A CHARACTERISTIC OF SELECTED PROPERTIES OF VULCANISED RUBBER ELEMENTS USED ON THE “Izabel” INLAND VESSEL

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Abstract. Vulcanised rubber as a complex system is made from the basic component being virgin rubber and various components amounting to 10-15 per cent or even more. The material gains its most valuable properties in the final phase of processing i.e. vulcanisation. In mechanical as well as automotive engineering it is important for vulcanised rubber to be resistant to grease, oil and fuel in high operating temperatures. Being one of the very valuable isolation materials, vulcanised rubber is also characterised by dielectric and elastic properties as well as distinguished resistance to operating conditions (high/low temperature, weather conditions). All the above mentioned applications of vulcanised rubbers are also found in the shipyard industry. Their use is also very much predicated on the properties such as: ability to attenuate mechanical vibrations, high elasticity, considerable elastic deformability under static and dynamic loads, low permeability of water and gas, resistance to various chemicals, and other. The purpose of this article was to determine the hardness of vulcanised rubber samples obtained from various places on the “Izabel” inland barge. The scope of the study covered sampling and preparing the samples for testing (i.e. cleaning and degreasing the samples). Then, the hardness of the samples was measured using the Shore hardness test. The first part of the article presents the general concept of vulcanised rubber, its main components, properties, applications, and ageing. The second part focuses on the research scope and measuring the hardness of vulcanised rubber samples obtained from the “Izabel” inland barge.

Keywords: vulcanised rubber, hardness, ageing, wear and tear

INTRODUCTION

Vulcanised rubber is an elastic product of the vulcanisation process (i.e. crosslinking the polymer chains) taking place in natural or synthetic virgin rubber in the temperature range 110÷180°C and the time range from several minutes to several hours. Apart from virgin rubber, the processed mixture contains other substances that facilitate the processing and provide the product with appropriate properties (Zawora J. 2001). All virgin rubbers are elastomers, i.e. polymer materials characterised by the ability (in an ambient temperature) to return to its original form almost immediately, even after a considerable deformation resulting from applied loads. The modulus of elasticity of virgin rubbers is very small and falls within the range 1÷10 MPa, the ultimate elongation is up to 1200%, and the reversible elongation is 50÷ 200% (Praca zbiorowa, 1996). There are two kinds of virgin rubbers: natural and synthetic.

The properties of vulcanised rubber vary within a vast range, depending on the kind of virgin rubber, quantity and kind of other ingredients of the rubber mixture, the preparation method and the vulcanisation conditions. By selecting appropriate ingredients of the mixture as well as specific technological parameters, it is practically possible to obtain many grades of vulcanised rubbers showing diverse properties. (1996)

Vulcanised rubber products, whether operated or stored, are subject to the so-called ageing process. This means deterioration of the physical properties of vulcanised rubber, which is manifested by increased tackiness of its surface, softening or hardening, and surface cracking. Vulcanised rubber is subject to ageing in reaction to oxygen, ozone, light, ionising radiation, mechanical deformations, excessively high or low temperatures.

Resistance to ageing is increased by adding appropriate anti-ageing substances to the virgin rubber mixture. Also, premature ageing of vulcanised rubber products may be prevented by appropriate storage. Rooms intended for vulcanised rubber products storage should be dark and airy, with the air relative humidity level of 65 ±15% and temp. 0÷20°C (in the case of chloroprene rubber products, the storage temperature should be above 12°C). Rapid changes in the storage temperature are inadvisable (Koszalew F.F. et al, 1972, Jaroszyńska D. et al. 1978, Gucma M. et al, 2015).

RESEARCH METHODS

One of the vital characteristics of vulcanised rubber is its hardness. Conventionally, it is defined as the resistance of the tested material to being indented by another material forced over a small area. Most often, in order to measure the hardness of a material, a ball or a cone of a specific shape is forced into the tested material with a specified force. In the course of hardness measurement, the most important factor is the friction forces between the vulcanised rubber surface and the measurement element being forced in.

The vulcanised rubber samples were taken from the "Izabel" barge operating on inland waterways (Fig. 1).

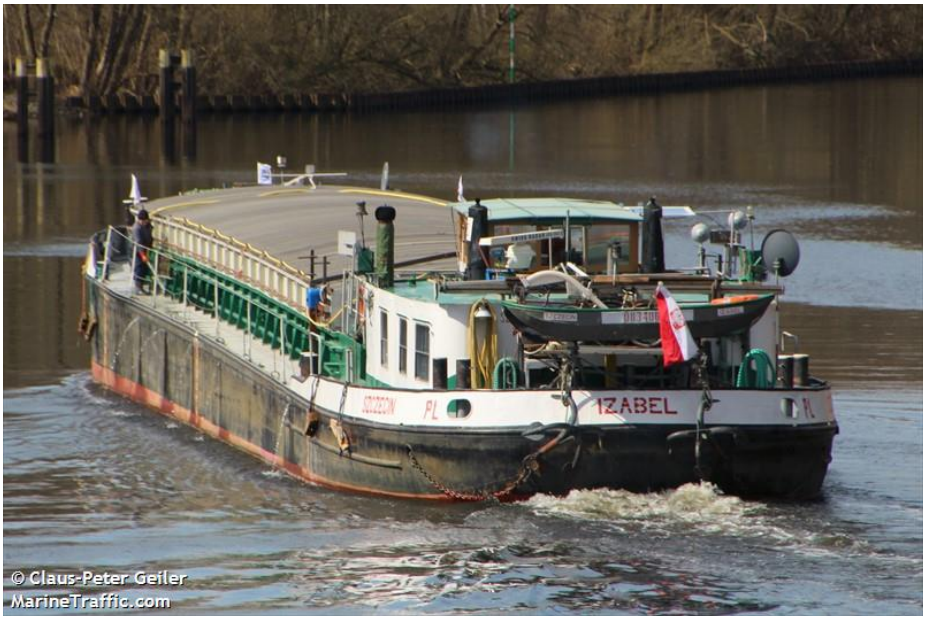

Fig. 1. "Izabel" barge

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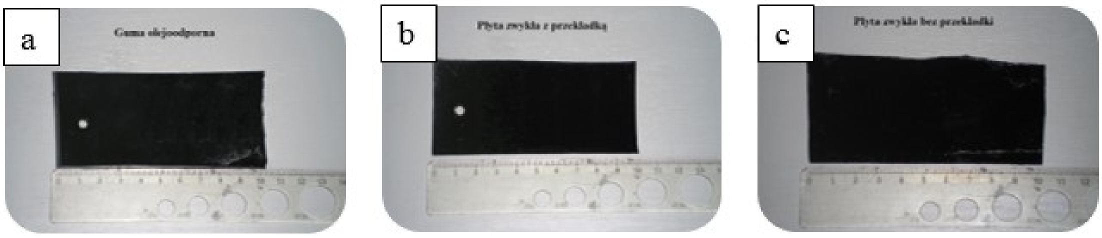
SHORE HARDNESS TESTING

Measuring the hardness by means of Shore's method (pursuant to the PN-71/C-04238 standard) consists in forcing an indenter into the vulcanised rubber sample and reading the size of the indentation which is expressed in Shore hardness units. The scale ranges from 0-100 units. There are three kinds of durometers using Shore's method. They are marked with letters A, B, C and D. For the purpose of this study, type A device was applied, in which the measuring element takes the shape of a truncated cone. The result of the hardness measurement can be read directly on the durometer scale (Jaroszyńska D. et al. 1978; PN-71/C-04238; PN-EN ISO 868:2005; ASTM D2240)

Figures 2 and 3 present the examined samples which were taken from the "Izabel" barge berthing in Szczecin. None of the samples had a defect that would prevent hardness measurement.

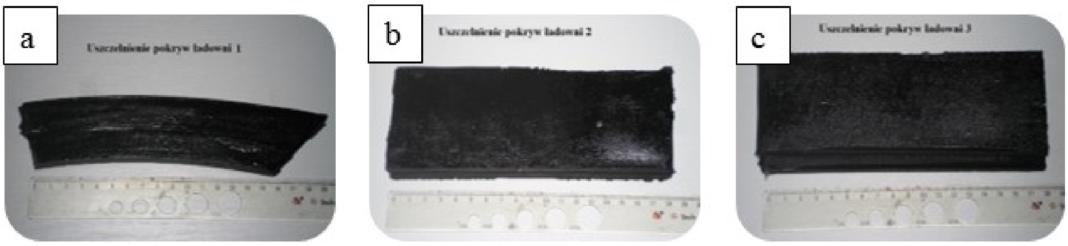


Oil-resistant vulcanised rubber | ordinary rubber board with a spacer | ordinary rubber board without a spacer

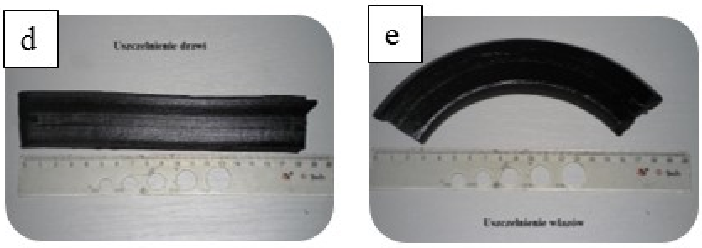
Fig. 2. Vulcanised rubber elements from the engine room and the workshop.

Fig. 2 shows the samples of the vulcanised rubber elements applied in the engine room and the workshop. The first sample (a) is oil-resistant vulcanised rubber. It is a piece of lining used in the barge workshop. The next one (b) is an ordinary board with a spacer, applied to protect the protruding edges in the engine room. The third sample (c) represents an ordinary board without a spacer, which was used as lining all over the workshop.

Fig. 3 presents various seals applied across the barge. The figure elements a, b, c show the seals of the cargo hold. They were sourced from various places so as to account for diverse operating conditions. Element d shows a sample of the door seal. This comes from the barge outside door. hatch seal (e) was sourced from one of the hatches found on the barge.



Seals of the cargo hold 1 | Seals of the cargo hold 2 | Seals of the cargo hold 3



Door seal | Hatch seal

Fig. 3. Seals

Each of the samples was adequately prepared for testing. Their surfaces were cleaned and degreased. Pursuant to the PN-EN ISO 868:2005 standard, the samples were stored in the temperature 20 +/- 2ºC for at least 1 hour. The measurements were taken at three points which were 5mm away from one another and at least 13mm off the sample edge.

In order to take correct measurements, the durometer should be positioned on the right-hand edge of the base, in which the measuring element is located (Fig. 4.a). Then, without exerting any pressure, we position the durometer on our sample in such a way so that its surface is parallel to the sample surface, it should come into contact with the sample surface evenly (Fig. 4.b). It is important that the durometer should not be pressed against the sample, as this could lead to false readings.

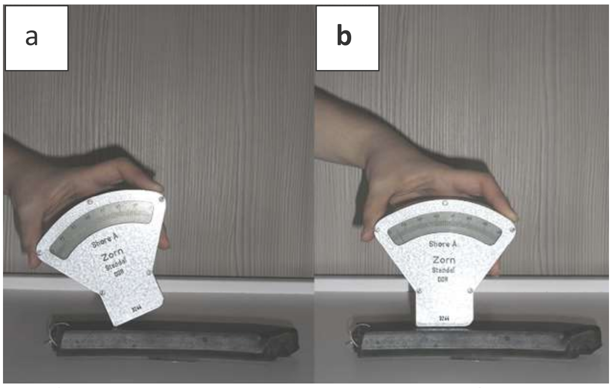


Fig. 4. The stages of taking the measurement with type A Shore durometer

Following the correct positioning of the durometer, the result can be read on the device scale. To characterise the individual samples, three measurements were taken in various places of the same sample. For the purposes of the analysis, their arithmetic mean was calculated. The obtained data are presented in Table 1.

Table 1.
Measurements taken on selected samples.

Kinds of vulcanised rubbers	measurement 1	measurement 2	measurement 3	average
oil-resistant vulcanised rubber	78	78	79	78.3
ordinary board with spacer	80	82	81	81
ordinary board without spacer	70	71	70	70.3
door seal	54	53	51	52.6
hatch seal	37	38	39	38
cargo hold cover seal - 1	48	50	49	49
cargo hold cover seal - 2	43	43	41	42.3
cargo hold cover seal - 3	42	45	47	44.6

According to the data, the hardest element is the board with a spacer – 81’ShA. The least hard are the hatch seals – 38’ShA, subsequently followed by: cargo hold cover seals, door seals, ordinary board without spacer and oil-resistant vulcanised rubber.
Pursuant to the ASTM D2240 standard, oil-resistant vulcanised rubber should show a hardness level from 50 to 80’ShA. The measurement taken with the durometer has shown the average value of 78.3’ShA. This means that the oil-resistant vulcanised rubber has not significantly deteriorated. Its hardness level is high, which is a proof of its perfect properties and which contributes to safety in the workshop.
The ordinary board with a spacer showed the average hardness of 81’ShA. According to the standard, it should be from 75 to 85’ShA. Thus, the hardness of the sample falls within the range. The sample of the board without a spacer should show a hardness level from 65 to 75’ShA, while the measurement indicated 70.3’ShA. The obtained result confirms that the condition of the vulcanised rubber element is very good. As for the door seals, their hardness should fall within the range from 50 to 65’ShA. The measured value was 52.6’ShA, which means that the material still is in an acceptable condition, though close to the lower end of the range. The measured hardness of the hatch seals was 38’ShA. According to the standard, the value should fall between 40 and 65’ShA. This means that the hatch seal hardness is below the acceptable range. The hardness of cargo hold cover seals should be between 40 and 50’ShA. The measurements for these samples fell within the required range.

CONCLUSION

The academic literature research as well as the empirical study results have shown that it is possible to assess the condition of vulcanised rubber elements used on the “Izabel” barge by determining their hardness level. Based on the obtained results of the measurements, it is possible to conclude that the hatch seals should be replaced earlier, as their hardness levels have fallen beyond the range stipulated in the standard. The hardness of the door seals is close to the minimum value stipulated by the standard, which suggests it is advisable to regularly replace the seals made of vulcanised rubber. The other measurements meet the requirements specified in the standard.

It is important to measure the hardness of the vulcanised rubber seals applied on ships or barges, as they may prevent leaks, damages or even sinking or other disasters. Any undesirable transgression of water into the ship or the engine (Gucma M. et al. 2015; Piesowicz E. 2016, Bejger A. et al. 2016, Chybowski L., Gawdzińska K. 2016) may lead to damaging e.g. the cargo or the machines (corrosion) and eventually to sinking of the vessel or damaging the engine room (Bejger A. et al. 2016, Chybowski L., Gawdzińska K. 2016, Chybowski L., Gawdzińska K. 2016). If water gets into the cargo hold, this may lead to damaging the cargo or reducing its value and consequently experiencing problems with selling it. Transgression of water in the case of leaking seals may result in the machines damage and failure, as a result, the vessel may be no longer manoeuvrable, which in turn may affect the vessel safety. This may also lead to a collision with another vessel or the shore, and consequently even sinking. Therefore, it is advisable to inspect the hardness of vulcanised rubber elements applied in operated watercraft.

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