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SECTION 5

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MECHANICAL ENGINEERING TECHNOLOGIES

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Optimization of Welding of the Truck's Rear Axle Semi-housing

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Abstract. The welding technology of the truck's semi-housing is presented in this paper. Steels of different mechanical properties and chemical composition were tested and influence of welding on those base metals was monitored. Their weldability was first analyzed (semi-housing tube, ring and flange), then the welding procedure and filler metals were selected and finally the welding technological parameters were defined. The analytical (computational) methods, the TTT diagrams were applied for estimates of the base metals weldability, as well as the experimental methods based on hardness measurements in the weld's critical zones and analysis of their microstructure.

Keywords: Welding, truck, semi-hosing, cored wire, high strength steel.

1. Introduction

The semi-housing assembly with the ring and flange is manufactured by welding. All the necessary dimensions are being measured from the front of the smaller diameter of the semi-housing tube (Figure 1) [1]. The welding procedure assumes welding of a flange (3) (fillet joint 5×5) and then the ring (2) with the fillet weld of the same dimensions. After that the other side of the flange is welded by the fillet weld of dimensions 7×7 which is turned towards the ring. During the whole welding period positioning was done by the special tools. The positioner also has a role to prevent appearance of deformation on the assembly.

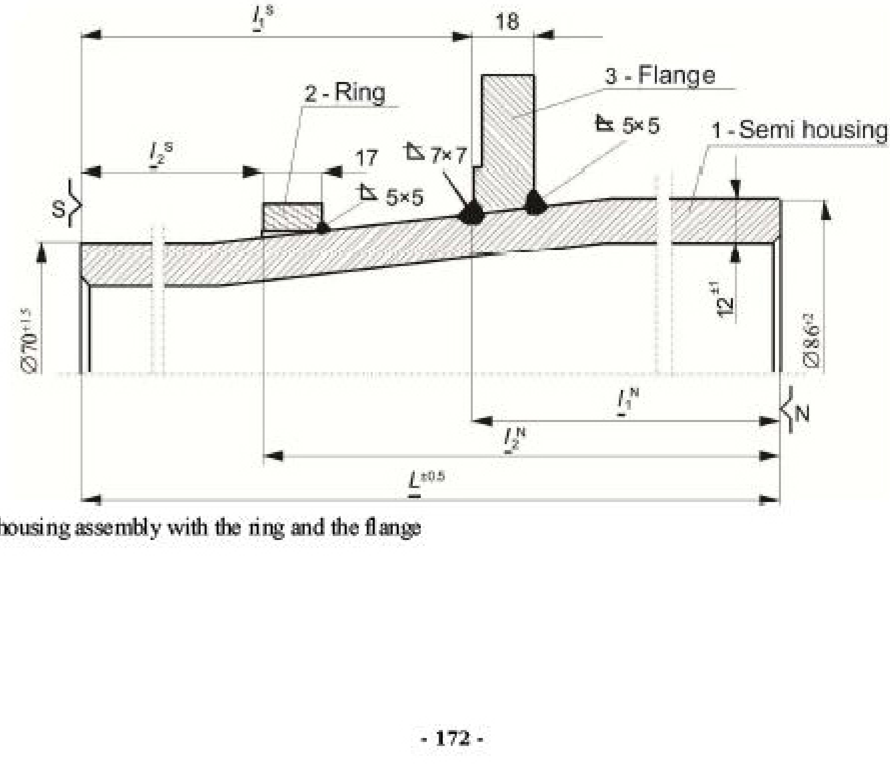


Fig. 1. Semi-housing assembly with the ring and the flange

2. Base and filler metals

In the selection of the welding procedure, the filler metal, welding parameters and protective gas, one starts from the chemical composition and thickness of the base metal (BM) and from its mechanical properties. One must primarily take into account all the requirements defined by construction drawing, which are related to required geometry and especially emphasized safety measures. Chemical composition of the steel, according to standard and analyzed in laboratory conditions is given in Table 1, while in Table 2 are presented mechanical properties, thickness and microstructure of the base metal [1, 6, 7].

Mark	Standard	Requirement	Chemical elements content, %									
			C	Mn	Si	P	S	Cr	Cu	Mo	Al	N
25MnCr6	UNI 6403 IVECO-52541	Prescribed	0.20 - 0.28	1.20 - 1.70	0.15 - 0.35	max 0.035	0.020 - 0.040	0.30 - 0.60	max 0.30	-	0.020 - 0.050	-
		Analyzed	0.26	1.28	0.15	0.012	0.020	0.40	-	-	-	-
25MnCr6	UNI 6403 IVECO-52541	Prescribed	0.22 - 0.29	0.50 - 0.80	0.15 - 0.40	max 0.035	max 0.035	0.90 - 1.20	-	0.15 - 0.30	-	-
≈ Č 4730	SRPS EN 10083-1:2011	Analyzed	0.27	0.71	0.26	0.033	0.027	1.13	-	0.21	-	-
FE 510	IVECO-52891	Prescribed	max 0.22	max 1.70	max 0.60	max 0.050	max 0.050	-	-	-	min 0.020	0.009
≈ Č 0561	SRPS EN 10025-1:2011	Analyzed	0.15	1.17	0.18	0.013	0.020	-	-	-	0.022	-

Tab. 1. Chemical composition of the base metal.

Mark	Thickness, s, *mm*	R_m, *MPa*	$R_{p0.2}$, *MPa*	A_5, %	HV	Microstructure
25MnCr6	10	875	640	14	172	Interphase tempering structure (predominantly sorbite)
(25MnCr6) ≈ Č4730	13	980	700	11	252	Interphase tempering structure (predominantly sorbite)
(FE510) ≈ Č0561	12	565	185	27	170	Lamellar ferrite-pearlite microstructure

Tab. 2. Mechanical properties of the base metal, thickness and microstructure.

Two versions are proposed for welding of the considered assembly:

1. Welding in the protective gas atmosphere with application of the cored wire VAC 60, of diameter Ø1.6 *mm* and

2. Welding with the cored wire with and without preheating with wire FLUXOFIL 42, of diameter Ø1.2 *mm*.

In table 3 are given the chemical compositions of the used wires, protective gas composition and mechanical properties of the pure weld metal [1]. By executing numerous test welds it was established that the best results are achieved by application of gas mixture of argon and carbon-dioxide in ratio $Ar/CO_2 = 80/20$ [1, 4].

3. Estimate of the base metals weldability

The semi-housing tube (position 1 in Figure 1) is made of low alloyed steel very sensitive to welding. According to computational methods for estimate of this steel's weldability, the steel should be preheated and the dried and clean welding wires should be used. Based on the corresponding continuous cooling diagram (CCT) one can determine the cooling time between 800°C and 500°C ($t_{8/5}$), i.e., the output properties of the joint, by the adequate selection of the welding regime or the preheating temperature, [3]. In Figures 2 and 3 are presented the CCT diagrams for the two used steels.

Wire type	Chemical composition, %						Gas mixture Ar/CO_2, %	Mechanical properties of the weld metal			
	C	Si	Mn	Cr	Ni	Mo		R_m, *MPa*	R_{eH}, *MPa*	A_5, %	KV, *J*
VAC 60 cored	0.1	0.9	1.5	-	-	-	80/20	510-590	410- 490	22-30	80-125
FLUXOFIL 42 cored	0.05	0.35	1.3	0.4	2.4	0.4		730- 830	670-720	16-20	80-120

Tab. 3. Chemical composition of wires, protective gas type and mechanical properties of the pure weld metal.

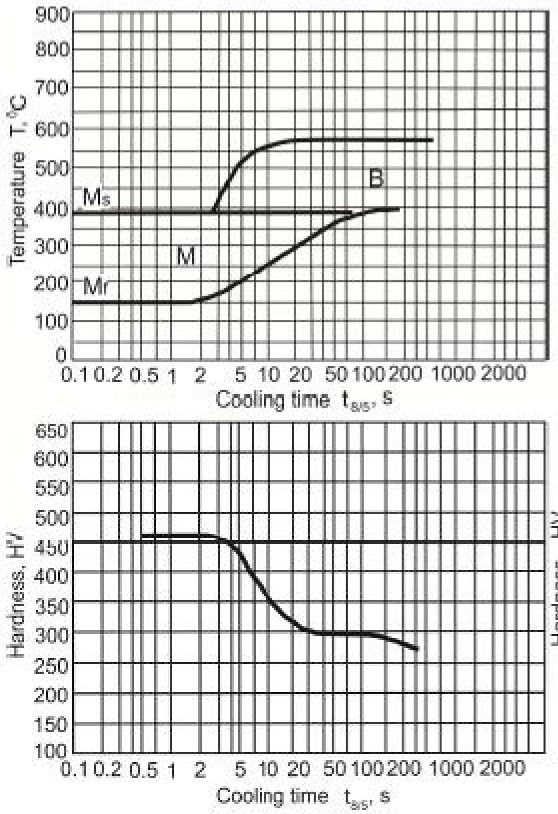


Fig. 2. KH diagram for steel 25MnCr6.

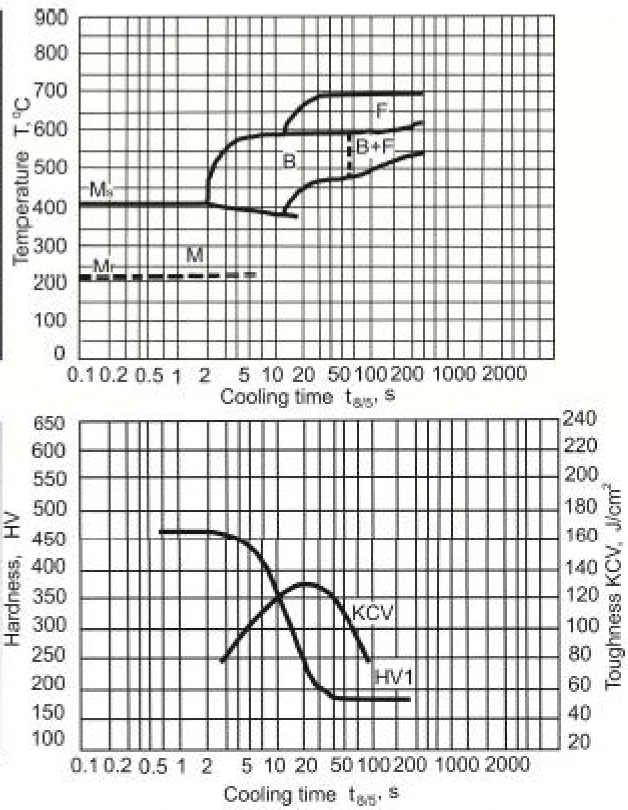


Fig. 3. KH diagram for steel FE 510.

The flange (position 3 in Figure 1) is being made of the C-Mn high strength steel, whose weldability is estimated based on the equivalent carbon formula (CE) and base metal thickness (s). Considering that in this case CE < 0.45 and s < 25 *mm*, it is assumed that this steel is well weldable and that it is not prone to appearance of cold cracks, namely the transitional brittleness. This is supported by the fact that measured hardness in the heat affected zone (HAZ) is less than 350HV. By adequate selection of the welding regime one can achieve the optimal toughness, as well.

By analyzing the CCT diagrams one can conclude that in both steels martensite appears for all the cooling times less than 3 seconds what points to necessity for the cooling time to be longer. In this case, the cooling time was controlled by the heat input, i.e., via the welding parameters – the driving energy and the welding speed.

4. Basic welding parameters

Welding parameters were adopted based on the corresponding computational methods and recommendations for selection of parameters for welding in the protective atmosphere of CO_2 (Table 4). Some earlier results were used in selecting the welding parameters [1, 2, 4, 5]. The prescribed welding parameters must be tested on several samples to establish whether the satisfactory properties of welded joints were obtained.

Weld dimensions	Basic welding parameters by the CO_2 procedure					q_l	a	$\delta_1, (\delta_1', \delta_1'')$	$\delta_2, (\delta_2', \delta_2'')$
Weld	I, *A*	U, *V*	v_z, *mm/s*	v_t, *m/min*	Q, *l/min*	*J/mm*	*mm*	*mm*	*mm*
5×5 Tube-ring	260-300	28-30	7.22-7.78	4.2-5.3	16-18	850-1000	6.2	2.2	3.2
5×5 Tube-flange	260-300	28-30	8.05-8.61	4.2-5.3	16-18	850-1000	6.8	6.8	3.2
7×7 Tube flange	300-350	30-32	5.5-6.1	5.3-7.2	18-20	1400-1800	8.0	3.8	2.8

Tab. 4. Basic welding parameters and penetration depth [1]

5. Results of hardness measurements and micro structure investigation

Measurements of hardness were done on specially prepared samples on the ZWICK 3812 device with indentation force of 3 N (0.3 daN). Hardness was measured only on samples welded by the full wire. In diagrams in Figures 4 and 5 are presented results of hardness measurements for joints tube-ring (5×5) and tube-flange (5×5), respectively executed by the full wire. The microstructure of the executed welded joints is given in figures 6 and 7, as well and the joints' characteristic zones are emphasized. On samples executed by the cored wire the hardness values were similar.

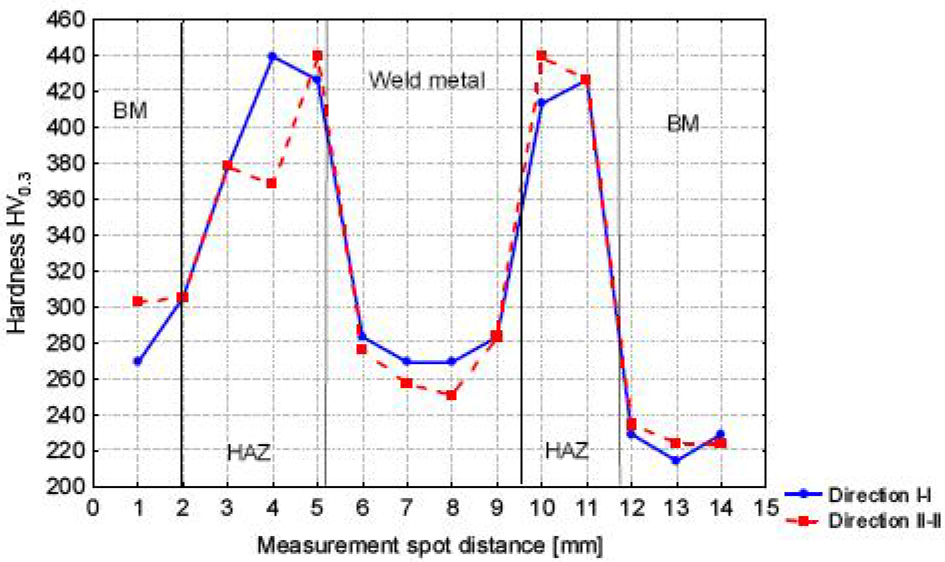


Fig. 4. Hardness distribution semi-housing tube – ring (5×5).

6. Conclusion

The truck's rear axle, as one of the most important assemblies on a vehicle requires not only prescribing the optimal welding technology for the parts of the assembly, but also that the obtained mechanical characteristics of joints and the microstructure be experimentally checked on the test samples. During the hardness measurements of the welded samples, certain zones with somewhat increased hardness were noticed, but that could be tolerated in the case when the prescribed welding technology is strictly obeyed.

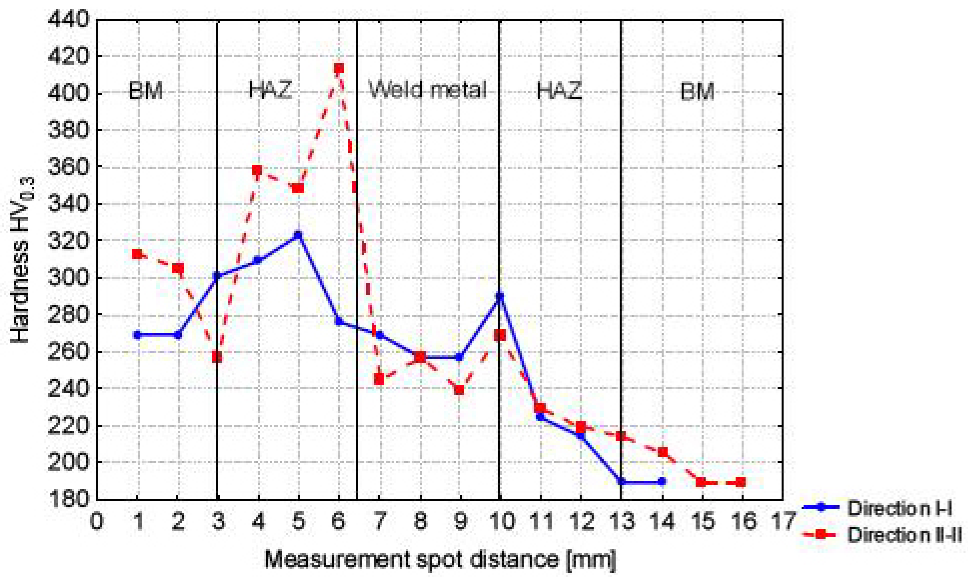


Fig. 5. Hardness distribution semi-housing tube – flange (5×5).

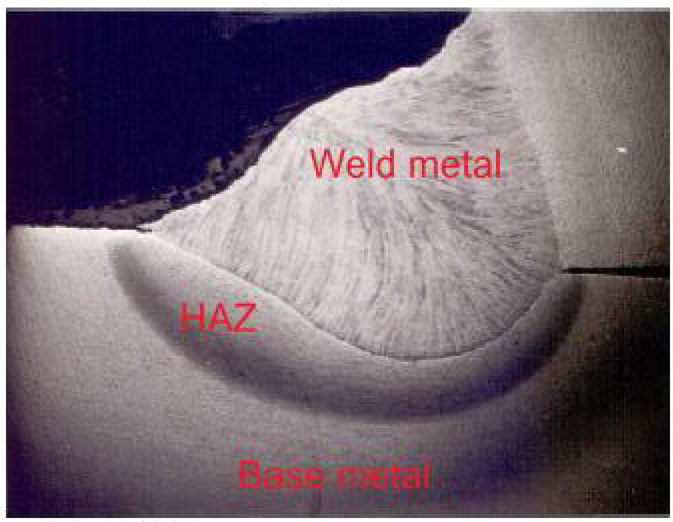
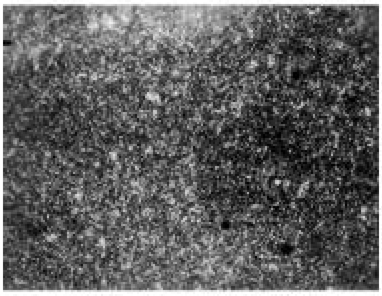
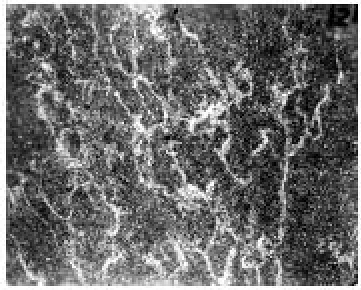


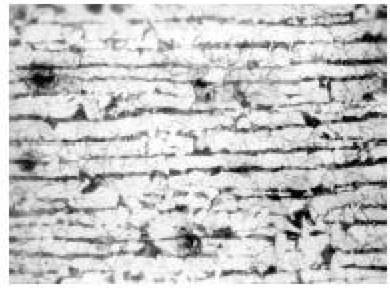
Fig. 6. Microstructure of executed welded joint



BM – tube – Interphase tempering structure – predominantly sorbite



Weld metal – Vidmanstetten structure



BM – flange- - Lamellar ferrite-pearilte microstructure

Fig. 7. Microstructure of individual zones of the assembly

Zones with traces of quenching structures were discovered by metallographic investigations and by measuring the hardness on the test samples. The appearance of zones with increased hardness can also be tolerated when the content of the diffused hydrogen in the weld and in the HAZ is reduced to a minimum (< 5 ml/100g of the weld metal). That is achieved by preheating, control of the content and flow of the protective gasses mixture, welding in the room without draft, maintaining the technological parameters, position of the gun during the welding, application of the clean and dry filler metals, as well as by preparation of the prescribed clean and dry groove and its vicinity.

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References

1. LAZIĆ, V., JOVANOVIĆ, M., ADAMOVIĆ, D., RATKOVIĆ, N., *Improvement of the welding procedure of the fire truck rear axle semi housing assembly*, Mobility and Vehicle Mechanics, Vol. 30, No. 1, pp. 45-57, 2004.
2. LAZIĆ, V., JOSIFOVIĆ, D., ADAMOVIĆ, D., JOVANOVIĆ, M., ***Design and application of apparatus for welding the truck body assembly in the protective gasses atmosphere***, Euromat '97, Maastricht, Nederland, 1997.
3. LAZIĆ, V., SEDMAK, A., ŽIVKOVIĆ, M., ALEKSANDROVIĆ, S., ČUKIĆ, R., JOVIČIĆ, R., IVANOVIĆ, I., Theoretical-experimental determining of cooling time ($t_{8/5}$) in hard facing of steels for forging dies, Thermal science, Vol. 14, No. 1, pp. 235-246, 2010.
4. ARSIĆ, D., LAZIĆ, V., ALEKSANDROVIĆ, S., MILOSAVLJEVIĆ, D., KRSTIĆ, B., MARINKOVIĆ, P., DJORDJEVIĆ, M., ***Application of high strength steels to responsible welded structures on motor vehicles***, Mobility & vehicles mechanics, Vol. 40, No. 4, pp. 79-88, 2014.
5. ARSIĆ, D., LAZIĆ, V., NIKOLIĆ, R., ALEKSANDROVIĆ, S., HADZIMA, B., DJORDJEVIĆ, M., ***Optimal welding technology of high strength steel S690QL***, Materials Engineering - Materiálové inžinierstvo, Vol. 22, No. 1, pp. 33-47, 2015.
6. **SRPS EN 10083-1:2011**, Steels for quenching and tempering - Part 1: General technical delivery conditions.
7. **SRPS EN 10025-1:2011**, Hot rolled products of structural steels - Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels.