METALLOGRAPHIC INVESTIGATION OF INDUCTION HARDENED PART TWO-SIDE LEVER

Prof. Dr. Eng. Cvetkovski S.[1], Asoc. Prof. Dr.Eng Nacevski G.[1]
Faculty of Technology and Metallurgy, Ss. Ciril and Methodius University, Skopje, Macedonia
E-mail: sveto@tmf.ukim.edu.mk, goran@tmf.ukim.edu.mk

Abstract: *Basic idea in this metallographic investigation is checking the effect of induction (surface) quenching of produced part, two-side lever made of 42CrMo4 steel. This part is build in railway wagon. According its production assignation it has to be surface hardened just in some positions. Formerly surface hardness of this part was realized by chemical-heat treatment i.e. case hardening of 16MnCr5 steel. But because of specific form of the part and increased britlness which appear in the thinnest parts of lever (between the rounded opening and the surface) and idea was obtained to change the case hardening with induction quenching. Efficiency of performed induction quenching i.e. hardness values and depth of quenched layer was controlled by optical microscopy and hardness measurement.*
KEYWORDS: *TWO-SIDE LEVER, INDUCTION QUENCHING, CASE HARDENING, TEMPERING,MARTENSITE*

Introduction

Investigated material has designation 42CrMo4 according EN10083-2 [1]. Material number is W.NR 1.7225. According chemical compositions it is low alloyed steel (CrMo) steel. Molibdenum aditions improve its temper britlness [2]. It is mostly delivered in quenched and tempered condition (Q&T) [3]. It belong to the group of steels intended for surface hardening. 42CrMo4 steel is versatile material. Its main application is automotive industry, transportation and mechanical engineering. Production of parts which possess very good impact toughness, wear resistance and fatique is the main implementation of this steel. It is ultrahigh strength steel and in the same time enable production of high stressed components. The most often produced components are crankshafts, gears and similar parts. One of its characterics is very good machinability. Chemical composition and mechanical properties of 42CrMo4 are given in tables 1 and 2. Because this steel is used for different methods of heat treatment in table 3 are given characteristic heat treatment (temperature points) [4].

Table 1 *Chemical composition of 42CrMo4 (DIN EN 10083-2)*

42CrMo4	C	Si	Mn	S	P	Cr	Mo
Comp, %	0.38 - 0.45	0.40	0.60 - 0.90	0.035	0.025	0.90 -1.20	0.15-0.30

Table 2 *Mechanical properties of 42CrMo4 steel in quenched and tempered condition (Q&T) accoding (DIN EN 10083-2)*

42CrMo4	values		
Diameter, mm	<16	>16-40	>40-100
Thickness,	<8	8<t<20	20<t<60
Yield strength, Re N/mm^2	min 900	min 750	min 650
Ultimate tensile strength, Rm, N/mm^2	1100-1300	1000-1200	900-1000
Elongation, A, %	min 10	min 11	min 12
Contraction, Z, %	min 40	min 45	min 50
Toughness, CVN, J	min 30	min 35	min 35

Table 3 *Recomended temperatures for heat treatment of 42CrMo4 [5]*

Operation	Temperature, ^{0}C
Soft anealing	680-720
Normalization	850-880
Hardening	820-850
Forging	1100-900
Isothermal anealing	850-900
Subcritical anealing	680-720
Tempering	550-650

Critical points (temperatures) of 42CrMo4 steel, which are of crucial importance for regular choice of heat treatment temperature are given in table 4 [4].

Table 4 *Critical points of 42CrMo4 steel*

Ms:	325°C
AC_1:	735°C
AC_3:	780°C

Induction quenching is heat treating process implementing for surface hardening of the heat treatable steel. The basic principles of induction quenching are: strengthening of surface layer, heating to ferrite-austenite transformation, fast cooling in order to perform martensitic transformation. Heating is very fast and there is not phase transformation in middle part of the treated material.

Adventages of this process are the following: energy saving, increasing of wear resistance, very small dimension change and minimising machining of part after quenching.

Induction quenching of 42CrMo4 can be accomplish in: oil, water or air water spray. Main intention of the process is increasing of surface hardness. Typical examples of parts intended for induction quenching

are gears and similar parts. Alternative current is used for surface heating of parts. Heated area is quenched after that. Finaly, the surface hardness of the quenched area is significantly increased. The process itself lasts very short. Tempering process which follow after that is accomplish at temperature of 550-650 ^{0}C [5].

Type of steel, its microstructure and performances of the part determine required hardness and internal stress. On the contrary of carburizing, induction quenching don't require heating of whole part. During inductive quenching only specific surfaces of the parts are heated. Success rate of quenched parts is function of the type and shape of of inductor as well as the heating way.

The aim of induction quenching is obtaining fine martensite after quenching while the microstructure od the remaining part, primarily the core stay unchanged.

Besides hardness, wear resistance, contact fatique and impact strength are increased as result of surface quenching. Basic factor which influence efficiency of induction quenching are: inductor power, frequency and current, voltage, temperature of austenitization, cooling rate, heating time, tempering temperature, pick temperature. Frequencies used for induction quenching are in range between 1-30kHz [6]. Knowing this characteristic of 42CrMo4 steel and induction quenching, preliminary treatment and investigation investigation of two-side lewer were performed.

2 Metallographic analyze of two-side lever

2.1 Preparation of part for metallographic analyze

As was point out two-side lever is produced from 42CrMo steel. For production was used bar with diameter □50 according EN10060 standard .

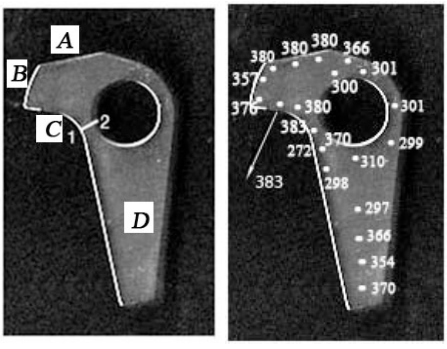
The aim of this metallographic analyze was the following:

- to check cleanliness of material concerning non metallic inclusions;
- to analyze initial microstructure of base material;
- to determine the thickness of quenched layer;
- to measure the hardness of surface quenched layer.

The first step in metallographic preparation of specimen was longitudinally cutting of specimen in two equal parts. One half was prepared for metallographic analyze (micro and macro). Appeaeance of metallograpahy prepared specimen is given in figure 1a. Surfaces (positions) of the two-side lever which need increased hardness in the exploratory conditions are marked with capital letter. In figure 1b are given measuring positions and obtained hardness values after induction quenching of the part implementing Vickers method (HV10). In figure 1c are presented hardness values obtained by implementing HRC method. HRC method is most often used for hardness measurement of the heat treatable steel. But with this method, load of 100 kg (HRC100) is used and biger imprints at the specimen surface is obtained. From another point of view thickness of quenched layer is pretty thin. Because of that, in order to be sure in the credibility of obtained values both method are used. For comparasion of obtained results, conversion of results from HV to HRC was made too (Table 5). All hardness measurement were realized on metallographic specimen.

Table 5 *Conversion of hardness values from HV10 too HRC100*

HV10	HRC
442	46
420	43
400	41
383	39
380	39
376	39
370	38
366	38
364	37
357	37
310	31
300	30
299	30
297	29

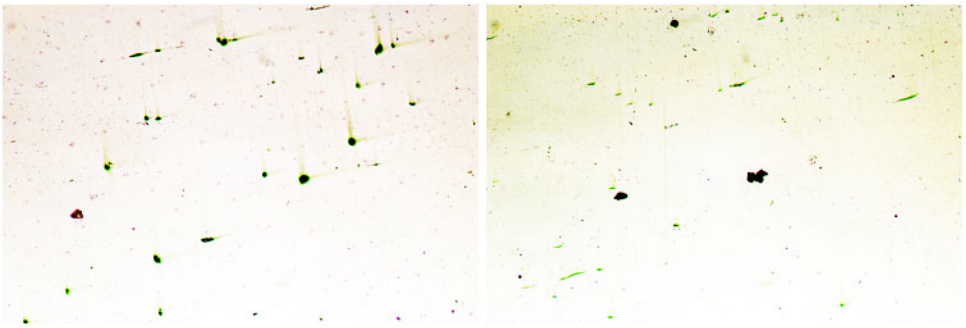


a b

c

Figure 1 *(a - c) Metallographic specimen and measured hardness values according Rockvel and Vickers method*

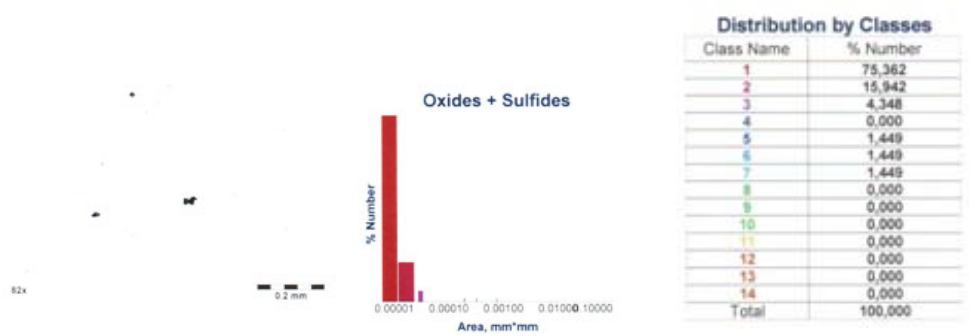
Metallographic preparation of specimen consists of mechanical grinding using different grinding abrasive papers: 180, 220, 280, 400, 600, 800 и 1200. After finishing grinding, specimen was polished with suspension of Al_2O_3. Polished specimen was subdued to analyze of nonmetallic inclusions at magnification of x100. This investigations were performed by automatic analyze using VideoTestMetal softver based on EN12457 standard. Automatic Quantitative and qualitative examination was performed for determination of type size and distribution of non metalic inclusions. In figure 2 (a and b) are given micro metallografic photos from polished specimen x100.



a b

Figure 2 *(a and b) Non metallic inclusions present in the investigated specimen, x100*

Results from automatic analyze of inclusions are given in figure 3.



Distribution by Classes

Class Name	% Number
1	75,362
2	15,942
3	4,348
4	0,000
5	1,449
6	1,449
7	1,449
8	0,000
9	0,000
10	0,000
11	0,000
12	0,000
13	0,000
14	0,000
Total	100,000

Figure 3 *Analyze of non metallic inclusions*

Next phase in metallographic preparation of specimen was chemical etching. First used etchant was Nital. But obtained results was not satisfactory. Next attempt was etcing with Kallings reagent. Something beter results were obtained (figure 4). The best revaling of microstructure was achieved with Villela etchant. This etchant is recommended for etching of heat treated steels. So further on this etchant was used. Initial microstructure of 42CrMo4 steel is given at figure 5 (a and b.)

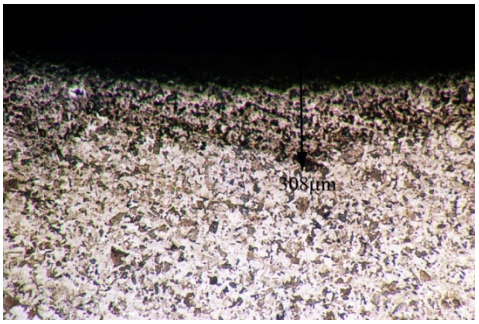
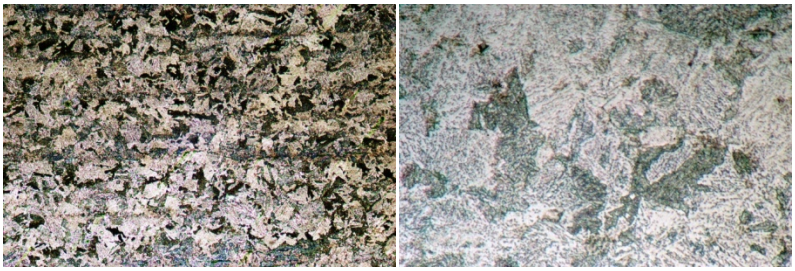


Figure 4 *Microstructure of induction quenched layer, x100, Kalings reagent*

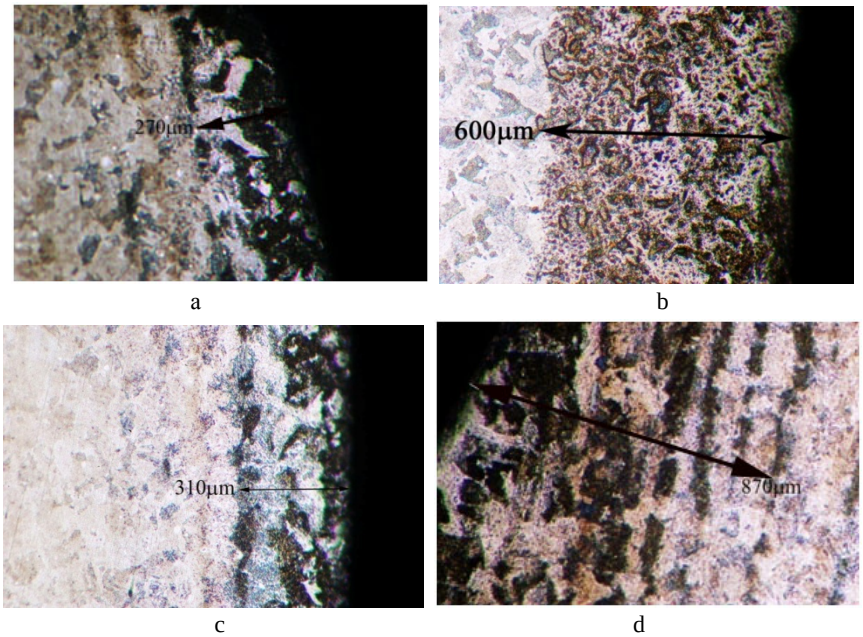


a *b*

Figure 5 *(a and b) Microstructrure of initial material, Villela reagent*
a. x100 *b. x200*

Microstructural photos of induction quenched layers taken from different position of specimen. 6 (a-d). Measurment are performed using Photoshop programe.

Figure 7 presents micro photo from the outer surface until to round opening. See figure 1b, position 1-2



a b

c d

Figure 6 *(a-d) Microstructure surface (quenched layer) at different positions of specimen*

Figure 7 *Microstructure of the specimen from the outer surface to the opening, position 1-2, microphotos 2b*

Discusion

Analyze of poslished surface of specimen confirmed that oxidic and sulfidic inclusions are present. According to size and distribution it can be said the very fine inclusion uniformly distributed are presented. Generally performed analyze showed that base material is pretty clean concerning non metallic inclusions. Principaly steel for induction hardening steel are cleaner concerning many othe types. In the middle of the lever there is no microstructural changes because heat treatment (induction heating) happen only on the surface of the part.

Initial microstructure of the two-sided lever consists of fine grained temepered martensite (Q&T), figure 5(a and b)) Hardness of initial microstructure according to literature dates should be 28–35 HRC. It was confirmed in our investigations too where hardness value is (29-30 HRC) [7].

Max measured hardness value is 383 HV10 (39 HRC). It means that requirement from technical documentation of 30-38 HRC are fulfilled. Probably hardness on the surface of part is something higher, because there is hardness gradient from the surface to the interior of the specimen.

There is no doubt that with optimal choice of quenching parameters higher values can be achieved (figure 8. It can be seen from the same figure (CCT diagram) that max mardness for 42CrMo4 steel can be reach during very high cooling speeds is 660 HV10 (56 HRC). Here we have to take in consideration that this steel contain 0.45 %C. For comparison, 16MnCr5 steel which was formerly used for production ow two-side has carbon concentration of 0.16%. Because of that this steel was subjected to case hardening [7]. There is migration of carbon atoms from the surface towards interior of part during carburisation and increase hardness. Max hardness which can be reached during quenching of 16MnCr5 is 46 HRC (continous cooling diagram figure 9). For obtaining higher hardness values case hardening is necessary. In that case hardness of 60HRC can be obtain [7].

According appropriate literature dates, deepness of quenched layer could be 0.25-2.3 mm. Measurments performed in this research are in the range 0.21 до 0.87 mm [8].

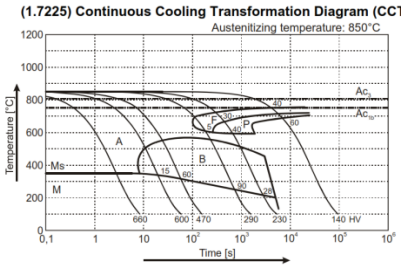


Figure 8 *Diagram of continous cooling (CCT) for 42CrMo4 steel [9]*

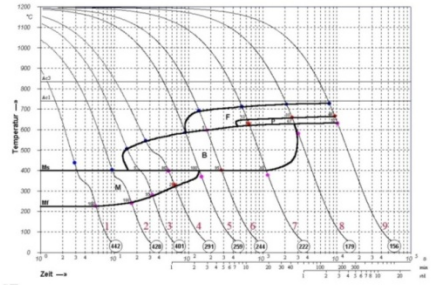


Figure 9 *Diagram of continous cooling (CCT) for 16MnCr5 steel [10]*

Conclusion

Microstructural analyse of polished surface of the specimen show presence of sulfidic and oxidic inclusions. Concerning the presence on non-metalic inclusions it can be said that material is very clean which is characteristic for this type of steel (heat tratable).

Microstructure in the middle of the specimen consists of fine grained tempered marteniste (Q&T). There is not any changes in the initial microstructure of material because induction quenching change the microstructure only in the surface.

Deepness of the quenched layer is different in different position of the two side lever. Measured values are between 210 до 870 □m. Different thickness is result of the iregular shape of the two-sided lever and the fakct that only determined surfaces has to be inductive quenched.

Max measured hardness value is 39 HRC, and it satisfy requirement of technical documentation. But according to characteristics of 42CrMo4 much higher hardness values can be reached by induction quenching.

Literature

1. EN 10083-1 steel for quenching and tempering
2. EN 10084: 2008 Case hardening steels. Technical delivery conditions
3. BS EN 10060:2003 Hot rolled round steel bars for general purposes. Dimensions and tolerances on shape and dimensions
4. ISO 6508-3 Metallic Materials – Rockwell hardness test (scales A, B, C, D, E, F, G, H, K, N, T) – Part 3: Calibration of reference blocks, 1999-09-01
5. F. Nürnberger, Microstructural Behaviour of Tempering Steels during Precision Forging and Quenching from Hot-forming Temperatures, © Metallurgical and Mining Industry, 2011, Vol. 3, No.
6. Harichand, Krishan Kumar and S.K. Jha, Heat Treatment for 16 MnCr5Material International Journal on Emerging Technologies 3(1): 60-64(2012)
7. Prof. Dr-ing Jurgen Maier, Induction hardening of Gear wheels made from 42CrMo4 hardening and tempering steel by employing water-air spray cooling Project A3 IRTG 1627 „Virtual Materials and Structures and their validation“
8. Sascha Brill, DirkM. Schibsch, Induction, Hardening Versus Case Hardening – A Comparasion, REPORTS, Induction Technology 15 Hu Zhizhong, The Handbook of Steel and Its Heat Treatment Curve. Beijing: Defence Industry Press,1987.
9. Hu Bao Xintao, Practical Handbook of Heat Treatment of Steel, Shanghai: Science and Technology Press of Shanghai, 2009.