Materials Research Proceedings **24** (2022) 189-195 https://doi.org/10.21741/9781644902059-28

Vickers Method Application for Quality Assessment the First Patterns of a Selected Product of the Automotive Industry – a Case Study

JAGUSIAK-KOCIK Marta[1,a] and IDZIKOWSKI Adam[1,b*]

[1] Department of Production Engineering and Safety, Faculty of Management, Czestochowa University of Technology, Al. Armii Krajowej 19b, 42-218 Czestochowa, Poland

[a] m.jagusiak-kocik@pcz.pl, [b]adam.idzikowski@pcz.pl

Keywords: Hardness Measurement, Vickers Method, Product Quality Assessment

Abstract. Production is one of the basic branches of the economy. Along with the development of techniques and technology, it expanded the scope of its activities, including a wide flow of information concerning, inter alia, the quality of manufactured products in order to increase competitiveness in meeting customer needs. The article assesses the quality of the first patterns of the selected product (detail X) by measuring the hardness using the Vickers method. The measurements were carried out for four samples marked with the letters A1, B1, C1 and D1, which for the Vickers test had to be properly prepared, which was associated with the need to meet both the requirements relating to surface roughness, the size of the detail and getting rid of contamination. This process follows the procedure prepared by the quality control section, specified in the detailed execution manual for detail X. The measurement of the samples confirmed the research carried out in the scope of quality assessment and the validity of the selection of the Vickers method for hardness measurement.

Introduction

Production is an activity that is spread over time and is mainly based on the physical production of a specific product [1, 2]. It is also considered to combine various types of inputs and production resources in order to obtain a specific effect in the form of a semi-finished or finished product [3-5].

The variety of materials used in production requires defining, inter alia, their mechanical properties, which determine the load-bearing capacity of the material [x6]. Mechanical properties affect the quality and strength of materials, and thus – the properties of the finished product [7, 8]. The study of mechanical properties is extremely important, e.g. during the production of large structures, where every smallest element is responsible for the safety and quality of the entire structure. One of the mechanical properties is hardness [9], and hardness is assessed by static hardness tests, dynamic hardness tests and scratch tests. Hardness measurement is a simple, quick and low-cost test. The obtained result can be converted into material strength by applying an appropriate formula, taking into account the linear relationship between the material hardness and tensile strength. Hardness is the resistance of a material that occurs when a specific object (indenter) is pressed into it. If the indenter goes deeper into the material with the same load, it means that the indenter is softer. To perform the measurement, a ball-shaped element is used, which is made of tungsten carbide or hardened steel. Sometimes an indenter is also used, which is in the form of a diamond cone or diamond pyramid. The element is pressed into the material in a static or dynamic manner.

Materials Research Proceedings **24** (2022) 192-198 https://doi.org/10.21741/9781644902059-28

The methods of static hardness measurement include the Brinell, Vickers and Rockwell methods. The Brinell method is one of the oldest methods of hardness measurement [10] and consists in perpendicularly pressing a hardened ball (or carbide ball) with a diameter of D and a force of F value into the tested material. The Rockwell method consists in pressing an indenter in the form of a diamond cone or steel ball into the surface material and consists of 2 stages: loading with the initial force F0 (in order to reduce the impact on the measurement of non-uniformity of the sample surface), and then applying the main force F1 and unloading to the force F0. This determines the permanent increase in the depth of the impression resulting from the initial force after unloading [11]. The Vickers method [12] consists in measuring the hardness (Fig. 1) using an indenter in the form of a simple pyramid, characterized by a square base and an apex angle equal to the Brinell ball indentation angle, i.e. 136° with an accuracy of 0.5". The hardness is calculated as the ratio of the load F to the side surface of the permanently imprinted part of the pyramid.

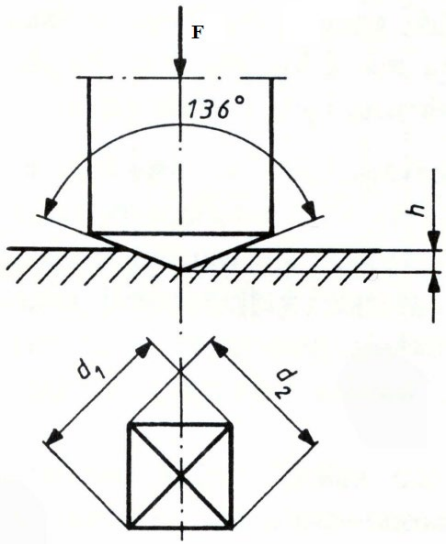

Fig. 1. *Scheme of hardness measurement by the Vickers method [12]*

The aim of the study is to use the Vickers hardness method to assess the quality of the first patterns of a selected product in the automotive industry [13].

The obtained results and methodology should be of interest to researchers in the field of material sciences [14-17], energy [18, 19], machining [20-22] and coating [23-25] but also quality engineers of the steel industry [26, 27], food [28, 29] and the automotive industry [30-33]. Increasing the quality of the materials produced will have a positive effect on the production of highly responsible parts and machines, where there is a risk of contamination [34], costly breakdowns [35, 36] or injury [37, 38]. The results can also inspire the further development of data analysis methods [39-41] and the development of risks in failure scenarios [42, 43] as a valuable source of experimental information.

Methodology

The tests used a hardness test with a low loading force, symbol HV1, i.e. with a nominal force value of 9.807 N. In order to carry out a hardness test using the Vickers method, it is necessary to properly prepare a sample of the detail. The surface of the sample should be free of impurities and characterized by a roughness of not more than 2.5 μm. The duration of the load for most of the tested materials should be in the range of 10 to 15 seconds, assuming an accuracy of 2 seconds. The sample thickness should not be less than 1.5d.

This is done according to an appropriate procedure, specified in the X detail execution manual, prepared by the quality control department. First, the upper part of the X detail is cut. It is necessary to properly set the handle before the cut, in order to properly set the laser line of the cutter, which determines the direction of the cut. Then the detail is fixed in the holder. Before the first cut, it is necessary to adjust the table setting by a blade thickness of 2 mm. The cuts are made along the angles determined for the X detail. In the selected detail for analysis, the cut was made along an angle of 88° and 110° along the cross-section of the entire detail. After each cut, the target area is marked. A transverse cut is then made below the X detail at a distance of 2 mm to avoid damaging the measuring surfaces. Fragments of the detail are then placed on the plunger of the metallographic press with the measuring side facing down, and then covered with thermosetting resin. Then the samples are included. After this process, the samples are polished and placed on the hardness tester pad, ready for measurement. In the case of the lower part of X detail, the first cut is made 2 mm above the upper part in order to obtain a fragment for further examination. Then the detail is placed in the holder in such a way that the laser line of the cutter passes through the center of the cam. The last cut is made 2 mm above in order not to damage the measuring surfaces. The obtained fragments are placed on the plunger of the metallographic press, and then, after the completed process, they are placed on the pad of the polishing machine. After its completion, the samples can be measured.

Results

The measurements were carried out for four samples marked with the letters A1, B1, C1 and D1. Basic measurement parameters are presented below (Tab. 1)

Table 1. *Measurement results for four samples by the Vickers method*

MEASUREMENT RESULTS FOR SAMPLE A1		
POINT	HARDNESS	POSITION
1	716	0,10
2	279	0,50
3	257	1,00
4	271	1,25
MEASUREMENT RESULTS FOR SAMPLE B1		
1	683	0,10
2	277	0,50
3	261	1,00
4	265	1,25
MEASUREMENT RESULTS FOR SAMPLE C1		
1	714	0,10
2	276	0,50
3	250	1,00
4	272	1,25
MEASUREMENT RESULTS FOR SAMPLE D1		
1	715	0,10
2	293	0,50
3	267	1,00
4	269	1,25

Obtaining similar hardness values for all analyzed samples proves about the good effectiveness of the Vickers method. Therefore, it can be used to assess the quality of the first standards, with special care for the proper preparation of the sample.

Summary

Modern enterprises operate in difficult market conditions. The demand for specific products depends on many factors, including meeting customers' requirements. Due to the variety of available offers, users have more and more requirements, including the high quality of manufactured products.

Checking the first patterns ensures early detection of abnormalities in manufactured items. It is very useful in simulating production processes, which are then translated into production. However, the effectiveness of this control depends on the methods used. The solution analyzed at work, used in the surveyed company of the automotive industry, is based on the application of the Vickers method, which based on the PN-EN ISO 6507-1: 2018-05 standard, it consists in indenting a diamond indenter into the sample surface with a predetermined force. The advantage of the Vickers method over the Brinell method is the universality of the diamond indenter. In addition, considering the advantages and disadvantages, it can be stated that the Vickers method, having the advantages, has the widest scale and high measurement accuracy, and the measurement result does not depend on the load applied during the test. On the other hand, the disadvantages of the Vickers method include: the difficulty of applying the method on heterogeneous or coarse-grained materials.

References

[1] T. Karpiński. Inżynieria produkcji, WNT, Warszawa, 2011.

[2] B. Liwowski, R. Kozłowski. Podstawowe zagadnienia zarządzania produkcją, Oficyna Ekonomiczna, Kraków 2007.

[3] A. Burduk. Modelowanie systemów narzędziem oceny stabilności procesów produkcyjnych, Politechnika Wrocławska, Wrocław, 2013

[4] B. Liwowski, R. Kozłowski. Podstawowe zagadnienia zarządzania produkcją, Oficyna Ekonomiczna, Kraków, 2006

[5] E. Masłyk-Musiał, A. Rakowska, E. Krajewska-Bińczyk. Zarządzanie dla inżynierów, PWE, Warszawa, 2012.

[6] R. Ulewicz, F. Nový, M. Mazur, P. Szataniak. Fatigue properties of the hsla steel in high and ultra-high cycle region, Production Engineering Archive 4 (2014) 18-21.

[7] N. Kopiika, J. Selejdak, Y. Blikharskyy. Specifics of physico-mechanical characteristics of thermally-hardened rebar, Production Engineering Archive 28 (2022) 73-81. https://doi.org/10.30657/pea.2022.28.09

[8] M. Szary, K. Knop. Ocena technologii i możliwości technologicznych przedsiębiorstwa z branży metalowej. Archiwum Wiedzy Inżynierskiej 3 (2018) 31-34.

[9] W. J. Klimasara. Badanie materiałów konstrukcyjnych 315[01].O2.02. Poradnik dla ucznia, Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy, Radom, 2007

[10] Z. Zatorski, R. Biernat. Energy-based determination of Brinell hardness, Scientific Journal of Polish Naval Academy 4 (2014) 103-116.

[11] W.J. Klimasara. Badanie materiałów konstrukcyjnych, Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy, Radom, 2007.

[12] PN-EN ISO 6507-1:2018-05. Metale. Pomiar twardości sposobem Vickersa. Część 1: Metoda badań.

[13] E. Staniszewska, D. Klimecka-Tatar, M. Obrecht. Eco-design processes in the automotive industry, Production Engineering Archive 26 (2020) 131-137. https://doi.org/10.30657/pea.2020.26.25

[14] A. Dudek, B. Lisiecka, R. Ulewicz. The effect of alloying method on the structure and properties of sintered stainless steel, Archives of Metallurgy and Materials 62 (2017) 281-287. https://doi.org/10.1515/amm-2017-0042

[15] A. Szczotok, N. Radek, R. Dwornicka. Effect of the induction hardening on microstructures of the selected steels. METAL 2018 - 27th Int. Conf. Metall. Mater. (2018), Ostrava, Tanger 1264-1269.

[16] N. Radek, J. Pietraszek, A. Goroshko. The impact of laser welding parameters on the mechanical properties of the weld, AIP Conf. Proc. 2017 (2018) art.20025. https://doi.org/10.1063/1.5056288

[17] T. Lipiński. Corrosion resistance of 1.4362 steel in boiling 65% nitric acid, Manufacturing Technology 16 (2016) 1004-1009.

[18] Ł.J. Orman. Boiling heat transfer on single phosphor bronze and copper mesh microstructures, EPJ Web of Conf. 67 (2014) art. 2087. https://doi.org/10.1051/epjconf/20146702087

[19] Ł.J. Orman Ł.J., N. Radek, J. Pietraszek, M. Szczepaniak. Analysis of enhanced pool boiling heat transfer on laser-textured surfaces. Energies 13 (2020) art. 2700. https://doi.org/10.3390/en13112700

[20] P. Szataniak, F. Novy, R. Ulewicz. HSLA steels - Comparison of cutting techniques, METAL 2014 – 23rd Int. Conf. Metallurgy and Materials (2014), Ostrava, Tanger, 778-783.

[21] A. Szczotok, J. Pietraszek, N. Radek. Metallographic Study and Repeatability Analysis of γ' Phase Precipitates in Cored, Thin-Walled Castings Made from IN713C Superalloy. Archives of Metallurgy and Materials 62 (2017) 595-601. https://doi.org/10.1515/amm-2017-0088

[22] I. Miletić, A. Ilić, R.R. Nikolić, R. Ulewicz, L. Ivanović, N. Sczygiol. Analysis of selected properties of welded joints of the HSLA Steels, Materials 13 (2020) art.1301. https://doi.org/10.3390/ma13061301

[23] J. Bronček, P. Fabian, N. Radek. Tribological research of properties of heat-treated cast irons with globular graphite, Materials Science Forum 818 (2015) 209-212. https://doi.org/10.4028/www.scientific.net/MSF.818.209

[24] N. Radek, J. Pietraszek, A. Gadek-Moszczak, Ł.J. Orman, A. Szczotok. The morphology and mechanical properties of ESD coatings before and after laser beam machining, Materials 13 (2020) art. 2331. https://doi.org/10.3390/ma13102331

[25] N. Radek, J. Konstanty, J. Pietraszek, Ł.J. Orman, M. Szczepaniak, D. Przestacki. The effect of laser beam processing on the properties of WC-Co coatings deposited on steel. Materials 14 (2021) art. 538. https://doi.org/10.3390/ma14030538

[26] A. Maszke, R. Dwornicka, R. Ulewicz. Problems in the implementation of the lean concept at a steel works - Case study, MATEC Web of Conf. 183 (2018) art.01014. https://doi.org/10.1051/matecconf/201818301014

[27] H. Danielewski, A. Skrzypczyk, W. Zowczak, D. Gontarski, L. Płonecki, H. Wiśniewski, D. Soboń, A. Kalinowski, G. Bracha, K. Borkowski. Numerical analysis of laser-welded flange pipe joints in lap and fillet configurations, Technical Transactions 118 (2021) art. e2021030. https://doi.org/10.37705/TechTrans/e2021030

[28] N. Baryshnikova, O. Kiriliuk, D. Klimecka-Tatar. Management approach on food export expansion in the conditions of limited internal demand, Polish Journal of Management Studies 21 (20200 101-114. https://doi.org/10.17512/pjms.2020.21.2.08

[29] N. Baryshnikova, O. Kiriliuk, D. Klimecka-Tatar. Enterprises' strategies transformation in the real sector of the economy in the context of the COVID-19 pandemic, Production Engineering Archives 27 (2021) 8-15. https://doi.org/10.30657/pea.2021.27.2

[30] K. Antosz, A. Pacana. Comparative analysis of the implementation of the SMED method on selected production stands, Tehnicki Vjesnik 25 (2018) 276-282. https://doi.org/10.17559/TV-20160411095705

[31] A. Pacana, R. Ulewicz. Analysis of causes and effects of implementation of the quality management system compliant with iso 9001, Pol. J. Manag. Stud. 21 (2020) 283 296. https://doi.org/10.17512/pjms.2020.21.1.21

[32] A. Pacana, D. Siwiec, L. Bednárová. Method of choice: A fluorescent penetrant taking into account sustainability criteria, Sustainability 12 (2020) art. 5854. https://doi.org/10.3390/su12145854

[33] G. Ostasz, K. Czerwińska, A. Pacana. Quality Management of Aluminum Pistons with the Use of Quality Control Points. Management Systems in Production Engineering 28 (2020) 29-33. https://doi.org/10.2478/mspe-2020-0005

[34] E. Skrzypczak-Pietraszek. Phytochemistry and biotechnology approaches of the genus Exacum. In: The Gentianaceae - Volume 2: Biotechnology and Applications, 2015, 383-401.https://doi.org/10.1007/978-3-642-54102-5_16

[35] S. Marković, D. Arsić, R.R. Nikolić, V. Lazić, B. Hadzima, V.P. Milovanović, R. Dwornicka, R. Ulewicz. Exploitation characteristics of teeth flanks of gears regenerated by three hard-facing procedures, Materials 14 (20210 art. 4203. https://doi.org/10.3390/ma14154203

[36] E. Lisowski, J. Rajda, G. Filo, P. Lempa. Flow Analysis of a 2URED6C Cartridge Valve, Lecture Notes in Mechanical Engineering 24 (2021) 40-49. https://doi.org/10.1007/978-3-030-59509-8_4

[37] A. Dudek, M. Klimas. Composites based on titanium alloy Ti-6Al-4V with an addition of inert ceramics and bioactive ceramics for medical applications fabricated by spark plasma

sintering (SPS method), Materialwissenschaft und Werkstofftechnik 46 (2015) 237-247. https://doi.org/10.1002/mawe.201500334

[38] A. Kubecki, C. Śliwiński, J. Śliwiński, I. Lubach, L. Bogdan, W. Maliszewski. Assessment of the technical condition of mines with mechanical fuses, Technical Transactions 118 (2021) art. e2021025. https://doi.org/10.37705/TechTrans/e2021025

[39] J. Pietraszek, E. Skrzypczak-Pietraszek. The uncertainty and robustness of the principal component analysis as a tool for the dimensionality reduction. Solid State Phenom. 235 (2015) 1-8. https://doi.org/10.4028/www.scientific.net/SSP.235.1

[40] J. Pietraszek, R. Dwornicka, A. Szczotok. The bootstrap approach to the statistical significance of parameters in the fixed effects model. ECCOMAS Congress 2016 - Proceedings of the 7th European Congress on Computational Methods in Applied Sciences and Engineering 3, 6061-6068. https://doi.org/10.7712/100016.2240.9206

[41] J. Pietraszek, A. Szczotok, N. Radek. The fixed-effects analysis of the relation between SDAS and carbides for the airfoil blade traces. Archives of Metallurgy and Materials 62 (2017) 235-239. https://doi.org/10.1515/amm-2017-0035

[42] J. Pietraszek, N. Radek, A.V. Goroshko. Challenges for the DOE methodology related to the introduction of Industry 4.0. Production Engineering Archives 26 (2020) 190-194. https://doi.org/10.30657/pea.2020.26.33

[43] J. Fabis-Domagala, M. Domagala, H. Momeni. A matrix FMEA analysis of variable delivery vane pumps, Energies 14 (2021) art. 1741. https://doi.org/10.3390/en14061741