Increase of Surface Hardness of Gunpoint According to Quality Rise of Firearm

Lukas Bridik^{1,*}, Olga Cicakova²

¹Department of Maintenance Techniques, Faculty of Special Technology of Alexander Dubcek University of Trencin, Trencin, 91106, Slovakia

²Institute of Electrical Engineering, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Bratislava, Slovakia

*Corresponding Author: lukas.bridik@tmuni.sk

Copyright © 2014 Horizon Research Publishing All rights reserved.

Abstract This article is treating the increase of hardness of different types of steels used for firearm manufacturing, using nitriding of steel in nitriding oven. The article evaluates hardening processes from the surface to the core of different nitrided steels of a material considering its use in arm manufacturing.

Keywords Plasma Nitriding, Barrel Of Firearms, Surface Hardness, Micro Hardness Measurement

1. Introduction

The gunpoint of low caliber weapon is made of construction steel, in special cases aluminium composition, titanium, plastic and compound materials are used. Gunpoint material must have high breaking strength to be resistant to high pressures of dust gases. It must be persistent to avoid brittle fracture especially when it is quickly and repeatedly loaded by shooting at low temperatures. It must have appropriate hardness in order not to lose its shape and not copy the impacts of moving bullet. It must be fireproof and chemical stable against act of dust gases and atmospheric effects. [1,2,3]

Nowadays, the increase in life of barrel by surface treatment, in case of automatic weapons mainly by hard chrome plating, is reached. [5,6] For surface treatment of the bore materials as molybdenum, nickel, cobalt and chromium are used. Hard chrome plating of the bore for the small arms barrel is usually used. Thus the life of barrel is increased significantly and it also allows manufacturing the barrel from alloy steels. The thickness of the chrome layer varies with required life. Typical properties as high smelting temperature (1863 °C) [7], possibility to be applied on bore surface by galvanization (so-called hard chrome plating), high hardness and strength at high temperatures, high ductility at low and high temperatures, erosion and corrosion resistances against chemical effect of dust gases are the advantages of chromium. [8]

In present time other possibility how to increase the wear resistance of bore can be processes of plasma nitriding, carbonitriding. By means of plasma nitriding, carbonitriding resp., a surface treatment of bore of small and long arms is standardly realized.

2. Process of Nitriding

Turned, ground, deburred and degreased samples are free placed on stand of nitriding furnace [6]. Before closing the furnace checking of furnace sealing is needed because of the leakage of nitriding atmosphere (hydrogen, nitrogen), which could lead to dysfunctionality of the whole saturation process. In our case, nitration time is estimated to be 6 hours to get chosen thickness by atomic nitrogen of saturated layer. [9,10] This thickness is for every material different and depends on the method of heat treatment and on the percentage of abundance of alloying elements. [11,12,13]

After inserting the elements into nitriding furnace and after closing the bell exhausting the origin oxygen atmosphere to the pressure 10 Pa is needed and consequently increases the pressure in the space where the nitriding is realized to 500 Pa. By heating the furnace to 500 °C the conditions for “cleaning” are achieved. The cleaning process lasts 30 min at voltage 800 V. [14,15] Nitrogen saturation itself runs at the nitriding temperature from 490 °C to 500 °C whereby the correction of saturation by changing the pulse length of discharge or by changing temperature setup on the walls of the bell is realized. [16,17,18,19].

3. Experimental Part

Experimental specimens were made of three materials [2,4]. Before nitriding and finish machining themselves some specimens heat treated by [2] were marked as 4-x and 5-x (Tab. 4.1) The reason is the observance of the analogy of heat treatment of barrel and the comparison with the specimens without heat treatment.

Table 1. Specific data of Column/Row

Specimen marking	Type of specimen material	Type of heat treatment of specimen
1 – 1 till 5	15 340	Not heat treated
1 – 6 till 10	15 340	Not heat treated, nitrided
2 – 1 till 5	15 142	Not heat treated
2 – 6 till 10	15 142	Not heat treated, nitrided
3 – 1 till 5	15 230	Isothermal hardened
3 – 6 till 10	15 230	Isothermal hardened, nitrided
4 – 1 till 5	15 142	Tempered, hardened
4 – 6 till 10	15 142	Tempered, hardened, nitrided
5 – 1 till 5	15 340	Tempered, hardened
5 – 6 till 10	15 340	Tempered, hardened, nitrided

The specimens marked as 4 were hardened from the temperature 850°C and tempered consequently at temperature 600°C. The specimens marked as 5 had the hardening temperature 900°C and tempering temperature 630°C. After the heat treatment the turning of outside and inside diameters, bevelling and deburring were realized. The outside diameter was ground by two techniques - using plunge grinding into material and by cross feed of abrasive wheel. The approximate value of the roughness Ra on the whole functional surface of the specimen reached by the first technique was 0.23, reached by the second one 0.53. The specimens of steel 15230 were made from semi-finished products of barrel of caliber 9 mm. During the forging of the bore the material was heat treated and consequently isothermal hardened. After the saturation of the surface by nitrogen using plasma nitriding the random tempered brittleness in these specimens was expected. In the case of bullet test this brittleness is manifested as macroscopic deformation of projectile chamber or barrel, resp. This anomaly is not documented yet and also the conditions at which that tempered brittleness in nitrided barrels from the steel 15230 occurs is not known.

4. Results

Predominant majority (approximately 90%) of the presented values gained from the experiments are original, the rest comes from literature.

4.1. Hardness Measurements

Hardness could be defined as the resistance of material against the penetration of strange body. This test was realized on the samples of material before surface treatment. The marked fluctuation in hardness of samples 1, 2, 4 and 5 is caused, with the greatest probability, by the absence of shaping technology „hot rolling“.

Table 2. Values of hardness for experimental specimen Nr. 1

Serial number of measurement	Hardness HV 0,05	Hardness HRC
1	182	-
2	191	-
3	202	-

Table 3. Values of hardness for experimental specimen Nr. 2

Serial number of measurement	Hardness HV 0,05	Hardness HRC
1	271	25,8
2	261	24,2
3	315	31,6

Table 4. Values of hardness for experimental specimen Nr. 3

Serial number of measurement	Hardness HV 0,05	Hardness HRC
1	177	-
2	175	-
3	177	-

Table 5. Values of hardness for experimental specimen Nr. 4

Serial number of measurement	Hardness HV 0,05	Hardness HRC
1	358	36,4
2	342	34,7
3	329	33,2

Table 6. Values of hardness for experimental specimen Nr. 5

Serial number of measurement	Hardness HV 0,05	Hardness HRC
1	349	35,4
2	349	35,4
3	341	34,6

4.2. Micro Hardness Measurements

The testing results show the hardness characteristics on experimental samples from the functional surface to the center of material.

Nitride material 15 340 without heat treatment (Fig.1) [4] showed tendency for surface deformation (fig.2) in form of cracking. The value of the measured material hardness in surface layer in the region of nitriding layer has changed up to 1100 HV.

Figure 1. Measured microhardness characteristics in the sample 1-10 (material 15 340, without heat treatment)

Figure 2. Cracking on the surface of specimen 1-10

At samples Nr. 1, 2, 4 and 5 the absence of hot rolling technology in production of experimental samples by marked scattering of measured values was manifested. These samples were turned from semi-product without any previous degree of reshaping which could be reached by forming. Marked fluctuation in hardness in the zone which was not influenced by nitride saturation was manifested, too. Fluctuation in measured hardness could also be caused by measuring error of device itself. The device was evaluated the surface hardness by means of digital camera. This camera was fastened as running centre as same as the inverter of micro hardness tester. The sample Nr. 3 was made from material 15 230 and its measured hardness was fluctuating maximum in the range 1 – 3 HV. After the samples Nr. 4 and 5 were tempered and hardened the microstructure of these samples became refined and it improved mechanical properties (material achieved martensitic structure), increased the hardness in core and in nitride surface layer,

but the fluctuation in hardness in the core and in surface layer remained.

Figure 3. Microhardness characteristics measured on the sample 2 -10 (material 15 142, without heat treatment)

Figure 4. Microhardness characteristics measured on sample 3 -10 (material 15 230, isothermal hardened)

Figure 5. Microhardness characteristics measured on the sample 4 -10 (material 15 142, tempered and hardened)

Figure 6. Microhardness characteristics measured on the sample 5 -10 (material 15 340, tempered and hardened)

In Fig. 1 and 3 till 6 are measured values from which it is apparent that the maximum hardness had the sample of series Nr. 5 – x, its hardness measured on the surface and in nitride layer reached sporadically as high as 1 150 HV_{0,05}. This surface layer hardness is comparable with chrome layer hardness which was used until recently for hardening the

surface of barrel bore. The hardness value was reached due to aluminum which as an additive element in base material achieved the value to 1,7 % by chemical analysis. Probably, this value contributed to mentioned hardness

4. Conclusion

From the graphic characteristics results that the specimen 5 – 10 is the most convenient one for small arms barrel manufacturing. This specimen is the steel 15 340. It is tempered and hardened, through which fine-grained martensitic structure was obtained. After nitriding the surface hardness was up to 1150 HV_{0,05}.

REFERENCES

- [1] M. Fišer, E. Popelínský, Hlavné zbrane - Část 5 - Automatické zbraňe, Brno, 1995.
- [2] J. Strba, J. Kusak, Geometric coefficients modifications of surface non-treated seven-perforated nitrocellulose powder, *Advances in Military Technology* 6(1). pp. 47-56. ISSN 1802-2308
- [3] P. Skočovský, a kol., Náuka o materiálu. ŽU Žilina, ISBN 80-7100-831-1, 2001.
- [4] Bucha, J., Lipták, P.: SIMULÁCIA A PROGNÓZOVANIE ŽIVOTNOSTI NÁPRAV, MOBILNÝCH PROSTRIEDKOV, Trenčianska univerzita Alexandra Dubčeka v Trenčíne, 2012, Trenčín, ISBN 978-80-8075-528-7, EAN 9788080755287.
- [5] Bucha, J., Turza, J.: Modeling of Stress in the Car half Axle, 2010, In: Scientific, Papers of the University of Pardubice : Series B The Jan Perner Transport, Faculty 15(2009). - Pardubice : Univerzita Pardubice, 2009. - ISBN 978-80-7395-364-5. - s.187-200.
- [6] L. R. Madureira, E. M. M. Fonseca , F. Q. Melo, The Deformation of Cylindrical Shells Subjected to Radial Loads Using Mixed Formulation and Analytic Solutions, *Universal Journal of Mechanical Engineering* 1(4): 128-132, 2013.
- [7] R. Kříž, J. Trkačka, Tabulky materiálů pro strojírenství, Ostrava, 1999.
- [8] B. Přenosil, Nitrocementace. Praha, SNTL , str. 323, 1964.
- [9] Z. Pokorný, O. Barborák, V. Hrubý, Characteristics of Plasma nitrided Layers in deep Holes, In: KOVOVÉ MATERIÁLY. - ISSN 0023-432X. - Vol.50, No.3(2012), p.209-212, 2012.
- [10] V. Hrubý, Z. Studený, D. Kusmič, Plazmová nitridace nerezavějících ocelí., Demánovská dolina, In: Vrstvy a povlaky. str. 67 -72. ISBN 80-969310-1-6., 2005.
- [11] V. Hrubý, J. Kadled, Plazmově nitridované vrstvy a jejich hodnocení. In: Vrstvy a povlaky, Trenčín, str. 47 – 50. ,2002.
- [12] D. Kusmič, V. Hrubý, Plazmová nitridace hlavní ručních zbraní, *Materiály a technológie ve výrobě speciální techniky*, ISBN 978-80-7231-644-1, 2009.
- [13] V. Hruby, R. Hrach, Computational simulation of metal ion propagation from plasma to substrates with uneven surfaces, *Vacuum*, Volume 90, April 2013, Pages 109-113.
- [14] H. Madanipour, M. Soltanieh, N. Nayeypashae, Investigation of the formation of Al, Fe, N intermetallic phases during Al pack cementation followed by plasma nitriding on plain carbon steel, *Source: MATERIALS & DESIGN Volume: 51 Pages: 43-50 DOI: 10.1016/j.matdes.2013.03.077 Published: OCT 2013.*
- [15] K. Yamanaka, Y. Onuma, S. Yamashita, Y. Masubuchi, T. Takeda, S. Kikkawa, Humidity effects in Fe16N2 fine powder preparation by low-temperature nitridation, *J. Solid State Chem.*, 183 (2010), pp. 2236–2241.
- [16] D. Kusmič, V. Hruby, Corrosion resistance of plasma nitrided structural steels. In: 22. International Conference on Metallurgy and Materials, METAL 2013. Brno: TANGER spol. s r.o., 2013. ISBN 978-80-87294-39-0.
- [17] D. Kusmič, V. Hruby, Vliv plazmové nitridace na změnu parametrů textury povrchu. *Hutnické listy*, 2012, sv. LXV, č. 5/2012, s. 26-29. ISSN 0018-8069.
- [18] D. Kusmič, V. Hruby, Z. Pokorný, Plazmová nitridace vývrtu hlavní. In: ARMAMENT AND TECHNICS OF LAND FORCES 2011. Liptovský Mikuláš: Akadémia ozbrojených síl generála Milana Rastislava Štefánika, 2011, s. 98-103. ISBN 978-80-8040-431-4.
- [19] A. Kharlamov, M. Bondarenko, G. Kharlamova, N. Gubareni, V. Fomenko, A New Method of Synthesis Carbon with Onion-Like Structure with High (10-13%) Content of Nitrogen from Pyridine, *Universal Journal of Materials Science* 1(2): 78-86, 2013.