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Quality of hydraulic hoses with reduced service life

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Abstract: The impact of using rubber hydraulic hoses with a shortened service life on environmental pollution has not yet been raised in the scientific national literature. Most researchers focus on the analysis of used engine oils or contaminated fluid in hydraulic systems, rather than on their direct environmental impact. For some time now, the European market has seen an increase in imports of cheap rubber hydraulic hoses from countries outside the Community. There is a potential risk of negative environmental impacts from the use of these hoses if they do not meet appropriate quality standards. The study examined samples of hydraulic hoses purchased directly from the manufacturers or traders of rubber hydraulic hoses from countries outside the European Union. The products were tested for compliance with PN-EN 853:2015-05 and PN-EN 857:2015-05. Out of 14 fully tested hydraulic hoses, only 2 were found to comply with the applicable European standards. The results encourage further research to determine the impact of rubber hydraulic hoses with reduced service life on environmental and economic costs.

Keywords: environmental and economic costs of using substandard components, environmental pollution, reduced service life of rubber hydraulic hoses, rubber hydraulic hoses

INTRODUCTION

Within the European Union, and therefore also in Poland, rubber hydraulic hoses are required to comply with the European standards: ISO 1436:2020(E) or ISO 11237:2017(E). There are over a dozen different brands of rubber hydraulic hoses available on the Polish market, each permanently marked with the above-mentioned European standards, using print or tape. A customer purchasing such a hose, most often a company or a farmer, does not test the actual quality of such a hose. After all, they are in common circulation and are not officially banned under ISO 1436:2020(E) or ISO 11237:2017(E). Additionally, customers typically do not have the appropriate apparatus for such testing. In consequence, the choice often falls on the cheaper option, which does not differ in appearance from products manufactured in Poland and the European Union. This is only an apparent saving, because the lower price often results from a failure to meet the relevant parameters included in the above standards. By purchasing a particular product, the user is convinced that the manufacturer has complied with all quality standards and made efforts to ensure that the product can be used safely and durably.

The problem of non-compliance with applicable standards may have significant negative effects associated with the release of hazardous substances into the environment, specifically gear motor oils. According to 1999 data (Gawrońska and Górski, 1999), the consumption of petroleum-based industrial oils in Poland was at the level of 110,000 $Mg \cdot y^{-1}$, with hydraulic oils accounting for about 40%. Jósko and Kołodziejski (2008), based on their own research and analysis of maintenance and repair documentation, concluded that about 80% of failures in hydraulic systems are caused by improper operation by the users and poor maintenance. The synthesis of the above data paints an alarming picture of the situation.

Negative environmental impact of rubber hydraulic hoses is primarily understood to be the three aspects (Hannon, 2012):
– biodegradability,
– aquatic toxicity,
– soil quality degradation.

According to the analysis of Markiewicz (Jakóbiec and Wysopal, 2005), used oil spilled on the ground penetrates deep into it, causing severe pollution of soil and contamination of groundwater. Moreover, it migrates through subsoil water and watercourses into rivers and reservoirs. During such an uncontrolled incidence, 1 kg of oil makes about 5 mln·dm^3 of water unfit for drinking (Przewoźnik and Grzesik, 2005; Syrek, 2005; Nogaj, 2011). Furthermore, according to the studies by Korzeniowska-Rejmer and Izdebska-Mucha (2006), oil-based contaminants can significantly alter the original properties of cohesive soils. Contamination affects the granulometric composition of soils, increasing the dust fraction while decreasing the clay and sand fraction. This significantly impacts the filter properties of the soils and the values of their mechanical parameters. Spills of petroleum-based hydraulic liquids and synthetic fluids contaminate soil, groundwater, river water, and seawater. Such fluids can harm humans, plants, animals, and marine organisms. The presence of harmful additives in hydraulic fluids, including zinc-based additives, can increase aquatic toxicity in river or seawater upon contact. Negative toxic effects on aquatic organisms may include mortality, as well as reproductive and growth impairment. Contaminants in the used oil, when released into the environment, can cause various diseases in humans and animals through inhalation, ingestion, and skin contact. Observed effects include lung diseases, dermatitis, and cancers such as skin and liver cancer (Katiyar and Husain, 2010). Although there are hydraulic fluids on the market with reduced environmental impact, e.g. Exxon Mobil's offer (Exxon Mobil Corporation, 2017) and hydraulic fluids with low environmental impact (Kučera *et al.*, 2013; Kučera *et al.*, 2017), older generation fluids are still in use due to their favourable price. Moreover, the reduced impact does not mean that the impact has been eliminated.

The use of poor-quality rubber hydraulic hoses involves many potential hazards and risks. Poor structure and use of low-strength materials can cause leaks and ruptures, potentially resulting in accidents, injury to operators, and damage to surrounding equipment. Low-quality hydraulic hoses can also have a lower resistance to heat and fire. In the event of a failure or leak, flammable hydraulic fluid can come into contact with heat sources or sparks, increasing the risk of fires and explosions in the working environment. High-quality rubber hydraulic hoses offer significant long-term savings over low-quality hoses. Although the initial purchase cost may be higher, their durability and extended service life outweigh the initial investment significantly. Their longer lifespan reduces the costs of frequent hose replacement, as well as the costs associated with downtime and labour required for replacement. Given these reasons, it is justified to analyse a selection of hydraulic hoses imported into Poland from outside the European Union.

MATERIALS AND METHODS

MATERIALS

Rubber hydraulic hoses from manufacturers outside the European Union, traded in Poland, were used in the tests. The names of these hoses were not disclosed. All tests were carried out in accordance with the two standards listed below, and the test methodology outlined therein was adhered to when performing the tests.

METHODS

- **Test according to ISO 1436:2020(E)**

This European standard provides requirements for four types of wire braid reinforced hoses and tubes with a nominal diameter from 5 to 51 mm. They are particularly applicable to the following cases:
- hydraulic fluids complying with EN ISO 6743-4:2015-09 (Polski Komitet Normalizacyjny, 2015), with the exception of HFD R, HFD S and HFD T[1], in the temperature range from –40 to +100°C;
- water-based fluids in the temperature range from –40 to +70°C;
- water in the temperature range from 0 to +70°C.

- **Test according to ISO 11237:2017(E)**

This European standard specifies requirements for two types of hydraulic hoses and pipes with nominal diameters from 6 to 25, reinforced with a compact wire braid, types 1SC and 2SC. The hoses are used:
- for hydraulic fluids in accordance with EN ISO 6743-4:2015-09 (Polski Komitet Normalizacyjny, 2015), with the exception of HFD R, HFD S and HFD T, in the temperature range from –40 to +100°C;
- for aqueous solutions in the temperature range from –40 to +70°C;
- for water in the temperature range from 0 to +70°C.

This standard does not specify the requirements for the ends (crimps). The provisions of the standard are limited to characterising hoses and tubes.

- **Dimensions – internal and external diameter**

When measured according to EN ISO 4671:2022-09 (Polski Komitet Normalizacyjny, 2022), hose diameters should comply with values given in Table 1 (acc. to PN-EN 857:2015-05) and Table 2 (acc. to PN-EN 853:2015-05).

[1] HFD R – phosphoric acid esters, HFD S – chlorinated hydrocarbons anhydrous, HFD T – mixture with HFD R and HFD S.

Table 1. Hose diameters (in mm), except for the nominal bore according to PN-EN 857:2015-05

Nominal bore	All types		SC1 type			SC2 type		
	inner diameter		diameter on reinforcement		outer diameter of hose	diameter on reinforcement		outer diameter of hose
	min.	max.	min.	max.	max.	min.	max.	max.
6	6.4	6.9	9.6	10.8	13.5	10.6	11.7	14.2
10	9.5	10.1	12.7	14.5	16.9	14.4	15.6	18.3

Source: own study.

Table 2. Hose diameters (in mm), except for the nominal bore according to PN-EN 853:2015-05

Nominal bore	All types		1ST type			1SN type				2ST type				2SN type		
	inner diameter		diameter on reinforcement		outer diameter of hose	diameter on reinforcement		thickness of outer layer		diameter on reinforcement		thickness of outer layer		outer diameter of hose	thickness of outer layer	
	min.	max.	min.	max.	max.	min.	max.	min.	max.	min.	max.	min.	max.	max.	min.	max.
6	6.4	7.0	10.6	11.6	15.1	16.7	14.1	0.8	1.5	12.1	13.3	16.7	18.3	15.7	0.8	1.5
10	9.5	10.1	14.5	15.7	19.0	20.6	18.1	0.8	1.5	16.1	17.3	20.6	22.2	19.7	0.8	1.5

Source: own study.

• **Resistance to pulsating pressure**

The resistance of hoses to pulsating pressure should be tested in accordance with PN EN ISO 6803:2017 (Polski Komitet Normalizacyjny, 2017). The test temperature should be 100°C. Hoses of 2SC type, tested at a pulsating pressure equal to 133% of the maximum working pressure, should withstand at least 200,000 pulse cycles. The hoses should not leak or otherwise fail before reaching the specified number of cycles. This test is a destructive test, after which the test samples should be disposed of in accordance with the local environmental guidelines.

The apparatus and fitting of hoses for the pulsation test are shown in Photos 1 and 2.

• **Adhesion between the layers**

Adhesion between the inner layer and the reinforcement, as well as between the reinforcement and the outer layer, tested in accordance with PN-EN ISO 8033:2006 (Polski Komitet Normalizacyjny, 2006), should not be less than 2.5 kN·m^{-1}. For testing adhesion between the inner layer and the reinforcement, type 5 test specimens should be used and for testing adhesion between the outer layer and the reinforcement, type 2 or type 6 specimens

Photo 1. Pulsator E3I 703 FLEX from Test Industry (production date 2022), located at BZPG "STOMIL" S.A. in Bydgoszcz (phot.: archiv of BZPG "STOMIL" S.A.)

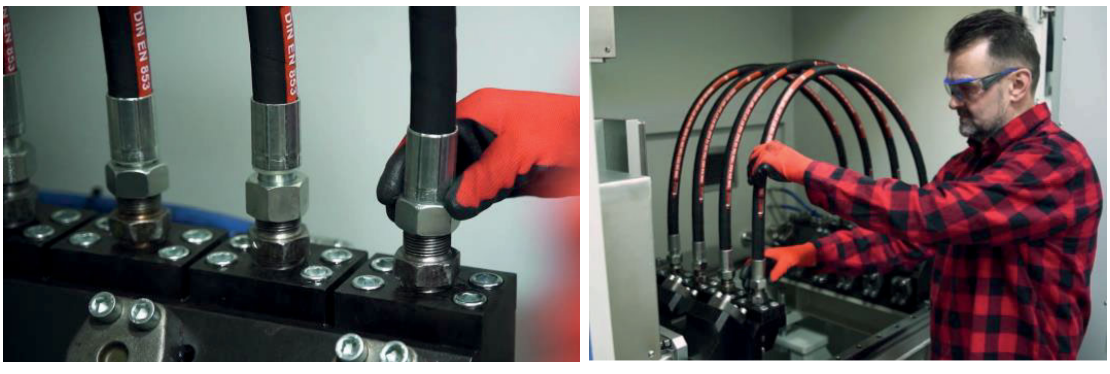


Photo 2. Assembly of hydraulic hoses for pulsation testing (phot.: archiv of BZPG "STOMIL" S.A.)

should be used, according to PN-EN ISO 8033:2006 (Polski Komitet Normalizacyjny, 2006, p. 3, Tab. 1).

• **Abrasion resistance**

All types of hose should be tested in accordance with Appendix A (PN-EN 853:2015-05; PN-EN 857:2015-05). When tested under vertical load (25 ±0.5 N), the loss of mass after 2000 cycles should not be greater than 0.5 g on average for three or more specimens.

RESULTS AND DISCUSSION

INTERNAL DIAMETER MEASUREMENT

Figure 1 shows the results of measuring the internal diameters of different hose types. The majority of the results are within the measurement tolerance, with slight variations from batch to batch. When analysing Figure 1a, it should be noted that only the first 2 hoses show perfect repeatability. The rest of the measurements of the hose samples are in the lower tolerance range or show insignificant dimensional differences. The observed lack of repeatability, with diameters in the lower tolerance range, may be the reason for the non-compliance with the standard in this range of the other samples not tested.

Figure 1b shows a comparison of the internal diameters for hose type DN 10. As before, a large difference in dimensions between the individual hose samples can be seen. Additionally, one of the results exceeded the upper acceptable tolerance limit.

MEASUREMENT OF OUTER DIAMETERS

Figure 2 shows the results of measuring outer diameters of various hydraulic hoses. All measurements meet the tolerance range specified in the standard. However, upon fully analysing the results, it is notable that there are significant differences between the individual diameters of hoses from different manufacturers. This could affect problems when crimping hoses if the end customer purchases hoses with varying outer diameters from different suppliers. This can lead to defects in hydraulic hoses (cupped hose), even though both the hose used and the cupping meet the standard.

RESULTS OF PULSATION TESTS

From the point of view of the durability of hydraulic hoses, the most relevant analysis is the resistance to pulsating pressure. Figure 3 shows aggregate results for hoses type DN 6. Significant discrepancies can be observed depending on the hose manufac-

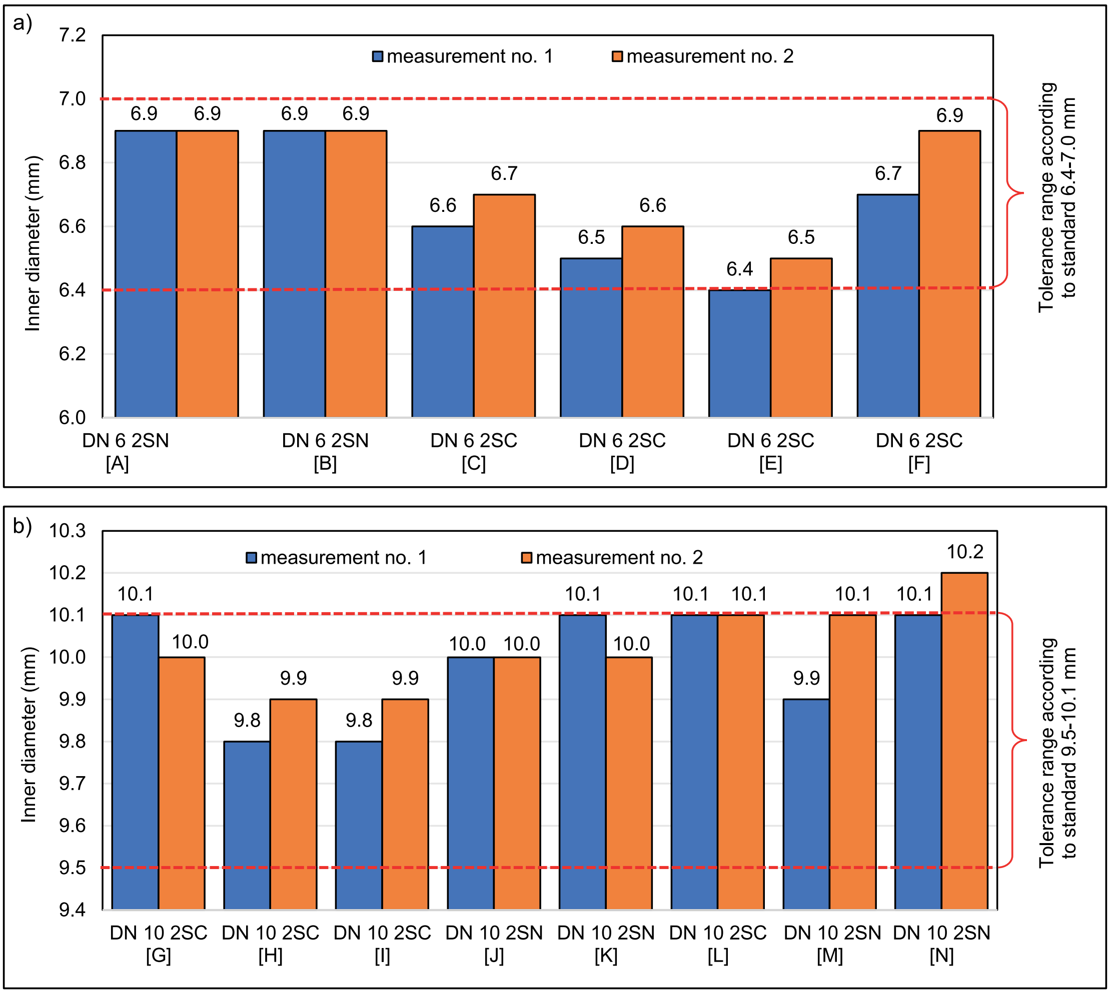


Fig. 1. Inner diameter of hydraulic hoses from various manufacturers type: a) type DN 6, b) type DN 10; DN 6 2SN, DN 6 2SC, DN 10 2SC, DN 10 2SN = type of hydraulic hoses, [A] … [N] = symbol of manufacturer; source: own study

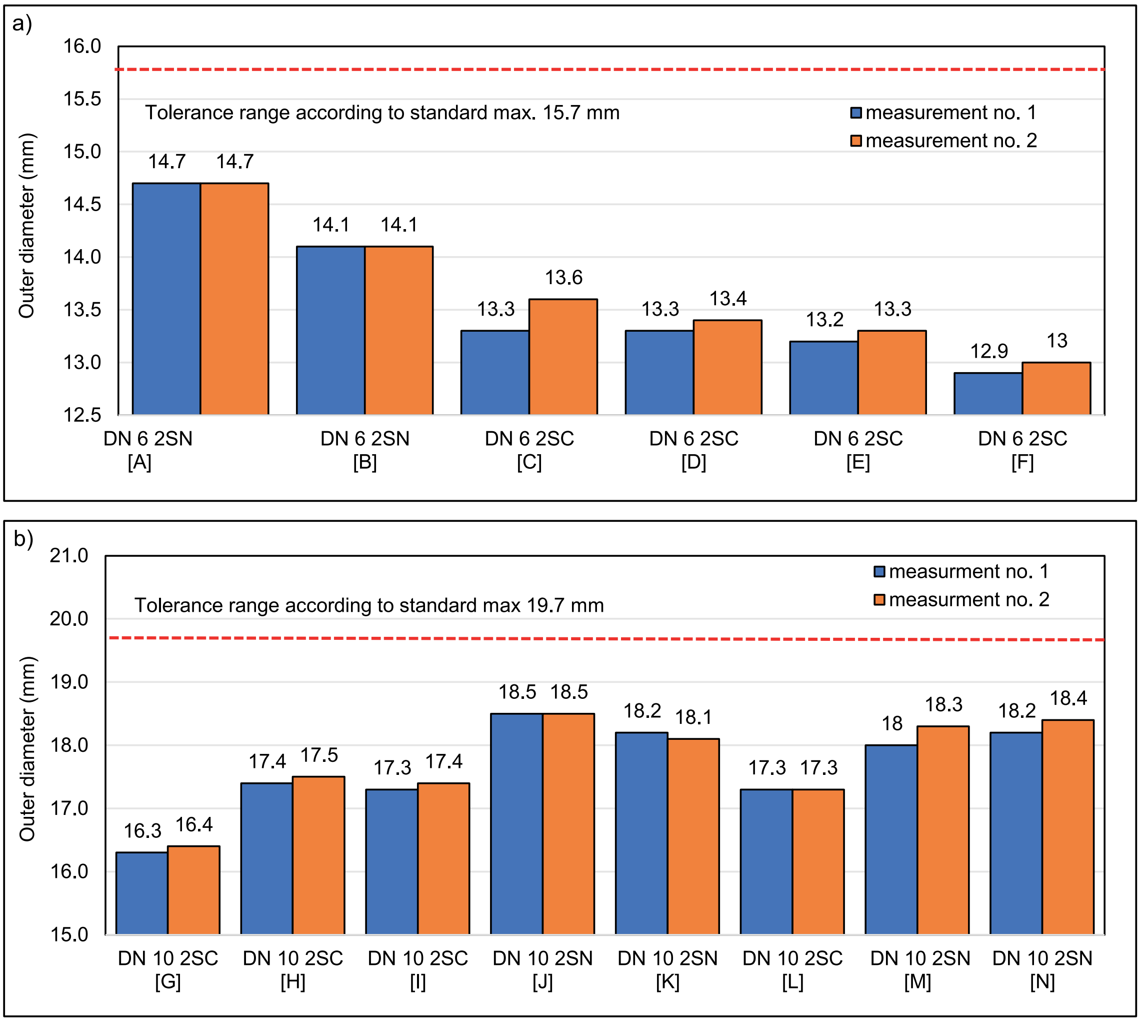
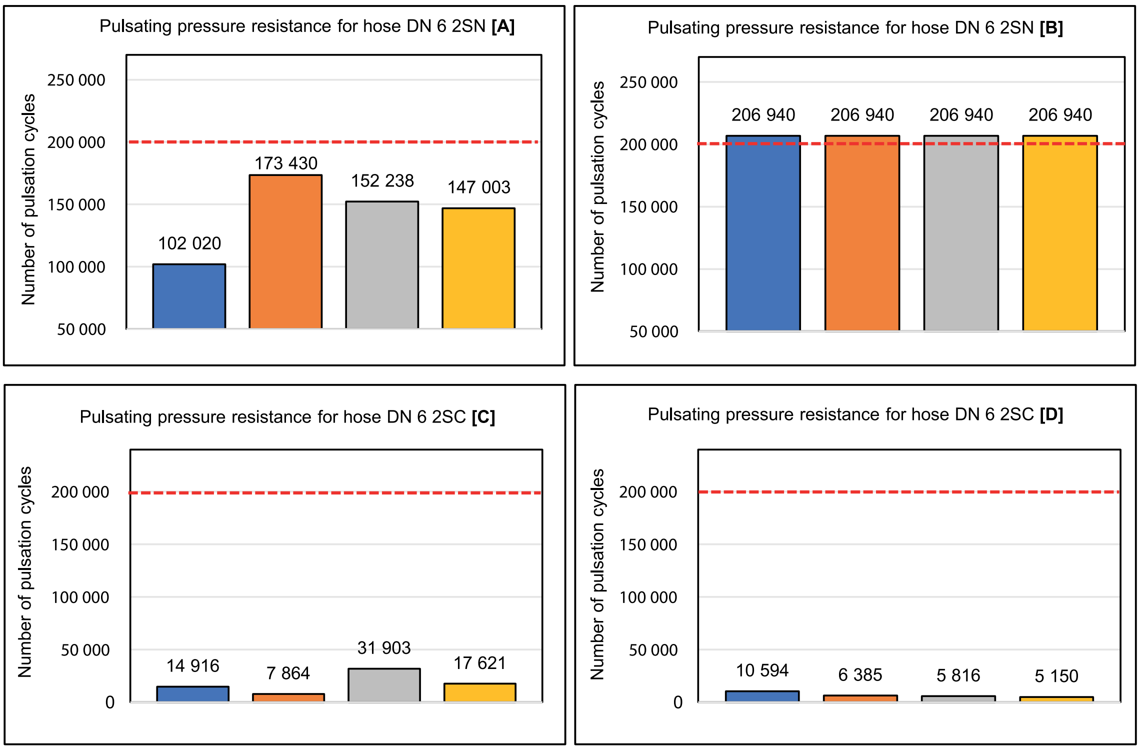


Fig. 2. Outer diameter of hydraulic hoses from various manufacturers a) type DN 6, b) type DN 10; symbols as in Fig. 1; source: own study



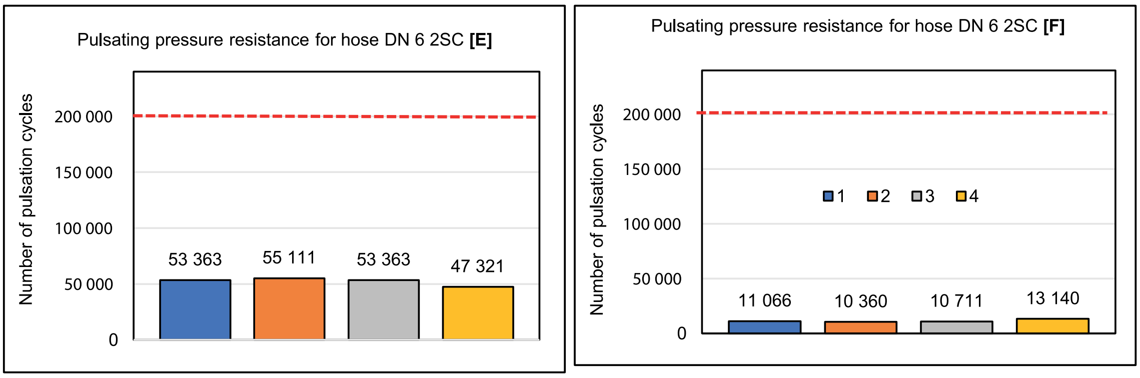


Fig. 3. Pulsating pressure resistance of type DN 6 hydraulic hoses from different manufacturers; 1, 2, 3, 4 = manufacturer number, other symbols as in Fig. 1; source: own study

turer. Only one hose passed all four tests (hose DN 6 2SN [B]). The test results for other hoses were negative, showing a resistance to pulsation pressure of approx. 75% of the minimum value (hose DN 6 2 SN [A]) or well below the standard at only approx. 25% (hose DN 6 2SN [E]) and approx. 5% of the minimum value (hoses [C], [D], [F]). Such a low number of pulsation cycles has negative impact on the use of the finished product, resulting in premature wear and release of hydraulic fluids into the environment[2].

The situation is slightly better for the DN 10 type hoses shown in Figure 4.

Of the 8 hoses tested, 4 withstood the required number of pulsation cycles ([G], [K], [M], [N]), hose [H] came very close to passing the test. Only one hose in the tested series failed the test. Hose [L] recorded very low pulsation results, and hose [J] even lower, resulting in negative tests.

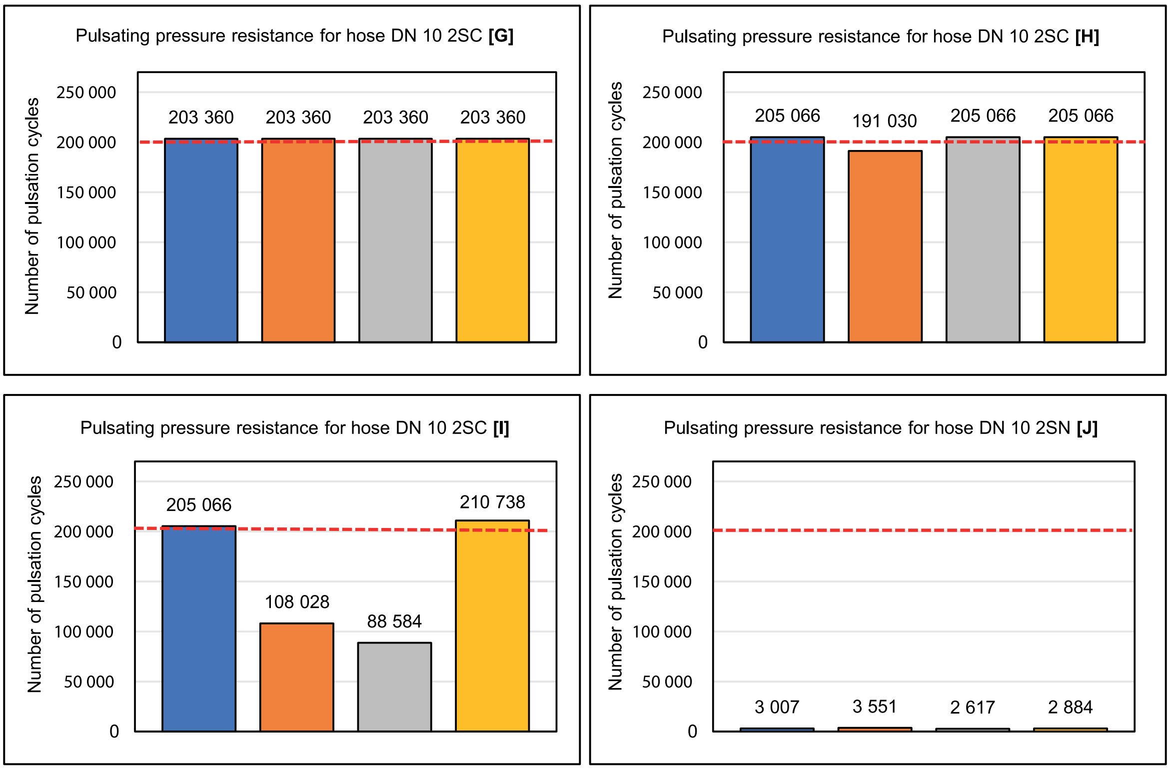
[2] The leakage of faulty hydraulic systems on fully operational tractors and machinery is discussed in Golka and Kamiński (2016).

ADHESION

Samples were prepared and interlayer adhesion was tested for the different hose types (Tab. 3). In all cases tested, the results were above the required minimum; thus all hoses met this parameter. A good bonding of the individual layers (adhesion) has a positive effect on the service life of the hose.

ABRASION RESISTANCE

In order to analyse the quality of the presented products in detail, a summary table was prepared (Tab. 4) with the abrasion resistance results correlated with the pulsation data. As a result of comparing the two parameters, it was found that only two types of hose met all the requirements presented in the applicable European standards.



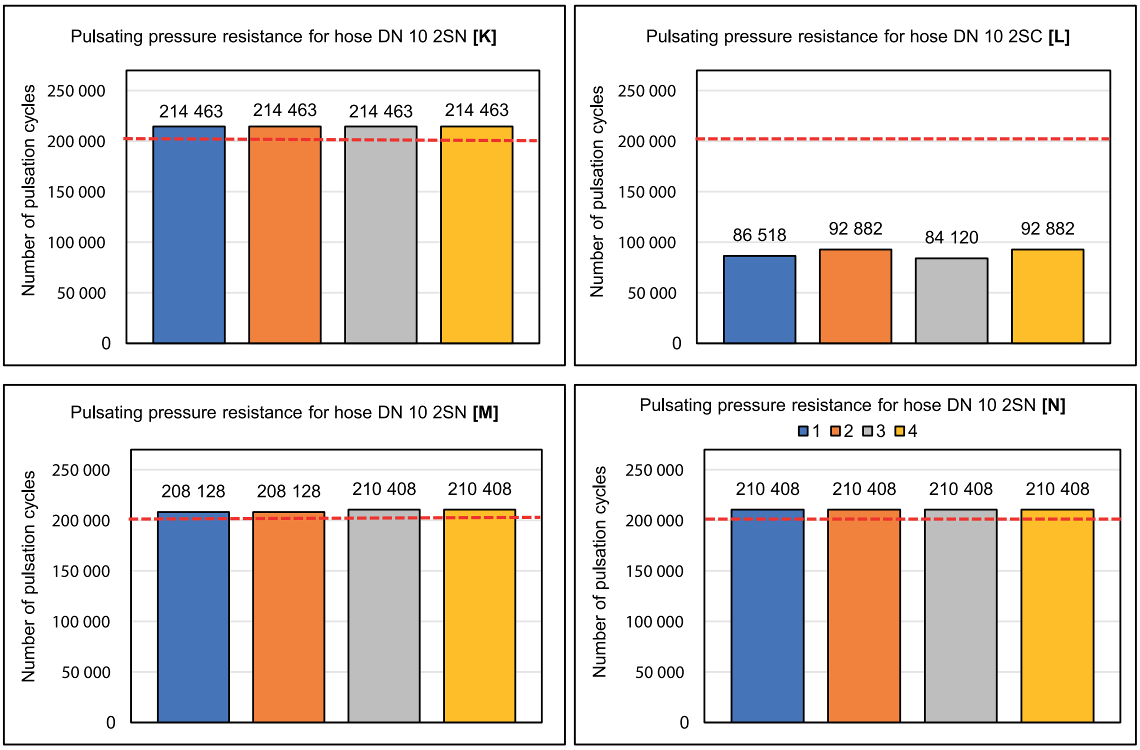


Fig. 4. Pulsating pressure resistance of hydraulic hoses type DN 10 from different manufacturers; 1, 2, 3, 4 = manufacturer number, other symbols as in Fig. 1; source: own study

Table 3. Adhesion between layers for different types of hydraulic hoses

Product name	Adhesion between layers[1] ($kN \cdot m^{-1}$)
Hose DN 6 2SN [A]	adhesion greater than rubber strength
Hose DN 6 2SN [B]	3.16
Hose DN 6 2SC [C]	adhesion greater than rubber strength
Hose DN 6 2SC [D]	adhesion greater than rubber strength
Hose DN 6 2SC [E]	adhesion greater than rubber strength
Hose DN 6 2SC [F]	adhesion greater than rubber strength
Hose DN 10 2SC [G]	3.02
Hose DN 10 2SC [H]	2.93
Hose DN 10 2SC [I]	3.14
Hose DN 10 2SN [J]	3.21
Hose DN 10 2SN [K]	3.27
Hose DN 10 2SC [L]	adhesion greater than rubber strength
Hose DN 10 2SN [M]	adhesion greater than rubber strength
Hose DN 10 2SN [N]	adhesion greater than rubber strength

[1] Adhesion between layers not less than 2.5 $kN \cdot m^{-1}$.
Explanations as in Fig. 1.
Source: own study.

Table 4. Abrasion resistance of various hydraulic hoses with a summary of pulsation test results

Product name	Abrasion resistance	Pulsation result	Total result
Hose DN 6 2SN [A]	–	negative	negative
Hose DN 6 2SN [B]	negative	positive	negative
Hose DN 6 2SC [C]	negative	negative	negative
Hose DN 6 2SC [D]	positive	negative	negative
Hose DN 6 2SC [E]	positive	negative	negative
Hose DN 6 2SC [F]	negative	negative	negative
Hose DN 10 2SC [G]	**positive**	**positive**	**positive**
Hose DN 10 2SC [H]	negative	negative	negative
Hose DN 10 2SC [I]	negative	negative	negative
Hose DN 10 2SN [J]	positive	negative	negative
Hose DN 10 2SN [K]	**positive**	**positive**	**positive**
Hose DN 10 2SC [L]	negative	negative	negative
Hose DN 10 2SN [M]	negative	positive	negative
Hose DN 10 2SN [N]	negative	positive	negative

Explanations: "–" = no test, sample destroyed before testing process, other explanations as in Fig. 1.
Source: own study.

SUMMARY

In this study, 14 rubber hydraulic hoses purchased from various manufacturers outside the European Union were tested. It was found that the vast majority of them did not meet the ISO 1436:2020(E) or ISO 11237:2017(E) standards declared by the suppliers. After collecting all the results, it was found that only 2 hydraulic hoses tested met the requirements of the above-mentioned standards.

This is a very disturbing fact because, according to the results of the Census of Agriculture 2020 (GUS, 2021), there were approximately 2,204,000 machines on farms (including approximately 1,448,000 agricultural tractors). If we assume that a tractor as a basic working machine, has a hydraulic kit in its equipment and there are approx. 10 linear metres (LM) of hydraulic hoses, this results in a simple calculation of more than 14,480,000 LM of hose in approximately 1–1.5 m sections. If the trend of replacing hoses manufactured within the EU with those from other sources continues and non-EU manufacturers do not improve quality, we could end up in a situation where, according to Table 4, out of 14 full tests on hoses only 2 meet the standards. This means that on installed hydraulic hoses totaling 14,480,000 m, consisting of 1 m lengths, as many as 85% may leak hydraulic fluids uncontrollably into the environment.

The tests carried out additionally show a large discrepancy in the results obtained, with some samples having extremely low resistance to pulsating pressure. This shortens the service life and increases the risk of operating hydraulically controlled equipment. Additionally, many samples exhibited insufficient abrasion resistance, which significantly shortens the life of the hoses and increases the risk of corrosion.

However, there are solutions in the form of biodegradable vegetable oils to reduce the environmental impact of hydraulic oils used in agricultural machinery (Tkáč *et al.*, 2017; Majdan *et al.*, 2019) and ships (Xinyu, 2023). They can be used in mobile hydraulic systems such as forestry and agricultural machinery (Rogoś and Urbański, 2009). According to the sources, mineral products can be replaced with these oils; however, it should be remembered that their service life may be shorter.

CONCLUSIONS

In fact, it seems necessary to continue the work we have started and to determine the precise impact on aquatic and land environments from the use of hydraulic hoses with reduced service life. What is surprising, however, is the scarcity of scientific publications and studies considering the above case, particularly in the context of hydraulic systems and hoses.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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