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**Dominika GRYGIER[*], Aleksandra KĘSKA[**]**

# THE ASSESSMENT OF THE INFLUENCE OF THE MATERIAL USED ON THE WEAR AND TEAR OF FORKLIFTS AND THEIR OPERATIONAL SAFETY

## OCENA WPŁYWU ZASTOSOWANEGO MATERIAŁU NA ZUŻYCIE EKSPLOATACYJNE I BEZPIECZEŃSTWO PRACY WIDEŁ WÓZKÓW WIDŁOWYCH

**Key words:** forklifts, forks, wear and tear, microstructure.

**Abstract:** The degree of wear of forklift forks is not always the effect of long operations or difficult operating conditions. The key parameter influencing the premature elimination of a vehicle from use is selecting an unsuitable material to make forks. Metallographic research allowed us to test the material structure and estimate which materials would allow us to extend the exploitation time of the forklift forks and, consequently, increase the operation safety level by excluding the inappropriate technical condition of a vehicle. The conducted research showed that the application of the properly selected heat treatment of steel allowed to obtain material characterised by high hardness and the lowest abrasion resistance, and simultaneously it accounted for the lowest fork wear level. Extending the standard macroscopic wear tests by microscopic tests may constitute an introduction to the research on standardising the material used to construct forklift forks.

**Słowa kluczowe:** wózki widłowe, widły, martenzyt, ferryt, perlit.

**Streszczenie:** Stopień zużycia eksploatacyjnego wideł wózków widłowych nie zawsze jest wynikiem długiego okresu użytkowania czy trudnych warunków pracy pojazdu. Najistotniejszym parametrem, który wpływa na zbyt szybkie wykluczenie pojazdu z użytkowania jest dobór nieodpowiedniego materiału, z którego wykonane są widły. Wykorzystanie badań metalograficznych pozwoliło zbadać struktury materiałów i ocenić, która z nich pozwoliłaby wydłużyć okres eksploatacji wideł wózka widłowego, a w konsekwencji zwiększyłaby poziom bezpieczeństwa pracy, wykluczając niewłaściwy stan techniczny pojazdu. Przeprowadzone badania wykazały, że zastosowanie odpowiednio dobranej obróbki cieplnej stali umożliwia uzyskanie materiału charakteryzującego się wysoką twardością i najmniejszą odpornością na zużycie ścierne powierzchni, a jednocześnie odpowiada za najniższy poziom zużycia wideł. Poszerzenie standardowych badań oceny makroskopowej zużycia wideł o badania mikroskopowe może stanowić wstęp do badań nad znormalizowaniem rodzaju materiału używanego w konstrukcji wideł wózków widłowych.

## INTRODUCTION

Lift trucks, frequently also called forklifts, are power-driven wheeled vehicles used to transport heavy loads in handling equipment and storage. All forklifts, regardless of their type, are subject to state inspections encompassing safety of use and technical installation efficiency. Under Polish law **[L. 23]**, the equipment is handed over to service after being granted the authorisation of the Office of Technical Inspection (UDT). The technical acceptance procedure encompasses inspecting gas and hydraulic system tightness, the steering and brake systems, lights and sound signalling, rated

[*] ORCID: 0000-0001-7062-6357. Wrocław University of Science and Technology, Automotive Engineering Department, Wybrzeże Wyspiańskiego 27, 50-372, Wrocław, Poland.
[**] ORCID: 0000-0001-8361-7580. Wrocław University of Science and Technology, Automotive Engineering Department, Wybrzeże Wyspiańskiego 27, 50-372, Wrocław, Poland.

load capacity, operator chair mounting, seatbelt efficiency, forklift marking, documentation, and also chain, tyre and fork wear. It transpired, however, that quite frequently, the parameter, which is not standardised, and yet it influences the premature elimination of a vehicle from use, is the selection of inappropriate material to make forks. The fork wear criteria encompass microcrack detection on the fork's surface, the inspection of straightness between the front surface of the mast and the top surface of a fork tip, fork line inclination angle and the difference between fork tips' height, fork security systems inspection, bottom fork surface thickness and manufacturer's marking on forks.

The inappropriate condition of the material factor is one of three main reasons for accidents at work (**Fig. 1**). The activities performed by a vehicle operator and the organisation of their work are the factors that the operator is responsible for while doing their duties. On the other hand, equipment, machines, and other material objects used during work should meet all safety requirements so as to minimise the risk of undesirable events happening independently of the user's intentions. The job-related Health and Safety regulations indicated that in the case of operating forklifts, it is necessary to check the technical condition of the forklift before starting its operation; this includes, among others, inspecting the operation of forks. However, noticing a material fault resulting from selecting a material with low strength properties, which may lead to causing an accident by a forklift driver, is not possible. The application of an appropriate construction material influences both the safety of the forklift operator and the people near his/her workplace.

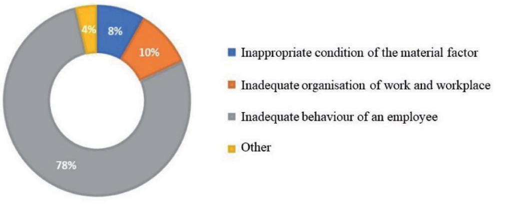


**Fig. 1. Reasons for accidents at work in Poland in 2020 [L. 1]**
Rys. 1. Przyczyny wypadków przy pracy w 2020 r. w Polsce **[L. 1]**

So far in the literature, the influence of the material selected to make the forks of forklifts on their wear, and hence also on the safety of people, has not been discussed. The research on forklifts focuses mainly on the use of various types of equipment and systems to control forklift operation and the work of operators, including the time of their work and events, as well as activities and processes. The subject matter of the research conducted in recent years on forklifts in the world can be divided into three main areas: work safety, transport logistics and the drive type (**Fig. 2**).

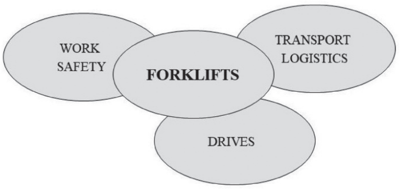


**Fig. 2. Main areas of research on forklifts between 2017 and 2022**
Rys. 2. Główne obszary badań wózków widłowych w latach 2017–2022

Work safety is a critical issue in the research on forklifts discussed in the literature for a few decades **[L. 6, 11, 18, 19]**. The reason why is that the use of forklifts is connected with the highest number of casualties in the workplace **[L. 4]**. The literature analysis encompasses mainly the reasons for human accidents and the influence of work on forklift operators' health. For instance, the literature presents the results of histopathological tests of an unusual head injury of an operator who fell off the forklift **[L. 7]**; the analysis of this event allowed us to examine the reasons for the accident and improve work safety. Another study presents the analysis of a numerical simulation of a forklift fall, which allowed us to determine the efficiency of passive safety systems in the vehicle **[L. 14]**. The influence of dangerous logistic activities in a company on the musculoskeletal system load of its employees was also examined. This allowed us to determine the optimal working parameters for an operator, in which they do not adopt unphysiological body postures influencing work discomfort **[L. 12]**. A new method to assess the acoustic comfort of forklift operators was developed; it allows them to meet the industry noise level standards and improve acoustic comfort **[L. 21, 22]**.

In the transport logistic sector, a new forklift fleet energy consumption method was developed to limit emissions and reduce operating costs **[L. 20]**. The method was verified in logistic centres and compared with computer simulation results. Another example of research is creating a data collection system which collects data on the status of forklift operations in large shipyards **[L. 13]**.

A frequent research direction in recent years has been assessing the potential of fuel and accumulator cells as power sources in the forklift to reduce greenhouse gas emissions **[L. 8, 9, 24]**. The research specifies, among others, the rules governing the development of the strategy of forklift fleet management to improve overall efficiency and energy saving **[L. 17]**. One of the ideas discussed is hydrogen storage so as to replace the counterweight system and use heat dissipation in fuel cells to generate energy **[L. 2]**. Another interesting aspect considered in the research is machine learning **[L. 10]**. An inherent component of research on wheeled vehicles is the exhaust emission tests from exhaust pipes in real operating conditions. By using a portable measurement system, the emission of harmful compounds was measured in forklift exhausts to calculate emission coefficients and their verification according to the national guidelines **[L. 16]**.

The metallographic analysis of materials used to construct forklift forks and the macroscopic evaluation of the condition of fork elements presented in this study proved that the safety degree of a vehicle during its exploitation is undoubtedly influenced by the type of used heat treatment and or plastic treatment in the manufacturing process of these elements.

## GOAL AND SUBJECT OF RESEARCH

The research goal was to assess the influence of the material selected for forklift forks on their wear and work safety by extending the range of standard UDT inspections by microscopic tests and hardness measurements of construction materials used in forklifts.

The analysis presented in this paper encompassed macroscopic tests of forks and metallographic tests of fork material. The macroscopic tests were performed on the forklift forks of various sizes, made by three different manufacturers (**Tab. 1**). Each manufacturer was asked to provide nine pairs of forks selected for inspection. The forks were used in the same working conditions; however, their time of use was different. The working conditions were divided into three groups depending on the number of monthly moto hours: easy – from 0 to 80 mtg, medium – from 81 to 160 mtg and difficult – over 161 mtg. The microscopic tests and hardness measurements were performed on three different forklift forks from various manufacturers (**Tab. 2**).

**Table 1. Forklift forks subjected to macroscopic tests**
Tabela 1. Widły wózków widłowych poddane badaniom makroskopowym

| No. | Producer | Forklift carriage class | Size [mm] | Period of use [months] | Operating conditions* |
|---|---|---|---|---|---|
| 1 | A | 2A | 100x45x1100 | 6 | 1 |
| 2 | | | | 12 | 2 |
| 3 | | | | 24 | 3 |
| 4 | | 3A | 120x50x1200 | 24 | 1 |
| 5 | | | | 18 | 2 |
| 6 | | | | 36 | 3 |
| 7 | | 4A | 150x60x1800 | 18 | 1 |
| 8 | | | | 48 | 2 |
| 9 | | | | 6 | 3 |
| 10 | B | 2A | 100x35x1100 | 12 | 1 |
| 11 | | | | 24 | 2 |
| 12 | | | | 12 | 3 |
| 13 | | 3A | 100x45x1200 | 24 | 1 |
| 14 | | | | 18 | 2 |
| 15 | | | | 36 | 3 |
| 16 | | 4A | 150x60x1800 | 9 | 1 |
| 17 | | | | 18 | 2 |
| 18 | | | | 24 | 3 |
| 19 | C | 2A | 80x40x1100 | 48 | 1 |
| 20 | | | | 24 | 2 |
| 21 | | | | 12 | 3 |
| 22 | | 3A | 100x45x1200 | 12 | 1 |
| 23 | | | | 48 | 2 |
| 24 | | | | 6 | 3 |
| 25 | | 4A | 150x60x2000 | 24 | 1 |
| 26 | | | | 18 | 2 |
| 27 | | | | 12 | 3 |

* operating conditions: 1 – easy, 2 – medium, 3 – difficult
* warunki pracy: 1 – łatwe, 2 – średnie, 3 – trudne

**Table 2. Forklift forks subjected to microscopic tests and hardness measurements**
Tabela 2. Widły wózków widłowych poddane badaniom mikroskopowym oraz pomiarom twardości

| Producer | Forklift carriage class | Size [mm] | Period of use [months] | Operating conditions |
|---|---|---|---|---|
| A | 2A | 80x40x1100 | 12 | medium |
| B | 2A | 80x40x1100 | 0 | medium |
| C | 2A | 80x40x1100 | 24 | medium |

## RESEARCH METHODS

Parametric tests, standard during UDT inspections, were conducted for the forks selected for macroscopic tests. However, the assessment of three parameters which do not determine the elimination of a vehicle from service due to the wear of fork construction material was neglected, namely the factory designation of forks, and prohibited modifications, which should be confirmed by a manufacturer's declaration of conformity of forks, and the condition of safety elements. The elimination of a vehicle from service due to construction material wear was caused by the following:

- all cracks and deformations of forks on their whole surface, especially on edges,
- visible deformations of fork tips in relation to the gauge put at the fork core – if the back of the fork was straight, the measure was adhered along its whole length (**Fig. 3**),

**Fig. 3. Testing deformations of the fork tip core**
Rys. 3. Sprawdzenie odkształcenia trzonu kła widły

- fork line inclination angle exceeding 3° – in the tests, control points on a core and fork blade were measured at a distance of 500 mm from a previously set cut on a heel; when the points connected with the used gauge indicated a green area, the fork dilation was smaller than 3%, the yellow area indicated that it was necessary to control further dilation, while the red part disqualified forks from further service (**Fig. 4**),

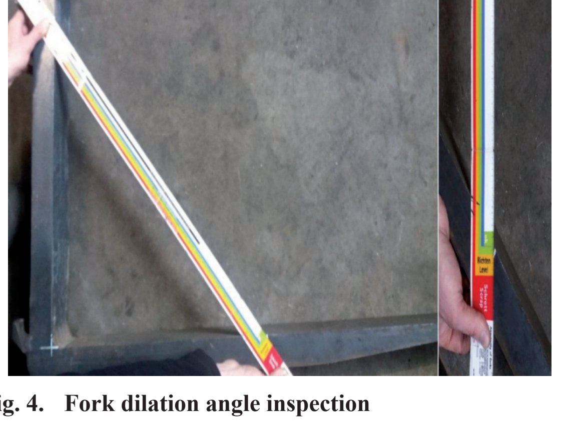

**Fig. 4. Fork dilation angle inspection**
Rys. 4. Kontrola kąta rozwarcia wideł

- fork height differences exceeding a 3% difference of their length in relation to their inclination at the end (**Fig. 5**),

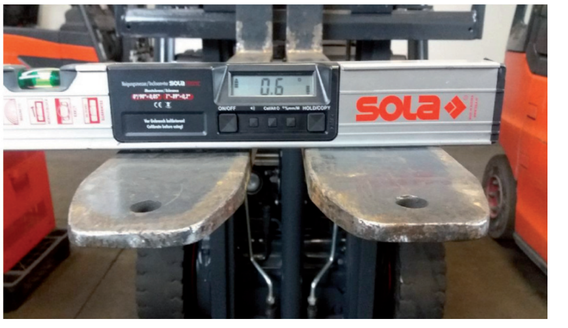


**Fig. 5. Inspection of fork height difference at the ends of forks**
Rys. 5. Sprawdzenie różnicy wysokości końców wideł

- fork tip abrasion up to 10%, however, not exceeding 5 mm, unless the manufacturer recommended otherwise – the inspections were made using a straight edge to measure fork cores, next an appropriate cut-out was applied to the tip; if the forks fell into the cut in the straight edge, they were no longer fit for use (**Fig. 6**).

**Fig. 6. Inspection of fork tip abrasion using a Vetter straight edge**
Rys. 6. Sprawdzenie wytarcia kła widły przymiarem firmy Vetter

The assessment of fork material structure was conducted using a NIKON ECLIPSE MA200 light microscope. The observations were made in the etched and unetched state, in the magnification range of 100x ÷ 1000x. Image registration was performed using a digital camera, Visitron Systems, coupled to a microscope, Spot Advanced and NIS Elements BR. The metallographic specimens of consecutively taken samples were made in the longitudinal and transverse direction to the plastic forming, using mechanical grinding and polishing, and also chemical etching with Mi3Fe.

The hardness measurements of the tested samples were made using the Vickers method with an MMT-X3 micro-hardness tester, compliant with the PN-EN ISO 6507-2:1999 standard. The measurement time was 15 s under a load of 1000g. The measurements were taken at ambient temperature.

## RESEARCH RESULTS

### Macroscopic tests

The macroscopic assessment of the fork surface demonstrated the occurrence of cracks in group A on forks in operation for two years under challenging conditions and four years in medium conditions (**Tab. 3**). The forks made by manufacturer B were eliminated from service after one year of operation. Likewise, group C forks had to be replaced after one year of operation in difficult conditions and after four years in medium conditions. It is worth noting that in the group of forks made by manufacturer A, the smallest number of fork pairs were eliminated from service.

**Table 3. Fork inspection results; X – elimination from service**
Tabela 3. Wyniki kontroli powierzchni wideł; X – oznacza wyłączenie z eksploatacji

| No. | Producer | Perid of use [months] | Operating conditions* | Fork surface |
|---|---|---|---|---|
| 1 | | 6 | 1 | |
| 2 | | 12 | 2 | |
| 3 | | 24 | 3 | X |
| 4 | | 24 | 1 | |
| 5 | A | 18 | 2 | |
| 6 | | 36 | 3 | |
| 7 | | 18 | 1 | |
| 8 | | 48 | 2 | X |
| 9 | | 6 | 3 | |
| 10 | | 12 | 1 | |
| 11 | | 24 | 2 | |
| 12 | | 12 | 3 | X |
| 13 | | 24 | 1 | |
| 14 | B | 18 | 2 | |
| 15 | | 36 | 3 | X |
| 16 | | 9 | 1 | |
| 17 | | 18 | 2 | |
| 18 | | 24 | 3 | X |
| 19 | | 48 | 1 | |
| 20 | | 24 | 2 | |
| 21 | | 12 | 3 | X |
| 22 | | 12 | 1 | |
| 23 | C | 48 | 2 | X |
| 24 | | 6 | 3 | |
| 25 | | 24 | 1 | |
| 26 | | 18 | 2 | |
| 27 | | 12 | 3 | X |

* operating conditions: 1 – easy, 2 – medium, 3 – difficult
* warunki pracy: 1 – łatwe, 2 – średnie, 3 – trudne

In the tested group, a few forks did not meet the core deformation criterion; as a result, they were eliminated from service (**Tab. 4**). In the case of group A, these were forks which had been in operation in medium-hard conditions for four years and difficult conditions for two years. In the group, only one pair of forks was eliminated from service; it had been in operation for two years in medium-hard conditions. In group C two pairs of forks were disqualified; they had been used for four years in easy conditions and one year under challenging conditions. In each of the forklifts, only one fork had a defect in the form of a core deformation. Unfortunately, this definitely disqualified both forks from service.

**Table 4. Fork core inspection results; X – elimination from service**
Tabela 4. Wyniki kontroli odkształcenia trzonu wideł; X – oznacza wyłączenie z eksploatacji

| No. | Producer | Perid of use [months] | Operating conditions* | Core deformation |
|---|---|---|---|---|
| 1 | | 6 | 1 | |
| 2 | | 12 | 2 | |
| 3 | | 24 | 3 | X |
| 4 | | 24 | 1 | |
| 5 | A | 18 | 2 | |
| 6 | | 36 | 3 | |
| 7 | | 18 | 1 | |
| 8 | | 48 | 2 | X |
| 9 | | 6 | 3 | |
| 10 | | 12 | 1 | |
| 11 | | 24 | 2 | X |
| 12 | | 12 | 3 | |
| 13 | | 24 | 1 | |
| 14 | B | 18 | 2 | |
| 15 | | 36 | 3 | |
| 16 | | 9 | 1 | |
| 17 | | 18 | 2 | |
| 18 | | 24 | 3 | |
| 19 | | 48 | 1 | X |
| 20 | | 24 | 2 | |
| 21 | | 12 | 3 | |
| 22 | | 12 | 1 | |
| 23 | C | 48 | 2 | |
| 24 | | 6 | 3 | |
| 25 | | 24 | 1 | |
| 26 | | 18 | 2 | |
| 27 | | 12 | 3 | X |

* operating conditions: 1 – easy, 2 – medium, 3 – difficult
* warunki pracy: 1 – łatwe, 2 – średnie, 3 – trudne

During the fork inclination angle inspection, only two fork pairs were eliminated as a result (**Tab. 5**). In group A, no pair with this type of wear defect was found. However, in group B forks with a too large inclination angle were found, they had been exploited for only nine months in easy conditions, and another eliminated pair had been used for 18 months in medium-hard conditions.

The results of the fork height inspection allowed us to find fork pairs in groups B and C, which qualified for elimination from service; they had been used for a year in easy conditions (**Tab. 6**).

**Table 5. Inclination angle inspection results; X – elimination from service**

Tabela 5. Wyniki kontroli kąta rozwarcia wideł; X – oznacza wyłączenie z eksploatacji

| No. | Producer | Perid of use [months] | Operating conditions* | Inclination angle |
|---|---|---|---|---|
| 1 | | 6 | 1 | |
| 2 | | 12 | 2 | |
| 3 | | 24 | 3 | |
| 4 | | 24 | 1 | |
| 5 | A | 18 | 2 | |
| 6 | | 36 | 3 | |
| 7 | | 18 | 1 | |
| 8 | | 48 | 2 | |
| 9 | | 6 | 3 | |
| 10 | | 12 | 1 | |
| 11 | | 24 | 2 | |
| 12 | | 12 | 3 | |
| 13 | | 24 | 1 | |
| 14 | B | 18 | 2 | |
| 15 | | 36 | 3 | |
| 16 | | 9 | 1 | X |
| 17 | | 18 | 2 | |
| 18 | | 24 | 3 | |
| 19 | | 48 | 1 | |
| 20 | | 24 | 2 | |
| 21 | | 12 | 3 | |
| 22 | | 12 | 1 | |
| 23 | C | 48 | 2 | |
| 24 | | 6 | 3 | |
| 25 | | 24 | 1 | |
| 26 | | 18 | 2 | X |

* operating conditions: 1 – easy, 2 – medium, 3 – difficult

* warunki pracy: 1 – łatwe, 2 – średnie, 3 – trudne

**Table 6. Heigh difference inspection results; X – elimination from service**

Tabela 6. Wyniki kontroli różnicy wysokości wideł; X – oznacza wyłączenie z eksploatacji

| No. | Producer | Perid of use [months] | Operating conditions* | Height difference |
|---|---|---|---|---|
| 1 | | 6 | 1 | |
| 2 | | 12 | 2 | |
| 3 | | 24 | 3 | |
| 4 | | 24 | 1 | |
| 5 | A | 18 | 2 | |
| 6 | | 36 | 3 | |
| 7 | | 18 | 1 | |
| 8 | | 48 | 2 | |
| 9 | | 6 | 3 | |
| 10 | | 12 | 1 | X |
| 11 | | 24 | 2 | |
| 12 | | 12 | 3 | |
| 13 | | 24 | 1 | |
| 14 | B | 18 | 2 | |
| 15 | | 36 | 3 | |
| 16 | | 9 | 1 | |
| 17 | | 18 | 2 | |
| 18 | | 24 | 3 | |
| 19 | | 48 | 1 | |
| 20 | | 24 | 2 | |
| 21 | | 12 | 3 | |
| 22 | | 12 | 1 | X |
| 23 | C | 48 | 2 | |
| 24 | | 6 | 3 | |
| 25 | | 24 | 1 | |
| 26 | | 18 | 2 | |
| 27 | | 12 | 3 | |

* operating conditions: 1 – easy, 2 – medium, 3 – difficult

* warunki pracy: 1 – łatwe, 2 – średnie, 3 – trudne

The inspection of fork tip abrasion, which is extremely important from the UDT perspective, demonstrated that in group A the forks working in difficult conditions for two and three years and the forks working in medium-hard conditions for four years had to be replaced (**Tab. 7**). In group B, all forks working in difficult conditions and the forks used in medium-hard conditions for 18 months were eliminated. However, in group C all forks operating in medium-hard conditions and hard conditions for one year had to be replaced.

**Table 7. Fork tip abrasion inspection results; X – elimination from service**

Tabela 7. Wyniki kontroli wytarcia kłów wideł; X – oznacza wyłączenie z eksploatacji

| No. | Producer | Perid of use [months] | Operating conditions* | Tip abrasion |
|---|---|---|---|---|
| 1 | | 6 | 1 | |
| 2 | | 12 | 2 | |
| 3 | | 24 | 3 | X |
| 4 | | 24 | 1 | |
| 5 | A | 18 | 2 | |
| 6 | | 36 | 3 | X |
| 7 | | 18 | 1 | |
| 8 | | 48 | 2 | X |
| 9 | | 6 | 3 | |
| 10 | | 12 | 1 | |
| 11 | | 24 | 2 | |
| 12 | | 12 | 3 | X |
| 13 | | 24 | 1 | |
| 14 | B | 18 | 2 | |
| 15 | | 36 | 3 | X |
| 16 | | 9 | 1 | |
| 17 | | 18 | 2 | X |
| 18 | | 24 | 3 | X |
| 19 | | 48 | 1 | |
| 20 | | 24 | 2 | X |
| 21 | | 12 | 3 | |
| 22 | | 12 | 1 | |
| 23 | C | 48 | 2 | X |
| 24 | | 6 | 3 | |
| 25 | | 24 | 1 | |
| 26 | | 18 | 2 | X |
| 27 | | 12 | 3 | X |

* operating conditions: 1 – easy, 2 – medium, 3 – difficult

* warunki pracy: 1 – łatwe, 2 – średnie, 3 – trudne

## Microscopic tests

The microscopic observations of the tested forks in the unetched state indicated the presence of non-metallic inclusions in the form of oxides and plastic silicates. The contaminants were spot distributed, and their number was small, according to PN-EN 10247:2017-08. Thus, it was assumed that such a small number of non-metallic inclusions has no influence on fork wear.

In the etched state, the tests conducted on the fork material used by manufacturer A exhibited the presence of plate martensite structures (**Fig. 7**). This structure is typical of low-carbon steel undergoing heat treatment encompassing quenching and tempering. The tests of manufacturer B's material indicated the ferritic-pearlitic structure, typical of medium carbon steel after the normalising annealing process (**Fig. 8**). In the case of the materials used to make forks by manufacturer C, the tempered troostite structure indicated quenched and medium tempered non-alloyed steel

(**Fig. 9**). High diversification in the structured of the investigated materials will translate into their mechanical properties and, hence, also on the exploitation wear degree of the tested forklift forks.

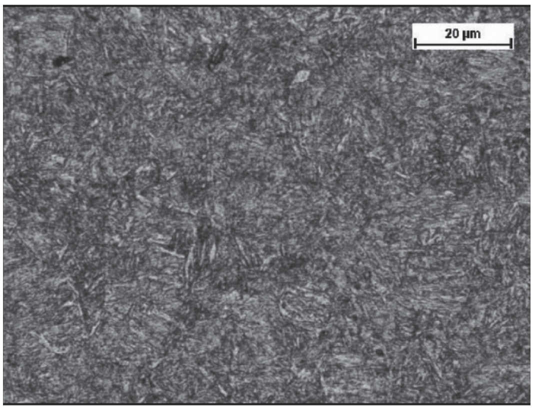

**Fig. 7. Manufacturer A's fork material, clear tempered martensite structure. LM. Etched state**
Rys. 7. Materiał wideł producenta A, widoczna struktura martenzytu odpuszczania. LM. Stan trawiony

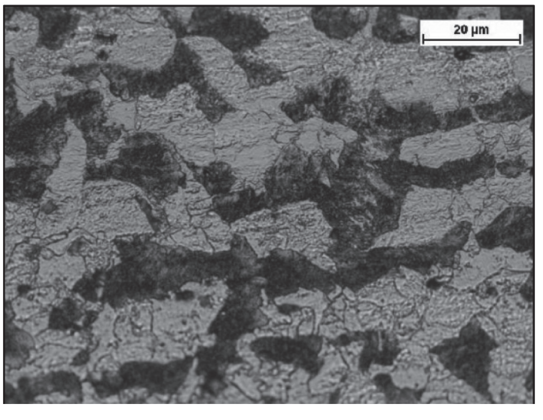

**Fig. 8. Manufacturer B's fork material, visible ferritic-pearlitic structure. LM. Etched state**
Rys. 8. Materiał wideł producenta B, widoczna struktura ferrytyczno perlityczna. LM. Stan trawiony

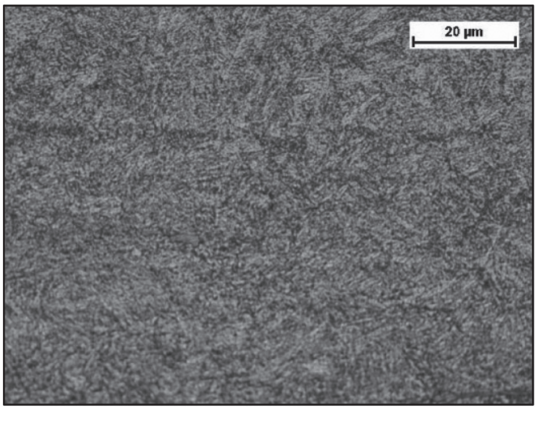

**Fig. 9. Manufacturer C's fork material, visible tempered troostite structure. LM. Etched state**
Rys. 9. Materiał wideł producenta C, widoczna struktura troostytu odpuszczania. LM. Stan trawiony

The hardness measurements of the investigated materials reflect the microscopic tests and the identified structures. The hardness of the materials used by manufacturer A was found to be the highest wand was 358 HV, and the lowest hardness was that of the material used by manufacturer B – 250 HV (**Tab. 9**).

**Table 8. Hardness measurements of tested materials**
Tabela 8. Wyniki pomiarów twardości badanych materiałów

| Producer | Hardness [HV] | | | | | Medium hardness [HV] |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| A | 322 | 331 | 387 | 397 | 356 | 358 |
| B | 257 | 243 | 259 | 241 | 253 | 250 |
| C | 308 | 301 | 311 | 319 | 339 | 315 |

## DISCUSSION AND CONCLUSIONS

As a part of standard UDT inspections, the macroscopic tests of forks evidently demonstrated how many faults can be the reason for elimination from service. Such faults as sharp edges and cracks in the fork's surface are caused by forks hitting other elements due to the operator's lack of attention. Fork deformation is most frequently the effect of the misuse of forks, exploitation in unsuitable operating conditions, and excessively heavy loads. Too large a difference in the height of forks results from transporting loads weighing too heavily on one fork and has nothing to do with an excessively long exploitation period and conditions. The lack of periodical chain length inspections can cause the abrasion of fork tips. When chains elongate, they cause fork tips to drag on the ground, which results in their abrasion. This type of wear usually occurs after a long exploitation period.

The research demonstrated that the service period and exploitation conditions of forklifts do not always significantly influence a particular type of fork wear. The largest number of forks was eliminated from service during the inspection of fork tip surface and abrasion. After the inspection of the fork surface, eight fork pairs were eliminated, while fork tip abrasion resulted in the necessity to replace ten fork pairs. Finally, four vehicles were eliminated from service in the group of vehicles made by the manufacturer A, in the group made by manufacturer B – seven vehicles and in group C – eight vehicles.

The microscopic tests demonstrated that forklift forks are made of various materials; consequently, they have different strength properties. A martensitic structure is characterised by high hardness; the ferritic-pearlitic one has mechanical properties depending mainly on carbon content, while the tempered troostite one is characterised by a high yield point and elastic limit and also improved impact strength **[L. 15]**. Another quite significant factor is the occurrence of contaminants in materials. The most disadvantageous ones are considered to be irregularly distributed longitudinal inclusions **[L. 3, 5]**. The hardness measurements of particular materials indicate that the microscopic observations were made correctly, and the tested microstructures were identified correctly recognised. Hardness was the highest in the material used by manufacturer A, which was confirmed by the occurrence of a martensitic structure.

The analysis of the conducted tests allows us to find a relation between the fork tip abrasion rate of the tested forks and the material they were made of. In the case of manufacturer A, whose forks were made of martensite, it was only after two years of exploitation that abrasion was identified in one pair of fork tips. The forklift forks made by manufacturer B, made of ferritic-pearlitic steel, fork abrasion was identified in one pair after one year of exploitation. The forklift forks were made of tempered troostite by manufacturer C, and fork tip abrasion in one of the fork pairs occurred after 1.5 years of exploitation. Thus, the use of martensite steel was responsible for the lowest material wear in the tested samples.

Extending the forklift fork inspection by metallographic analyses, including material microstructure assessment and hardness measurements, maybe an introduction to the research on standardising the material type characterised by optimum strength properties ensuring good abrasion resistance.

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