AN ANALYSIS OF THE INFLUENCE DOUBLE NORMALIZATION PROCESS ON MECHANICAL PROPERTIES AND MICROSTRUCTURE 38MNVS6 STEEL

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Abstract

The aim of the article is to analyse of the impact the double normalization process of 38MnVS6 micro-alloy steel on the achievement of the required microstructure and selected mechanical properties. The analysis was made based on values of elongation at break and the criterion of the minimum permissible breaking work. The products used in the automotive industry were analysed. It were the forgings from 38MnVS6 steel in ball-shape and weights 28N forged at a temperature of 1250°C. It was shown that the double normalization process of 38MnVS6 steel was improved its microstructure and allowed on achieving the needs mechanical properties. The results shown in the work can be useful for other enterprises to achieve the effective processing of products, e.g. from the automotive industry.

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

1. INTRODUCTION

Improving the production process of the products includes for example reduction of heat treatment time [1-4], and the improvement of product properties. It is possible by using micro-alloy steel. These steels in compared e.g. to alloy steels [5] allow for reducing the production costs even to 30% [6]. It results from not needs to subjecting these steels to hardening and tempering [6, 7]. The popular micro-alloy steel is 38MnVS6 steel (38MnSiVS5 or 38MnVS5) [7, 8]. This steel is mainly used in the automotive industry for production of products in the form of forgings. The examples are crankshafts and also engine pistons [9-12]. The literature review has shown a need to make an analysis of the 38MnVS6 steel [12, 13]. For example in work [13], it was shown that by added 0.05 % Nb it is possible to achieve the maximum hardness of steel and tensile strength. This hardness was 200HV, while the tensile strength was equal to 720 MPa. It was shown, that normalization of the steel with the addition of the niobium allows for achieving the homogeneous microstructure and fine perlite colonies evenly distributed in the ferrite. Then, in the work [14] the impact of additives on 38MnVS6 steel was analysed. The impact of manganese sulphides on the fatigue life of 38MnVS6 steel was analysed. The Wohler curves were used for that. These curves were appropriate at high nominal stress amplitude levels compared to the forged material [14]. Additionally, it was shown the positive relationship between shape and manganese sulfide content, taking into account the forging process and the fatigue life of the material. In turn, the authors of work [15] were analysed the additional tellurium to 38MnVS6 steel. It was shown that the diameter of the inclusions increased with increasing tellurium content in the steel. The proportion factor of inclusions was small. Then, the authors of work [16] have shown the influence the heating 38MnVS6 steel on the weld structure during laser welding. Also, it was researching the mechanical properties of the welded joints in different preheating temperatures. The results were shown that e.g. preheating allows the greater laser absorption

capacity of the metal, what is generates an increase in the width of the weld. Despite in the work [17], deformation of hot-rolled micro-alloyed steel bars 38MnVS6 was shown by the MES model. It was concluded that the proposed model allows on optimize: groove geometry, roll transition schedule, and mill parameters and temperature. Wherein, the aim was to achieve a better quality and product performance. Then, in publications [18-20] it was presented the mathematical models of dynamic recrystallization (DRX) and steel grain growth 38MnVS6 hot compression tests. Also, the tests of isothermal annealing on the Gleeble-1500 thermomechanical simulator were made. Among other things, it was found that the simulated mean values of the full-grain size DRX showed good agreement with the measured. Another example is work [21], in which the hot flow stresses of 38MnVS6 steel were analyzed. These stresses were described by Cingar and McQueen, JMAK or Hensel-Spittel equations. The graphical and statistical comparison was shown that e.g. the predicted curve of the flow according to the proposed model enables adjustment to the experimental data. Additionally, the authors of work [22] have presented the production of 38MnVS5 steel as part of improving its quality. Except that, the vat slag with alkalinity (CaO/Al_2O_3) and an indicator that enables the improvement of desulphurization and absorption capacity in steel was designed.

Based on the literature review it was concluded, that previous analyses did not cover the issues of double normalization of the 38MnVS6 steel. It can result from the fact that is important to limit the number of heat treatments. Thanks to that it is possible to reduce the production costs. However, the enterprises still researching for different treatments, thanks for which the right combination of properties, i.e. strength, impact strength, as well as proper fragmentation of the microstructure, will be achieved. This type of problem was solved by performing double normalization of 38MnVS6 steel in one of the Podkarpacie enterprises. Therefore, the aim of the article is to analyse the impact of the double normalization process of 38MnVS6 micro-alloy steel on achieving the required microstructure and selected mechanical properties. The analysis was made based on research results obtained from Forgex Polska Sp. z o. o. enterprise localized at Podkarpacie in Poland. The article is a continuation of the article [23], in which the yield strength, tensile strength and Brinell hardness were analysed.

The obtained results, documenting a significant improvement in the technological properties of steel and a strong reduction in costs, may be of interest to a wide group of industrial recipients, including in the field of quality [24, 25] and risk management [26, 27], corrosion protection [28, 29] and the use of structural steel in construction [30] and railways [31-33]. The subject matter may also be interesting for the research area, where work on the corrosion protection of materials [34-36] and their coatings [37] is still in progress, as it determines the operation of laboratory equipment in aggressive biological environments [38]. The results should also be valuable as a source of data for the area of mechanics [39, 40], including fracture toughness [41] and material sciences [42, 43]. The obtained data set can also be a valuable source of inspiration in the development of analytical methods, both image analysis [44-47], parametric [48-50] and non-parametric [51] prediction models.

2.   SUBJECT OF STUDY AND MATERIAL

The research was in aim to achieve the required microstructure and selected mechanical properties of 38MnVS6 micro-alloy steel. The required was to achieve elongation at break ≥ 15 %, and the criterion of the minimum allowable breaking work equal to 27 J. The measures were made on ZWICK BZ200/SN6S-M testing machine and Charpy LabTest CHK300J impact hammer. The research was realized based on three forgings from 38MnVS6 steel has applied in the automotive industry. The characteristic of the subject of study and description of the double normalization process of 38MnVS6 micro-alloy steel were shown in the work: [23].

3.   RESULTS

The results of double normalization of 38MnVS6 micro-alloy steel are shown in **Table 1**.

Table 1 The results of double normalization of 38MnVS6 micro-alloy steel

Step of normalization process	Sample number	Elongation at break (A5, %)	The criterion of the minimum allowable breaking work (KV$_{min}$, J)
Material from the smelter	1 – 2 – 3	20.6 – 20.8 – 19.1	36.5 – 36.8 – 57.3
A bite steel after forging	1 – 2 – 3	16.3 – 11.7 – 11.3	6.5 – 7.9 – 5.5
Forging without heat treatment	1 – 2 – 3	14.5 – 9.7 – 14.7	8.1 – 9.2 – 12.3
Forging after normalization	1 – 2 – 3	19.4 – 20.7 – 21.5	28.4 – 43.9 – 37.4
Forging after normalization twice	1 – 2 – 3	22.26 – 21.83 – 22.71	36.1 – 36.4 – 34.1

It was shown that the selected mechanical properties of 38MnVS6 micro-alloy steel for the process of bite after forging and for forging without heat treatment were definitely below the required values. While the required properties for forgings after double normalization were achieved. Wherein, after double normalization, the increase elongation at break from 19.4 % to 22.71 % was obtained. The values of this property for one normalization from 19.4 % to 21.5 % were determined, in turn for double normalization from 21.83 % to 22.71 % (i.e. minimum and maximum values of three forgings). Additionally, it was shown that the double normalization process allows achieving required values of the criterion of the minimum breaking work, i.e. from 28.4 J to 36.4 J (i.e. the minimum value, after one normalization and maximum value after double normalization). In the case of the forgings subjected to double normalization, it was observed that this process allows an increase in the value of the breaking work from 5.5 J (value for the bite after the forging process) to 36.4 J. Therefore, it was considered that the process of double normalization was effective. It is important to mention that it was necessary to achieve not only the currently analysed properties but also the properties presented and analysed in the previous article [i. e.: 18], i.e. yield strength, tensile strength, and hardness, which were also met after applying double normalization.

The example of the microstructure of 38MnVS6 micro-alloy steel before and after the double normalization is shown in **Figure 1**. The microstructure was examined with an OLYMPUS PMG 3 metallographic optical microscope.
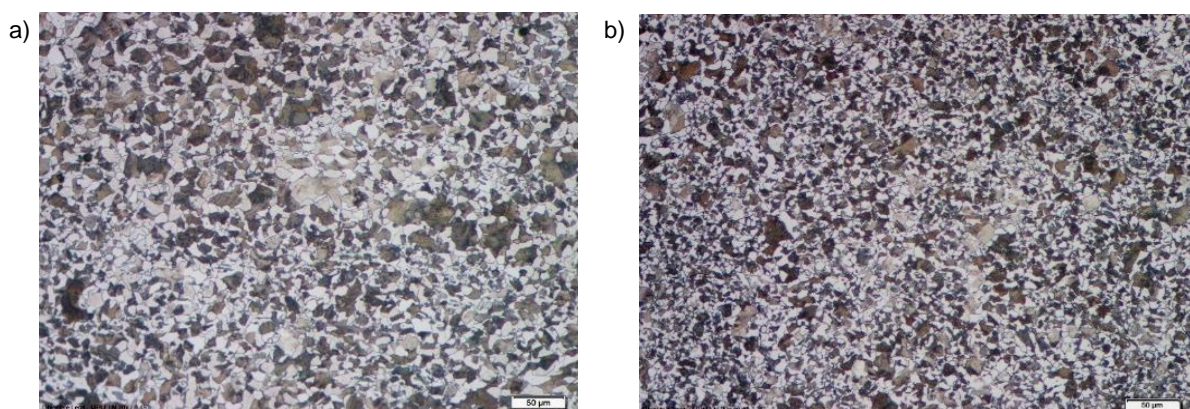
Figure 1 The comparison of microstructure the 38MnVS6 micro-alloy steel at 200 times magnification, nital digestion: a) after one normalization, b) after double normalization

The double normalization process made it possible to achieve the required homogeneous, fine-grained pearlitic-ferritic microstructure of the 38MnVS6 micro-alloy steel.

4. CONCLUSION

The improvement of mechanical properties of the products is possible in effect by the normalization processes. These processes are effective for micro-alloy steels, which are more popular in the automotive industry than alloy steels. One of the often use steel is 38MnVS6 micro-alloy steel. However, it has been shown that so far this steel has not undergone a double normalization process in order to achieve its required mechanical properties and microstructure. Therefore, the aim of the article was to analyse the impact of the double normalization process of 38MnVS6 micro-alloy steel on achieving the required microstructure and selected mechanical properties. The problem with achieving the required mechanical properties and microstructure this steel was solved in Forgex Polska Sp. z o. o. enterprise localized at Podkarpacie in Poland. The analysis has included the properties of elongation at break and the criterion of the minimum allowable breaking work. The products were the forgings from 38MnVS6 steel in ball-shape and weights 28 N forged at a temperature of 1250 °C. The conducted analysis showed that the double normalization process allows to obtain the recommended elongation at break properties from 21.83 % to 22.71 % and the criterion of the minimum allowable breaking work from 34.1 J to 36.1 J. Additionally, it was concluded that this process provided a homogeneous, fine-grained structure. For this reason, the results presented in the article may be useful for other companies in achieving effective processing of products, e.g. from the automotive industry.

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