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Analysis of Modification of Nose Gear Support with Aspect of Post Weld Heat Treatment of Aerospace Steel 15CrMoV6

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This paper examines the stress calculation of the nose gear support on the airplane "SOVA" both before and after modification, as well as the definition of welding specifications. During the design and development of a new aircraft "SOVA", the need to modify the nose gear support of "Utva-75", emerged, aiming to eliminate areas of high stress where cracks had previously been detected. Modification will impose welding of 15CrMoV6 steel and our specially developed specific welding procedure specification and to check the benefits experimentally. Stress occurrence calculation is realized with a FEM analysis. The given results are used for creating proper welding procedure specification and to prove that, after welding, material does not loose characteristics in heat affected zone. The process of welding analysis is done experimentally. The experiment was conducted on standard specimens. The specimens are composed from aerospace steel 15CrMoV6 (1.7734). The results are compared and presented in the paper.

Key words: **Nose gear support, Welding, TIG, 15CrMoV6, FEM.**

Introduction

THE design and development of aircraft Utva-75A41M-SOVA are based on a well-known Utva-75. Airplane Utva-75 had a crack occurrence problem in nose gear support (NGS), so it was necessary to completely define the occurrence of stress state in the NSG and to propose the modification to relieve high concentration stress zone.

The NSG assembly is produced through welding, and due to the specific modifications, it is essential to outline the technological process and to establish the correct welding parameters. To achieve this, a detailed analysis was conducted:

- Nose gear support Stress analysis;
- Design of modification;
- The experiment, which focuses on determining the optimal welding parameters and materials.

Finite Element Analysis (FEM) is used to conduct the stress analysis.

During the experiment, data varied are:

- Characteristics of specific state of material
- (PWHT) Post weld heat treatment of welded joints

The steel utilized for NGS production is 15CrMoV6 (1.7734) aviation steel. This is an exceptional low alloy, low carbon steel known for its exceptional tensile strength, hardness, and good weldability. Its primary applications include the manufacturing of pressure vessels, rocket engines, solid-fuel missiles, as well as use in the automotive, railway, and aviation industries. The chemical composition of this steel is provided in Table 1.

The filler materials for 1.7734 steel include 8CrMo12 (8CD12) or 15CDV6 (1.7734.2) steel, which have lower properties in comparison to the base material. This approach, where the filler material's characteristics are inferior to those of the base material, is referred to as under-matching. Additional welding guidelines for these types of steels can be found in the referenced source. [1].

Table 1. Chemical constituents of 1.7734 steel

Element	Min %	Max %
C	0,12	0,18
Si	-	0,2
Mn	0,8	1,1
S	-	0,015
P	-	0,02
Cr	1,25	1,5
Mo	0,8	1
V	0,2	0,3

To assess the properties of the material following modification, tests were performed on welded steel samples in condition 1.7734.4 and 1.7734.5.

Mechanical characteristics of steel in those conditions were given in Table 2, and further information can be found in [4].

Table 2. Mechanical characteristics of steel 1.7734.4 and 1.7734.5

Properties	1.7734.4	1.7734.5
0.2% Proof Stress [N/mm^2]	550	790
Tensile Strength [N/mm^2]	700	980-1180
Elongation [%]	12	10
Hardness	[205 HV]	29 [HRC]

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Stress analysis

The NGS calculation is performed based on the requirements outlined in [5], with the relevant input values provided in Table 3 for the most critical scenarios.

Table 3. The limit force components

	CS 23.499 (a) aft loads	CS 23.499 (b) forward loads	CS 23.499 (c) side loads
Z+ comp.	5598 N	5598 N	5598 N
X+ comp.	4478 N	-	-
X- comp.	-	2239 N	-
Y comp.	-	-	3918 N

Stress analysis was conducted using FEM. To minimize errors caused by mesh density, various mesh sizes were tested until convergence of stresses and displacements at key points were reached [2].

Figures 1 to 3 display the results obtained for the specified load in the area where cracks were previously detected on the airplane Utva-75.

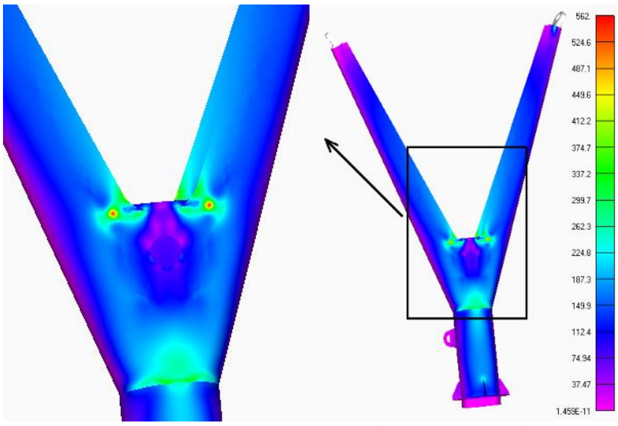

Figure 1. Stress distribution in the area of previous crack formation under aft loads

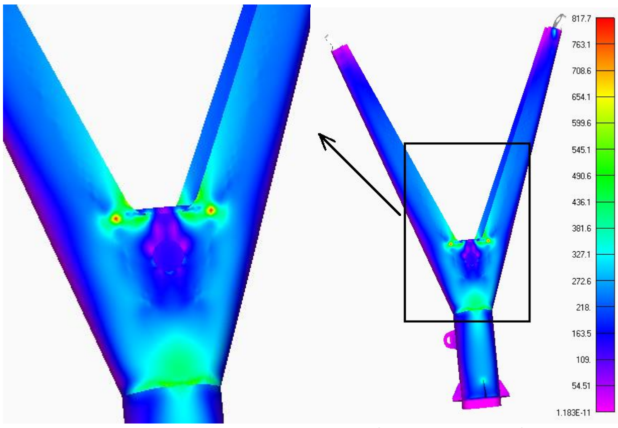

Figure 2. Stress distribution in the area of previous crack formation under forward loads

It has been observed that the maximum Von-Mises stress values occur in the areas where the cracks formed on the unmodified NGS. Therefore, it can be concluded that the additional reinforcement should fully eliminate regions with high stress concentrations.

In Figures 4 to 6, indicated stress values and position of stress concentration of NGS welded modification are shown.

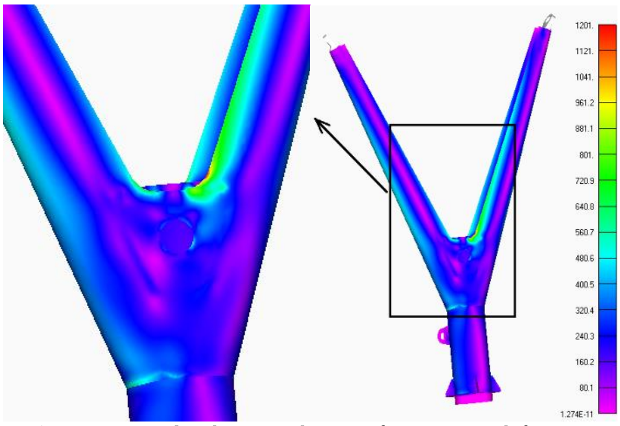

Figure 3. Stress distribution in the area of previous crack formation under side loads

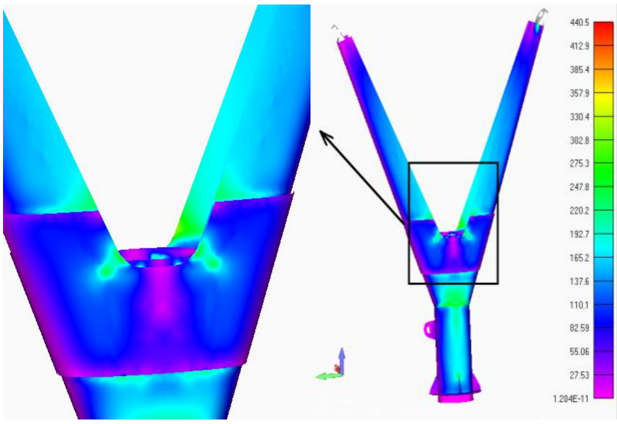

Figure 4. Stress distribution in the welded joint area under aft loads

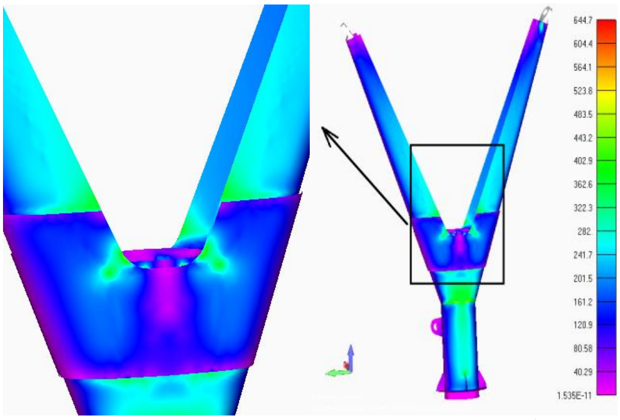

Figure 5. Stress distribution in the welded joint area under forward loads

The results indicate that the maximum stress occurs in the NGS under side load conditions. The normal stress values in this area will be used for calculating the welded joints.

It can be seen that the stress levels are highest for 23.499(c) side loads condition when landing. Without modification the concentration of Von-Misses stress in the root of NSG is 1201MPa with modification that concentration still exists but position has shifted upwards. After the modification the level of Von-Misses stress is 775,5MPa.

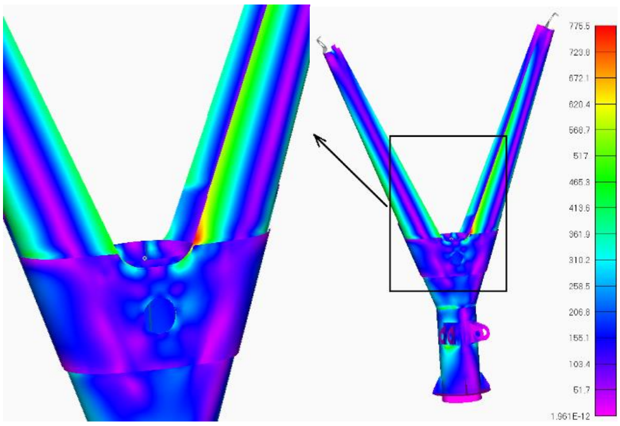

Figure 6. Stress distribution in the welded joint area under side load conditions

Experiment details

The experiment considers the impact of PWHT on the base material. A butt weld joint, utilizing a 1.2 mm thick sheet (commonly used in this assembly), is analyzed. Standard specimens, as per [3], were employed and extracted from the welded plates. The groove weld features a 1mm gap, and the welding sequence was performed in a single pass.

The following tests were conducted:
—Tensile testing,
—Hardness testing.

An overview of the specimens used to obtain the mechanical properties of the welded joints is provided in Table 4.

Table 4. Testing specimens and configuration

MATERIAL	PWHT	No. of specimens for tensile tests	No of specimens for hard-ness tests
1.7734.4	600°C/1.5h	3	2
1.7734.4	580°C/4h	3	2
1.7734.5	600°C/1.5h	5	2
1.7734.5	580°C/4h	5	2

The plates used for specimen production are displayed in Figure 7.

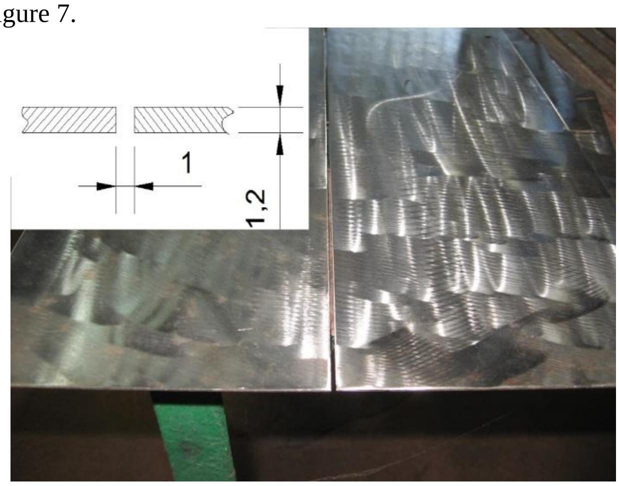

Figure 7. Pre-welding groove

The 141 (TIG) welding process involves joining metals by melting both the base and filler metals using heat. This heat is generated by an electric arc between the tungsten electrode and the base material. The filler metal, in the form of wire, is introduced into the molten pool, where it melts and fuses with the base metal. Argon is used as the inert gas during the welding process. The welded plates, following post-weld heat treatment (PWHT), are shown in Figure 8.

The specified parameters from the welding procedure are provided in Table 5.

Table 5. Welding specifications

Filler material	1.7734.2
Filler diameter [mm]	1,6
Current [A]	50-60
Voltage [V]	12
AC/DC current	DC-
Welding speed [cm/min]	3
Gas flow [l/min]	9,5

Figure 8. Welded sheets

The specimens are fabricated from welded plates, which are cut and milled to the specified dimensions as outlined in [3]. Figure 9 illustrates the form of the specimens prepared for tensile testing, while Figure 10 shows the dimensions of the specimens.

Figure 9. Tensile test specimens

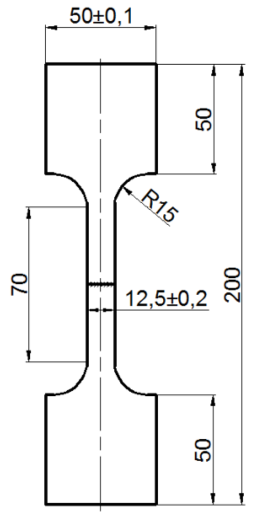

Figure 10. Specimen size

Results

Hardness testing is conducted using the Rockwell method. Measurements are taken in the base metal, weld seam, and heat-affected zone (HAZ). The hardness test data for the butt joint are provided in Table 6.

Table 6. Hardness measurement values

Specimen configuration	Specimens number	Base metal	Weld seam	HAZ
1.7734.4 600°C/1,5h	1	28	41	34
	2	28	41	37
	3	28	41	37
	4	28	40	35
	5	29	36	33
1.7734.4 580°C/4h	1	28	36	40
	2	28	44	34
	3	29	43	34
	4	30	41	36
	5	30	44	33
1.7734.5 600°C/1,5h	1	30	35	28
	2	29	35,5	28
	3	29	35,5	29
	4	28	37	28
	5	28	36	29
1.7734.5 580°C/4h	1	32	35	29
	2	33	38	32
	3	32	38,5	32
	4	32	35	31,5
	5	33	38	33

The data from Table 5 are shown in Figure 11 for WH 1.7734.4 steel and in Figure 12 for WH 1.7734.5 steel.

As shown in Figure 11, it can be concluded that the hardness of steel 1.7734.4 is highest in the weld seam zone, as anticipated.

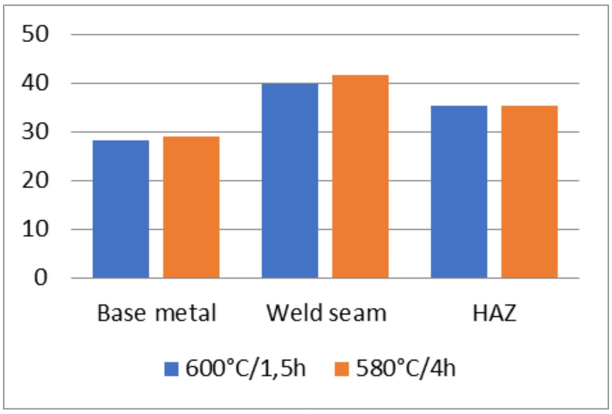

Figure 11. Hardness of steel 1.7734.4 samples

Changing the PWHT parameters from 580°C for 4 hours to 600°C for 1 hour leads to lower measured hardness values:

—4,3% for weld metal,

—0,6% for HAZ.

For the 1.7734.5 steel specimens, the data shows a 2.8% decrease in hardness in the weld seam and a 10% decrease in hardness in the HAZ following the same change in PWHT parameters.

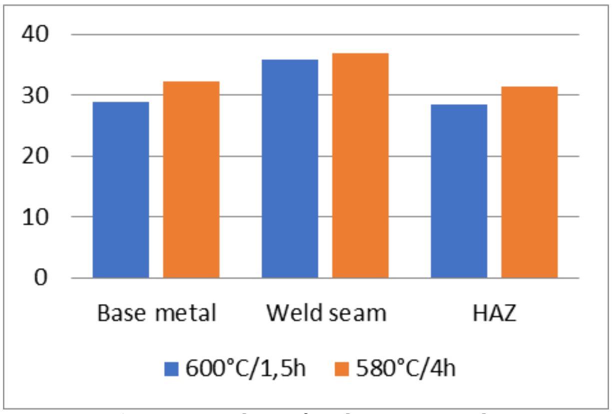

Figure 12. Hardness of steel 1.7734.5 samples

Tensile testing of 1.7734.4 steel specimens was conducted on machine SHIMADZU at “Military Technical Institute”, while testing for 1.7734.5 steel specimens was carried out in location ”Utva-AI”

The test setup is depicted in Figure 13, while the specimens after testing are shown in Figures 14 and 15.

Figure 13. Tensile strength testing machine “SHIMADZU”

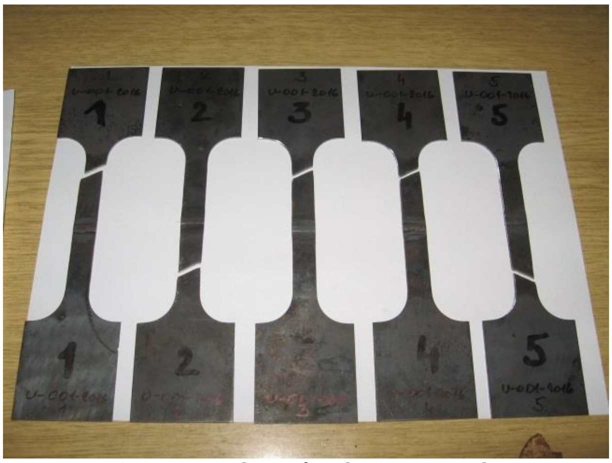

Figure 14. Hardness of steel 1.7734.4 samples

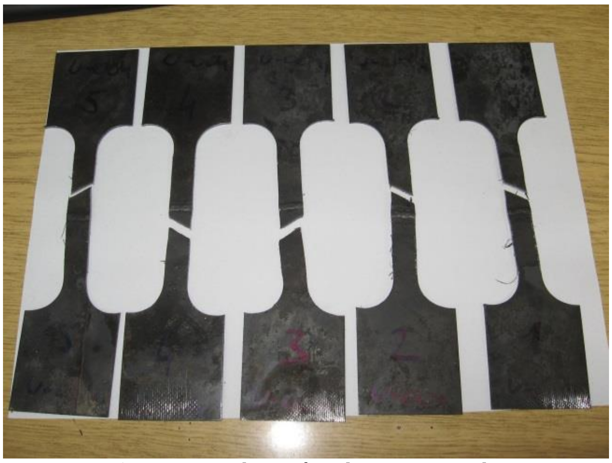

Figure 15. Hardness of steel 1.7734.5 samples

The results of the tensile tests are provided in Table 7 for steel 1.7734.4 and in Table 8 for steel 1.7734.5. The test was conducted on three specimens of steel 1.7734.4 and five specimens of steel 1.7734.5. The tensile strength is determined using the following expression:

$$R_M = \frac{F_M}{a \cdot b}$$

Where:

- R_M [N] – Peak tensile force
- a [mm] – Sample thickness
- b [mm] – Sample width

The data from Table 7 are presented in graphical form in Figures 16 and 17, while the data from Table 8 are shown in Figure 18. The graphs provide a comparative overview of the observed values for different PWHT conditions.

Changes in PWHT from 580°C for 4 hours to 600°C for 1 hour for specimens made of steel 1.7734.4 result in an 1.25% increase in tensile strength at the fracture location and in an 12.5% increase in tensile strength at the weld seam.

Table 7. Results of tensile testing on steel 1.7734.4

			Place of brake		Weld seam	
Material / PWHT	Sample number	Maximum force [KN]	Tensile strength [MPa]	Yield strength [MPa]	Tensile strength [MPa]	Yield strength [MPa]
1.7734.4 600°C/1,5h	1	13,2551	864	804	515	479
	2	13,6046	890	826	644	598
	3	13,2761	888	823	641	595
1.7734.4 580°C/4h	1	12,336	804	781	516	476
	2	12,6201	826	804	547	502
	3	12,3069	823	846	511	489

Table 8. Results of tensile testing on steel 1.7734.5

			Place of brake		Weld seam	
Material / PWHT	Sample number	Maximum force [KN]	Tensile strength [MPa]	Yield strength [MPa]	Tensile strength [MPa]	Yield strength [MPa]
1.7734.5 600°C/1,5h	1	15	979	-	564	-
	2	14,6	972	-	547	-
	3	15,3	997	-	671	-
	4	14,8	978	-	544	-
	5	15,2	992	-	652	-
1.7734.5 580°C/4h	1	15,6	984	-	614	-
	2	15,3	974	-	591	-
	3	15,4	971	-	655	-
	4	14,9	964	-	514	-
	5	14,9	942	-	568	-

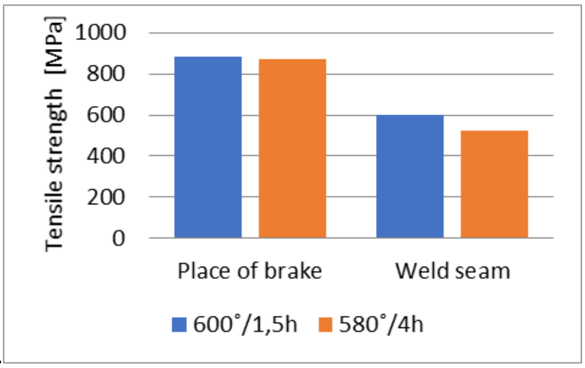

Figure 16. Steel specimen tensile strength 17734.4

A change in the PWHT parameters for specimens made of steel 1.7734.5 results in an 1.7% increase in tensile strength at the fracture location and in an 1.2% increase in tensile strength at the weld.

The measured yield strength of specimens made of steel 1.7734.4, as shown in Figure 17, indicates that changing the PWHT from 580°C/4h to 600°C/1h results in an 0.3% increase in yield strength at the fracture location and in an 4.3% increase at the weld seam.

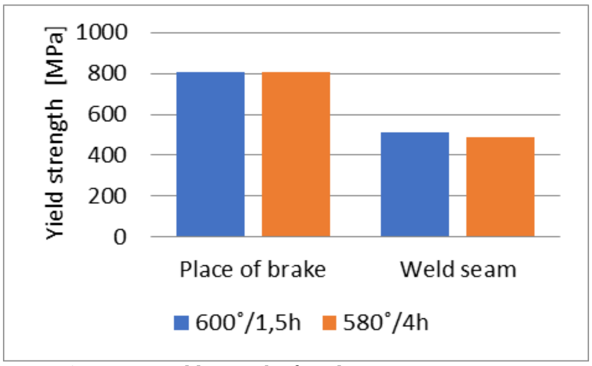

Figure 17. Yield strength of steel specimens 17734.4

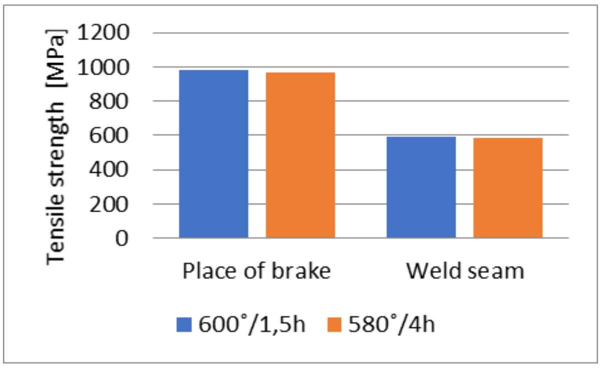

Figure 18. Steel specimen tensile strength 17734.5

Conclusion

The analysis presented in this paper focuses on determining the stress distribution in both the structure and welded joints of the NGS, under the loading conditions outlined in [5]. The stress analysis was performed using FEM.

The analysis of the NGS for the Utva-75 basic airplane revealed the necessity for modifications to reduce stress in the critical areas of the assembly. It was demonstrated that the additional stiffening could prevent local high-stress concentrations and lower the overall stress levels.

Another aspect of the paper focuses on testing welded joints using standard specimens to determine the most effective welding procedure, considering both material strength and production optimization.

Standard specimens of steel 1.7734 were tested, with varying PWHT parameters to assess the mechanical properties of the welded joints under different welding procedure specifications. The aim was to evaluate the potential for production optimization.

It is demonstrated that altering the PWHT parameters from 580°C for 4 hours to 600°C for 1 hour does not weaken the welded joints of the standard specimens. From a production optimization perspective, it is shown that the NGS could be manufactured using steel 1.7734.5 with PWHT parameters of 600°C for 1.5 hours, which would reduce the production costs and shorten the manufacturing time.

The presented results are consistent. However, further testing should be conducted using a larger number of specimens, with the possibility to vary additional parameters, in order to more accurately define the welding procedures for welded joints required in the production of NGS.

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Procena operativnog uticaja SecuDroneComm-a: Simulaciona analiza bezbedne komunikacije bespilotnih letelica u vojnim okruženjima

Savremene vojne misije zahtevaju sigurnu i komunikaciju u realnom vremenu između bespilotnih letelica (UAV) i komandnih jedinica. Ovaj rad ocenjuje platformu SecuDroneComm putem simulacija korišćenjem MATLAB-a i NS3. Ključni metrički parametri: kašnjenje, propusnost i stopa uspešnosti misija – procenjeni su u neprijateljskim i ograničenim uslovima. SecuDroneComm, sa hibridnom serverskom arhitekturom, AES-256 enkripcijom i logikom inspirisanom SDN-om, konstantno nadmašuje tradicionalne IKT platforme. Platforma pokazuje smanjeno kašnjenje, poboljšanu dostupnost sistema i bolju koordinaciju misija. Opterećenje usled enkripcije nadoknađeno je dinamičkim rutiranjem, čime se obezbeđuje integritet podataka i brz odziv. Uporedni grafikoni ističu operativne prednosti kroz nekoliko ključnih parametara važnih za misije. Rezultati potvrđuju pogodnost platforme SecuDroneComm za implementaciju u bezbednoj komunikaciji UAV sistema u vojnim uslovima. Omogućavanjem pouzdane, prilagodljive i šifrovane razmene podataka u realnom vremenu, platforma poboljšava uspešnost misija i efikasnost odlučivanja. Studija pozicionira ovu platformu kao rešenje spremno za buduće taktičke operacije.

Ključne reči: **bojni otrovi, bezbednost komunikacije, vojni UAV sistemi, razmena podataka u realnom vremenu, SecuDroneComm, simulaciona analiza i taktička efikasnost.**