IMPROVING THE PROCESS OF ACHIEVING REQUIRED MICROSTRUCTURE AND MECHANICAL PROPERTIES OF 38MNVS6 STEEL

Dominika SIWIEC[1], Renata DWORNICKA[2], Andrzej PACANA[3]

[1]*Rzeszow University of Technology, Rzeszow, Poland, EU, d.siwiec@prz.edu.pl, ORCID ID: 0000-0002-6663-6621*

[2] *Cracow University of Technology, Cracow, Poland, EU, renata.dwornicka@mech.pk.edu.pl, ORCID ID: 0000-0002-2979-1614*

[3]*Rzeszow University of Technology, Rzeszow, Poland, EU, app@prz.edu.pl, ORCID ID: 0000-0003-1121-6352*

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Abstract

The micro-alloyed steel 38MnVS6 (38MnSiVS5 or 38MnVS5) applied mostly in the automotive industry (for example production of forgings), has a high yield point and relatively good wear resistance. Aim of the study was preliminary to analyse the influence of twice the normalization process of micro-alloyed steel 38MnVS6 on its microstructure and mechanical properties. The normalization process was made in two steps in a pusher furnace PP-300 at temperatures 910 °C (cooling under the fan 5200 rpm) and 880 °C (cooling in open air). The total normalization time was 16200 seconds each time. Yield strength, tensile strength and hardness were analysed. Analysis was occurred based on results of the normalization process of three forgings for use in the automotive industry, ball-shaped and weight 28 N, forged from a temperature of 1250 ° C from micro-alloyed steel 38MnVS6. It has been shown that carrying out two processes for normalizing micro-alloy steel 38MnVS6 allows achieving its homogeneous and fine-grained microstructure and obtaining better mechanical properties and thus filled the gap regarding the lack of analysis of the impact of the normalization process on 38MnVS6 steel.

Keywords: 38MnVS6, mechanical engineering, normalization process, mechanical properties, quality of product

1. INTRODUCTION

The dynamic development of industry caused that need for reliable and relatively low-cost production of products has become a key in making the effective actions of enterprises as part of their sustainability development [1-3]. These actions are referred in particular to the minimization of the costs of logistic actions, thermal treatment and realization production process time [4]. As part of these activities particularly important, mainly in the automotive industry [4], is using the micro-alloy steel, for example, 38MnVS6 (38MnSiVS5, previously marked 38MnVS5) [5,6], so the medium-carbon-manganese steel [7,8], about an application to controlled cooling from forging temperature. It results among others from content for example Al, Ti or V, which allows the growth of steel strength, without hardening and tempering. Addition, the 38MnVS6 steel has high yield strength and good wear resistance [1,9]. Therefore, it has particularly application to production the automotive components in the form of forgings [10,11], for example crankshafts [12], and also engine pistons, which successfully replace pistons from aluminum-silicon alloy [13]. Using the micro-alloy steel, although that steel needs the mechanical machining constituting approx. 50 % - 60 % of all production costs [4], is allowed to reduce the energy and production costs [7,11,14], for example compared to heat-treated steel or hardened steel by 30 % and 20 % respectively [1]. Also, in the context of reduction of cost by production among others forgings made of micro-alloy steel, it is important the fact that when are produced under the right conditions, they do not require normalization. It results from micro additions introduced into steel, which allows creating a homogeneous and fine-grained structure, preventing the growth of recrystallized austenite grains [15]. However, if the need arises to the normalization of micro-alloy steel, which the aim is creating required microstructure and mechanical properties of steel, it anyway this process is less expensive than normalization of the alloy steel [16]. In the context of normalization of the micro-alloy steel, the authors of works [16,17] analysed the mechanical properties and microstructure of normalized micro-alloy steel with including the influence of micro additions, i.e. Nb [17], zirconium and titanium [17]. At work [17] in context of based on the weld, it was shown that as increases holding time at normalization temperature 920 °C, the microstructure of the columnar grain zone (CGZ) is modified from one column grain to one equiaxed grain (both in joint with the addition of Nb and without the addition of Nb). It also was shown, that the mechanical properties have not shown the clear changes with increases holding time at normalization temperature 920 °C, both with the addition of Nb and without the addition of Nb. Also, for example, with increases holding time at normalization temperature the hardness of weld with Nb was increased, but the elongation and impact strength have decreased significantly. Whereas at work [16] the influence of zirconium and titanium in connections were analysed, for microstructures and mechanical properties, among others the micro-alloy steel, and it was comparing the results with the low-alloy stainless steels. It was concluded, i.a. the presence of sludge contributes to the improvement of strength and impact strength of steels containing micro-alloy in the heat-treated condition. However, though the analyses in the context of normalization of micro-alloy steel it was concluded that not analysed the normalization one of the micro-alloy steel i.e. 38MnVS6 (38MnSiVS5 or 38MnVS5) [4], which is mainly used in the automotive industry [10-13]. At the same time, as part of the review of the literature on the subject, it was shown that this steel is an important research area.

The steel 38MnVS6 was analysed for example in terms of machinability [4], elastic properties after the hardening process [18], as well as the influence on its microstructure of the controlled forging and cooling process [1]. For example, at work [12] authors were analysed the steel machinability, by the influence the cutting speed, cutting force and feed speed for flank wear and hardness of TiN coated carbide tool inserts. It was concluded, that machined chips are regular and discontinuous, therefore it was considered that steel machinability is more effective than the alloy steels about the same hardness (i.e. AISI 1405 and AISIS 5140) heat-treated at the same conditions. In turn, at work [1] was analysed the influence of controlled forging and cooling process on the structure of steel, analysed the parameters of the process, value and temperature of strain, and also the cooling speed after forging. It was shown, that the smallest austenite grain is possible to achieve by 70 % strain and at temperature 850 °C in the final stage of the forging process, while the authors of [18] analysed the elastic properties of steel after the induction hardening process. In the part of analysis, the steel sample was annealed before quenching. The analysis was shown that in effect if annealed the changes of elastic properties were done, where the transverse wave speed was highest than longitudinal wave velocity, and at the same, it was caused the increase in Poisson's ratio about 0.32 %. A review of the literature on the subject indicates that so far the analysis of the micro-alloy steel were making, but these analyses did not include double normalization of 38MnVS6 steel. Therefore, it was concluded that it is a gap, in view of shown importance of micro-alloy steel 38MnVS6 in the production of products mainly from the automotive industry [4,10-13]. Therefore, the aim of the work was to analysed the influence of double normalization of micro-alloy steel 38MnVS6 as part of changing its microstructure and mechanical properties. The analysis was made based on research results obtained from enterprise ForgeX Polska Sp. z o.o. localized in Podkarpacie. The research was concerned about double normalization in the context of the pursuit of achieving the required microstructure and mechanical properties of the forgings from micro-alloy steel 38MnVS6.

2. SUBJECT OF STUDY AND MATERIAL

The micro-alloy steel 38MnVS6 (38MnSiVS5, before called 38MnVS5) [5, 6] is medium-carbon-manganese steel 38MnVS6 [8, 10], which is one of main of unhardened steels [7] about destiny for controlled cooling from forging temperature. One of the benefits using micro-alloy steel 38MnVS6 is the content of micro alloys, for example V (**Table 1**), which allows on the growth of steel strength without necessarily hardened and tempered, which in turn off allows reducing the production costs [7,14].

Table 1 Chemical compositions of micro-alloy steel 38MnVS6 [7,9,19]

Component	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**V**	**N**	**V**
Content [%]	0.34 – 0.41	0.15 – 0.80	1.20 – 1.60	<0.025	0.02 – 0.06	<0.30	0.08 – 0.20	0.01 – 0.02	0.08 – 0.20

The steel 38MnVS6 because i.a. has high yield strength and good wear resistance [1,9] has applies to the production of hot forged products from the automotive industry [9,12,14] for example car forgings [10] which are the subject of this work. The subject of the study were three forgings with a ball shape and weight 28 N, forged from temperature 1250 °C from 38MnVS6 steel, which choice resulted from the need of achieving their required mechanical properties (**Figure 1**).

Figure 1 An example of forging after shot blasting process (source: own study)

The aim of making the double normalization process was to achieve the required microstructure and mechanical properties of 38MnVS6 steel, which are presented in **Table 2**.

Table 2 Set of required mechanical properties

Hardness [HBW]	**Yield Strength Re [MPa]**	**Tensile Strength Rm [MPa]**	**Elongation A5 [%]**	**KVmin [J/cm2]**
4.51 – 3.97	≥ 450	600 – 770	≥ 15	27

As the part of selected subject of the work, it was analysed main, selected mechanical properties, ie. yield strength (Re, MPa), tensile strength (Rm, MPa) and hardness (HBW). During the measurements it were used, among others testing machine ZWICK BZ200/SN6S-M and impact hammer Charpy LabTest CHK300J. From three pieces of samples with dimensions 105 mm × 105 mm, a bite of material from protruding material from micro-alloy steel 38MnVS6 (rolled steel mill material) was cut. The bit of material was obtained in effect material overheating in a gas furnace at temperature 1250 °C and forging by a five-ton hammer, which was cooling was on free air. Next, the bit of material was heated in the gas furnace at temperature 1250 °C, in a matrix on the five-ton hammer, receiving forging with a ball shape and weight 28 N, which was cooling was on free air. Then, forgings were double normalized in a pusher furnace PP-300. In the first step of normalization, the furnace was heated to 910 °C, and cooling took place with a fan about parameters 5200 rpm. In the second step, three normalized forgings were normalized again (i.e. double normalized), where the furnace was heated to 880 °C, and cooling was on free air. Total time of normalization both in the first and second steps was 16200 seconds (i.e. 4h 30 minutes) by moving the tape every 1800 seconds (i.e. 30 minutes). The results achieved of selected mechanical properties after each step of the machining stage were analysed.

3. RESULTS

The set of the mechanical properties selected for analysis after the double normalization process of three forgings from 38MnVS6 steel is shown in **Table 3**.

Table 3 The set of selected mechanical properties

Step of process	Mechanical properties			
	Sample number	Re (MPa)	Rm (MPa)	HBW
Material from the smelter	1 - 2 - 3	578 – 568 - 593	822 - 821- 852	234 - 249 - 241
A bite after forging	1 - 2 - 3	530 -509 - 521	867- 808 - 817	266 - 252 - 252
Forging without heat treatment	1 - 2 - 3	512 - 514 - 505	825 - 833 - 825	249 - 249 - 252
Forging after normalization	1 -2 - 3	413 - 478 - 424	751- 752 - 756	224 - 224 -217
Forging after normalizing twice	1 -2 - 3	480.59 – 473.5 – 463.01	733.83 – 767.38 – 741.08	-

a) b)

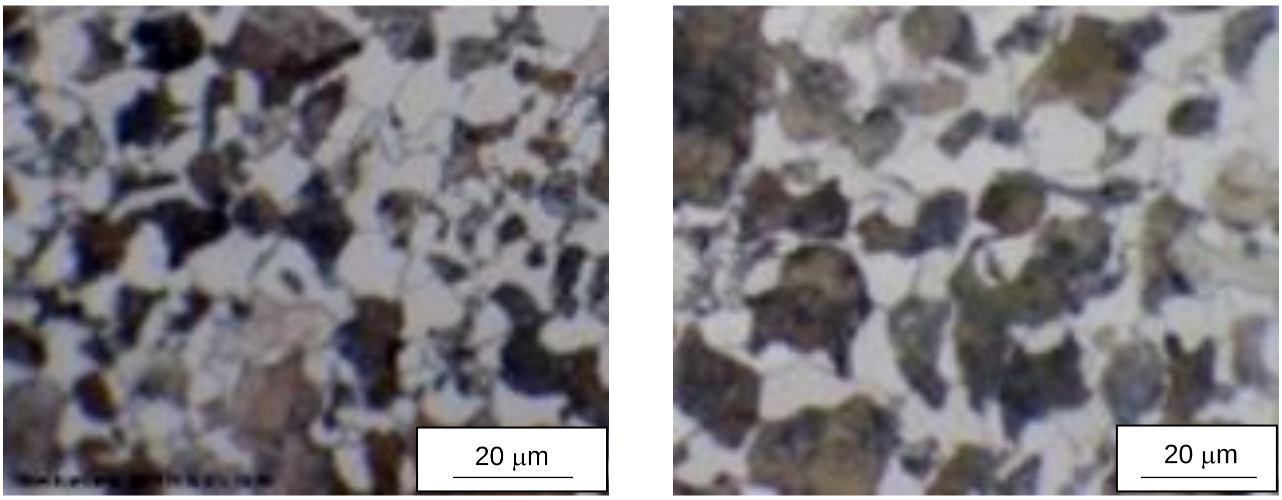

Figure 2 A comparison of the microstructure of micro-alloy steel 38MnVS6 in zoomed 500, digestion: nital, a) before double normalization, b) after double normalization (source: own study)

After analysis the values of selected mechanical properties for three samples cut from initial material from 38MnVS6 steel (i.e. material from the smelter), and also a bite after forging and forging without heat treatment, incompatibilities meeting properties of tensile strength, which were exceeded 770 MPa were shown. Next, it was demonstrated that made one time of normalization process allow achieved only selected mechanical properties, resp. yield strength and hardness. Despite this, the yield strength was not achieved yet, which for samples about numbers 1 and 3 were respectively equal 431 MPa and 424 MPa. In turn, it was shown that made double normalization process was effective and allows achieved all intended mechanical properties. Additional, during analyses the microstructures of 38MnVS6 steel was analysed before and after double normalization process (**Figure 2**) by using a metallographic optical microscope OLYMUS PMG 3. It was concluded that the double normalization process was allowed achieved homogeneous, fine-grained perlite-ferritic microstructure.

4. CONCLUSION

Making the right actions of enterprises in part of their sustainable development is a necessary area in pursuit of continuous improvement [3,20-22]. One of the key actions of enterprises from the automotive industry is the right machining steel under to achieving its need properties. Therefore, the aim of the work was preliminary analysed the influence of the double normalization process of micro-alloy steel 38MnVS6 on its microstructure and mechanical properties. Analysis was made based on results of the normalization process, regarding normalization three forgings about ball shape and weight 28 N, forged from a temperature of 1250 °C from micro-alloy steel 38MnVS6, having applications in the automotive industry. The selected properties were analysed, i.e. hardness, yield strength and tensile strength. It has been shown that carrying out two processes for normalizing micro-alloy steel 38MnVS6 allows achieving its homogeneous and fine-grained microstructure and obtaining better mechanical properties. It was demonstrated the influence double normalization process of microstructure and mechanical properties of 38MnVS6 steel, and thus the gap was filled regarding the lack of analysis of the impact of the normalization process on 38MnVS6 steel. The applied improvement procedure may be of interest for other industry branches i.a. in steel industry [23-25], corrosion resistance [26,27] coatings [28] and bioceramics [29-31] as well as in management [32-34].

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