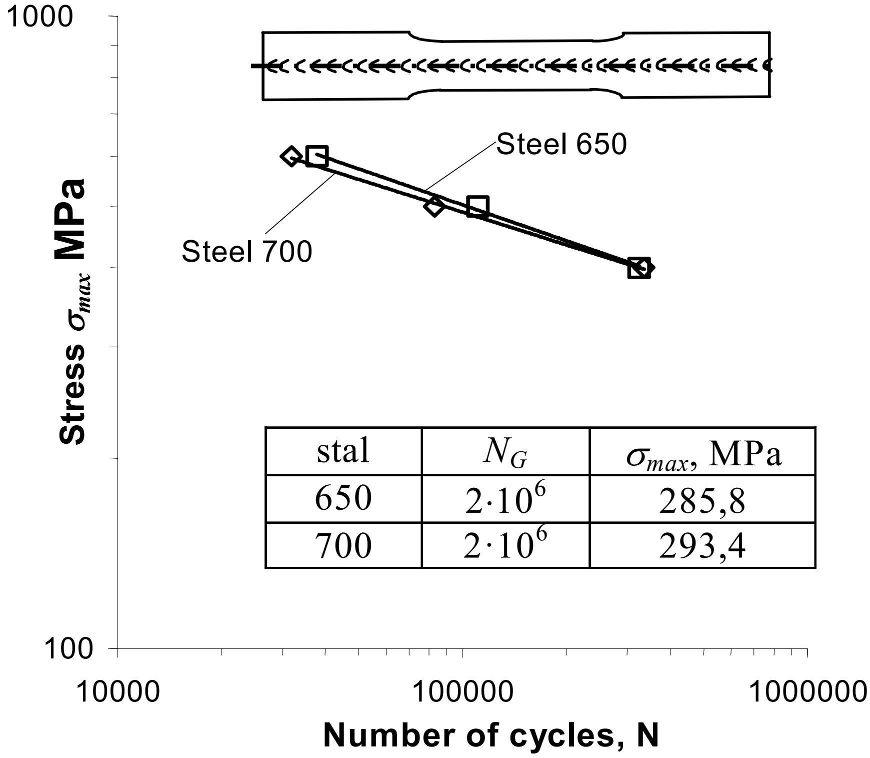
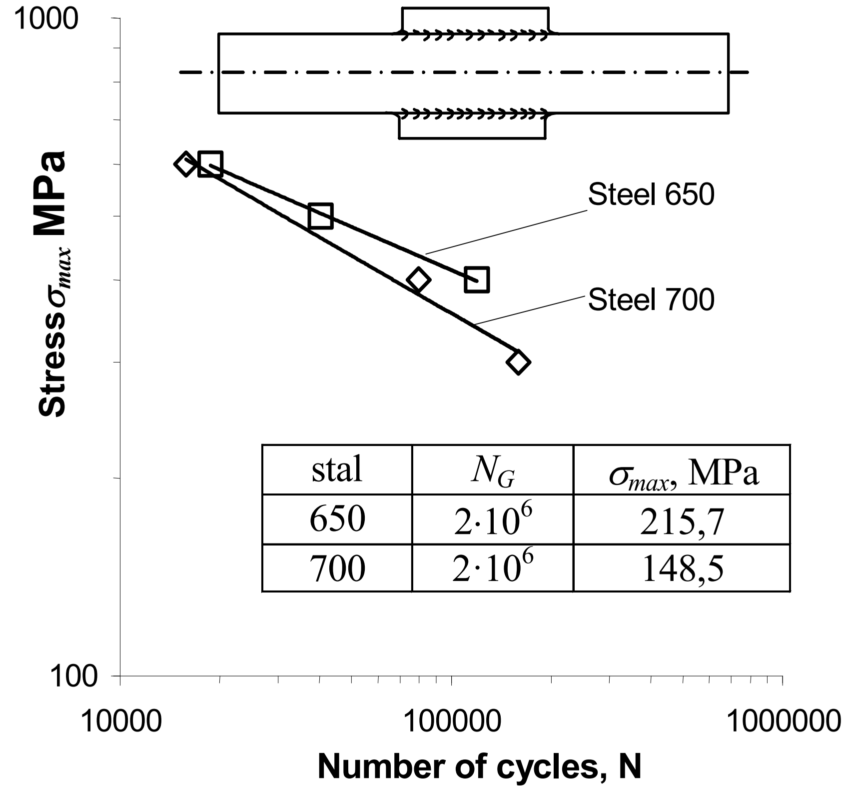


stal	N_G	σ_{max}, MPa
650	$2\cdot10^6$	285,8
700	$2\cdot10^6$	293,4

c)



stal	N_G	σ_{max}, MPa
650	$2\cdot10^6$	215,7
700	$2\cdot10^6$	148,5

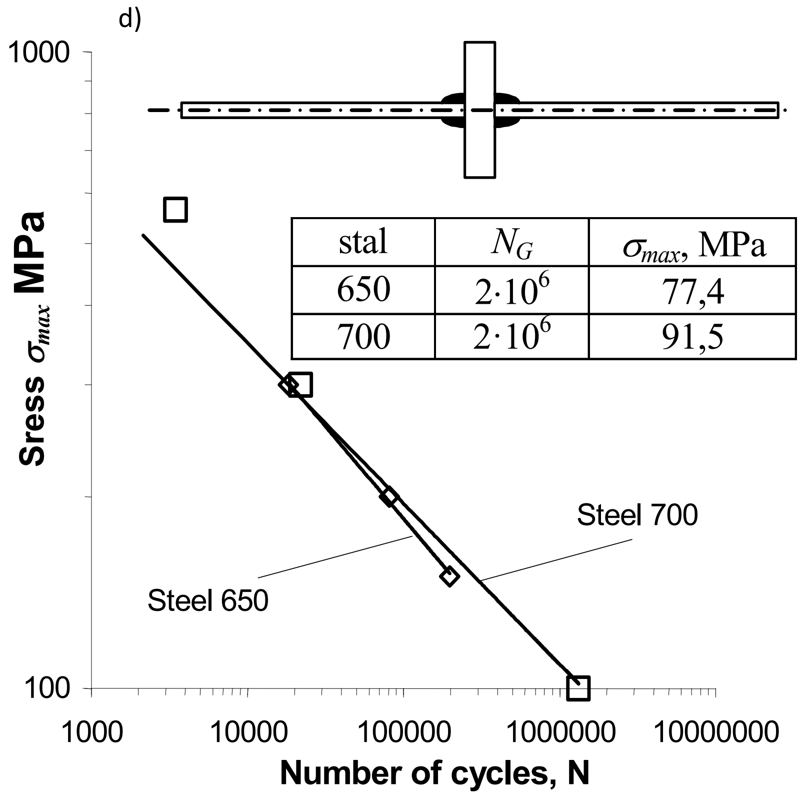


Fig. 10. Fatigue graphs obtained from different sample types: a) uniform sample (type a) , b) with the longitudinal weld (type b), c) with the longitudinal welds (type c), d) cross-joint (type d)

4. Summary

The results of the laboratory tests containing counterfeit and without weld joints are made of two sheets of homogeneous species allows us to formulate the following general conclusions:strength is strongly dependent on the type of weld as well as a method of congestion;

- fatigue life of samples arranged in a sequence dependent on the nature of the sample (in the order of D, C, B, A) which does not change its place for the different materials;
- fatigue limit of 2 * 10 ^ 6 cycle for samples A and C has a higher level of stress for steel 650, which is changed in favor of the steel type 700 for samples B and D;
- the occurrence of weld samples tested leading to immediate increases strength and reduces fatigue strength compared to the native materials.

The results of the study sheets bonded the two most common types of welds showed that the type of bond has a significant effect on the strength and fatigue received emergency calls:

- Front - high load capacity fixed and variable;
- fillet - easy to make, lower strength especially in the case of variable loads.

Junction and its location due to strength should be considered in the design of welded objects.

Reference

[1] http://engineeringtraining.tpub.com/14070/css/14070_37.htm

[2] PN-EN 10002-1:2004. *Metale. Próba rozciągania. Metoda badania w temperaturze otoczenia.*
[3] PN-74/H04327- *Badanie metali na zmęczenie. Próba osiowego rozciągania ściskania przy stałym cyklu obciążeń zewnętrznych*
[4] Muchryj J., Stachurski M., *Badania złączy spawanych*, Biuro Gamma, Warszawa 2003