ANALYSIS OF THE RELIABILITY OF SELECTED MACHINES IN A PRODUCTION ENTERPRISE – CASE STUDY

ZASADZIEŃ Michał

Politechnika Śląska, ul. Roosevelta 26, 41 –800 Zabrze, PL
E–mail: michal.zasadzien@polsl.pl

Abstract: The article presents the results of analyses which were conducted on the basis of data collected in one of production companies manufacturing pre-insulated pipes for the heat engineering industry. The data from the facility maintenance system included among others duration of failures, duration of breakdown removal and the type of failures for the major machines in the enterprise, i.e. polyethylene pipes extruders. The conducted analysis allowed determining the reliability indices. The obtained values and information on the type of breakdowns allowed developing recommendations for facility maintenance service teams regarding the organisation of technicians' work, management of human and material resources as well as the planning of inspections and overhauls.

Keywords: reliability, facility maintenance, MTBF (Mean Time Between Failures), failure rate, breakdown

1 Introduction

Ensuring the total production capacity of a company requires having a very well organised and effectively managed facility maintenance system. The efficiently working fleet of machines will largely determine the company's position on the market by providing its clients with goods and services in the required quality and quantity, within a required term. Failure to keep delivery terms or worsening the goods' quality may lead to losing the clients' trust and, in consequence, will result in losing the sales market for the company's goods [1]. Facility maintenance is usually one of the biggest items in the company's operational costs. For this reason, endeavours are constantly made to find more effective methods of work and management of this area of the company's activity [2]. The increasing share of direct costs of facility maintenance department in the company's changeable costs as well as the competitive situation currently faced by companies force continued searches for cost reduction possibilities [3]. The analysis of various approaches to facility maintenance versus time enables determining three periods, which overlap in the process of development [4].

1) Reactive maintenance – overhauls after a damage
2) Preventive maintenance – preventive overhauls

3) Predictive/proactive maintenance – preventive inspections, technical condition monitoring, participation of machine operators in facility maintenance

Despite minimizing the risk, it is impossible to avoid breakdowns of machinery fleet elements. In case of breakdown, service teams responsible for maintaining the machinery park in good conditions should try to remove the breakdown as soon as possible, shortening the duration of downtime to minimum. In terms of the effects caused by a breakdown in the production process we can make a division presented in Fig. 1.

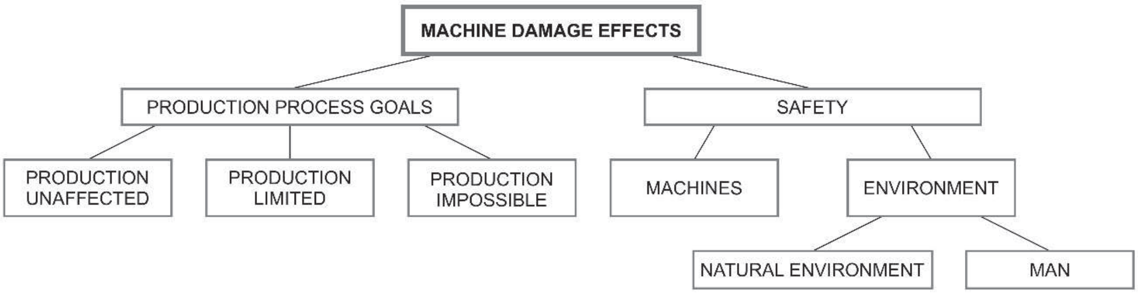


Fig. 1. Breakdown effects [5]

The possible effects caused by a breakdown of a machine taking part in the production process include: impossibility to continue production, reduced yield – delays in production, threat to operators or natural environment, increased risk of not keeping the delivery terms or worse quality of the products [1]. There are also failures which do not affect the production process – however, these are rare occurrences and concern mainly:

- machines which support but do not participate directly in the production process,
- machines that can be replaced (the company has surplus machinery),
- machines which do not have to take part in the production at a given time (there is a surplus of half-products manufactured with these machines – they are stored in the warehouse).

Current modern concepts of facility maintenance management to be implemented require considerable resources. Not every organisation can afford such sacrifices; also, the invested expenditure will not return a profit in every company. Changes can also be made to a limited extent, where it is absolutely necessary. To identify such areas, one must first of all consider the types of failures and major machines from the point of view of production process goals and safety. Based on the analysis of the indices of their failure rate, the management of their operation should be reorganized.

In this article single-screw extruders applied in the production of pipes used for installing heat pipelines have been studied. An example of this type of machine has been presented in Fig. 2.

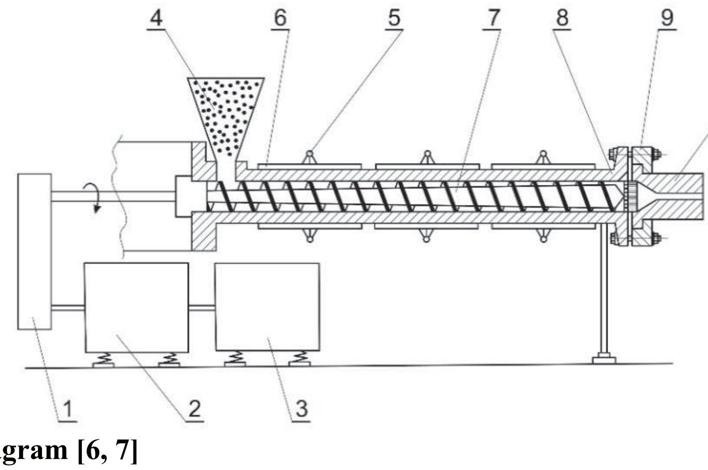


Fig. 2. Extruder diagram [6, 7]

Basic elements of a typical extruder are (Fig. 2):
1) electric motor driving the extruder screw,
2) transmission system for regulating the screw rotation speed,
3) drivetrain,
4) feed hopper for polyethylene granulate connected with a silos for granulate by means of an intake pipe,
5) extruder cylinder cooling system,
6) system for heating the plastic in the cylinder,
7) screw feeding the plastic to the head,
8) extruder body,
9) head installation,
10) head body.

Other necessary elements include the extruder parameters control system as well as a supply system with all indispensable connections and sensors.

Technological lines providing a basis for their production have been presented in Fig. 3.

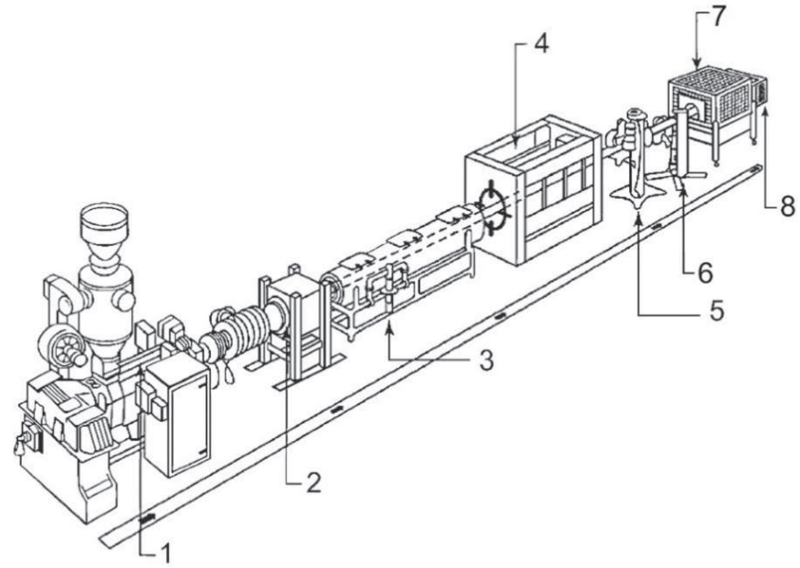


Fig. 3. Diagram of a pipe production line [8]

The basic machine in the pipe production line (Fig. 3) is an extruder (1), in which plastic is plasticized and a pipe is extruded. Next, the pipe, which is still plastic, gets to a vacuum calibrator (2), which is placed directly behind the extruder – it is here where the final dimension and shape of the product are determined. Behind the calibrator there is a cooling bath (3), where the pipe dimensions and shape are solidified. In the cooling bath the product moves owing to the rollers placed in the bath. Another element of the line is the caterpillar capstan (4), which ensures the pipe's movement through the production line. Behind the capstan there is a pipe stamping machine (5), which allows placing inscriptions on the product. Behind the stamping machine there is a device for plasma crowning, i.e. a pipe internal surface activator. At the end of the line there is a planetary saw (6), which cuts the pipes to the set length as well as an ejector (7), which puts ready products on the transporting trolley.

As can be seen in the enclosed diagram (Fig. 3), machines in the extruder line are placed in a serial configuration. For this reason, a breakdown of one of the line elements disables the whole production process.

2 Research results

The data on the machine failure rate was generated from the system supporting the facility maintenance management, and its processing was based on a spreadsheet. The data covered a period of 30 months and included information about: duration of machine downtimes, facility maintenance working time and a description of the breakdown given by the reporting person.

The initial analysis of the obtained results was aimed at identifying particular failures (according to reported descriptions) and assigning them to one of the following groups:

- mechanical breakdown: a mechanical failure of a part or some parts due to their wear or improper use, which must be removed by a mechanic;
- electric breakdown: an electric failure (of control or supply), which must be removed by an electrician having a licence;
- automation breakdown: a failure of the machine's control system, which must be removed by an automation specialist;
- anomaly: abnormal work of a machine resulting from its improper use or human error, which requires a specialist's intervention (e.g. inadvertent machine stoppage).

The results of the initial analysis have been presented in Fig. 4.

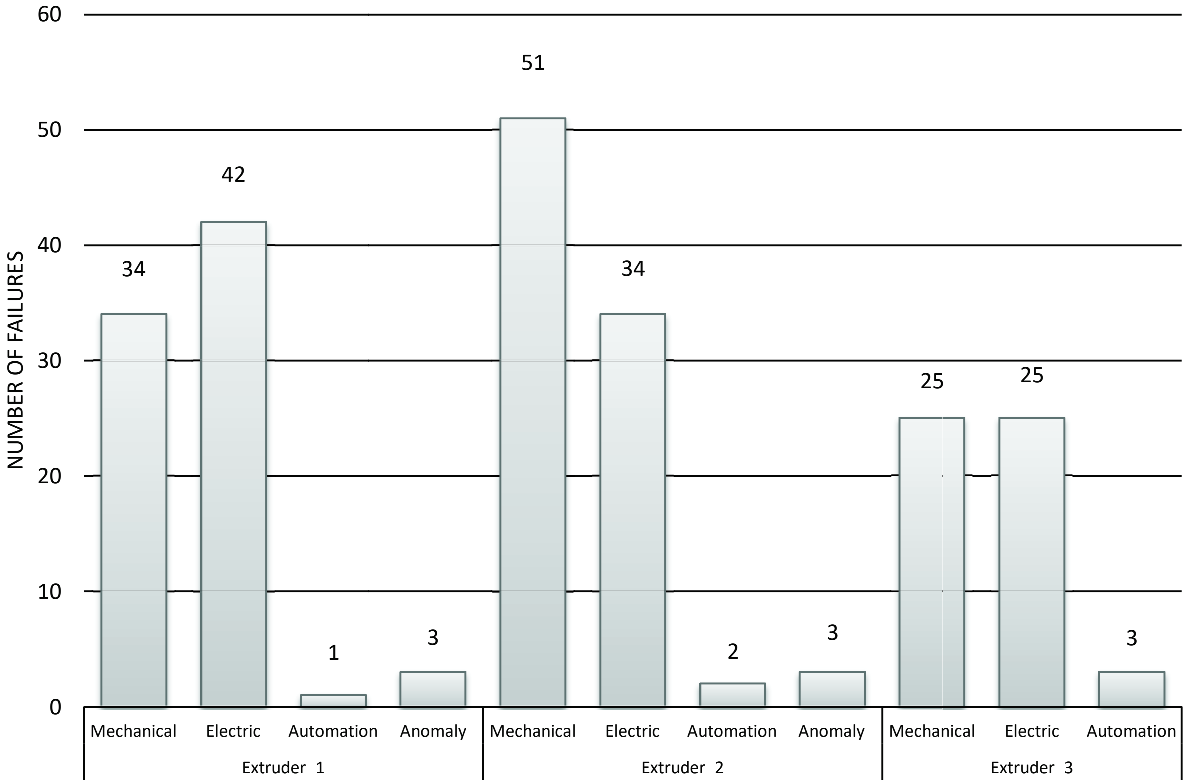


Fig. 4. Number of breakdowns by the type and machine

It was observed that irrespective of the type of machine, most breakdowns were mechanical and electric – accounting for nearly 95% of all the identified failures. Therefore, further analysis was focused on these two types of breakdowns.

The next step was to analyse mean time between failures for particular types of machines. MTBF indices for particular machines and types of failure were calculated from the following formula:

$$MTBF_m; MTBF_e = \frac{working\ time + tim\ \ of\ downtime}{n}$$

where:

MTBFm – mean time between mechanical failures,

MTBFe – mean time between electric failures,

n – number of failures.

The results of calculations have been presented in Fig. 5.

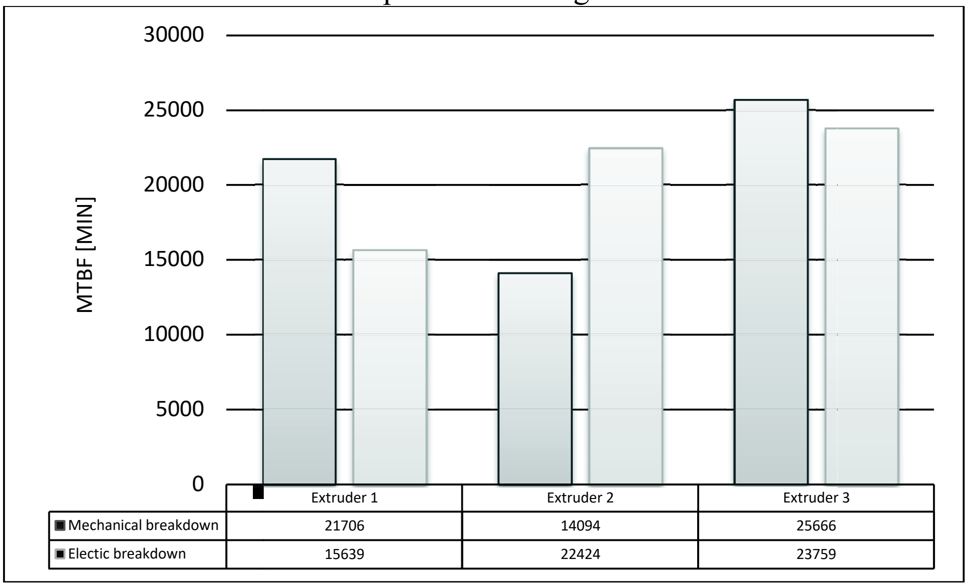


Fig. 5. MTBF for particular types of failures and machines

Based on the data resulting from calculations of MTBF indices for particular types of failures, the mean values for particular machines were calculated ($MTBF_s$). As the types of failures should be treated like a serial configuration, the formula has the following form:

$$MTBF_s = (\frac{1}{MTBF_m} + \frac{1}{MTBF_e})^{-1}$$

$MTBF_s$ for Extruder 1 was 9090 minutes, for Extruder 2 – 8654 minutes, and for Extruder 3 – 12338 minutes. In the case of Extruder 1 it is electric failures that determined the low values of MTBF, while for Extruder 2 it was mechanical failures; in the case of Extruder 3 the results were comparable, but it had the lowest number of failures of all the extruders.

The MTBF index is determined by the working time and downtime, which depends on the failure removal duration and the time of waiting for spare parts. The results regarding the mean downtime components have been presented in Fig. 6, 7 and 8.

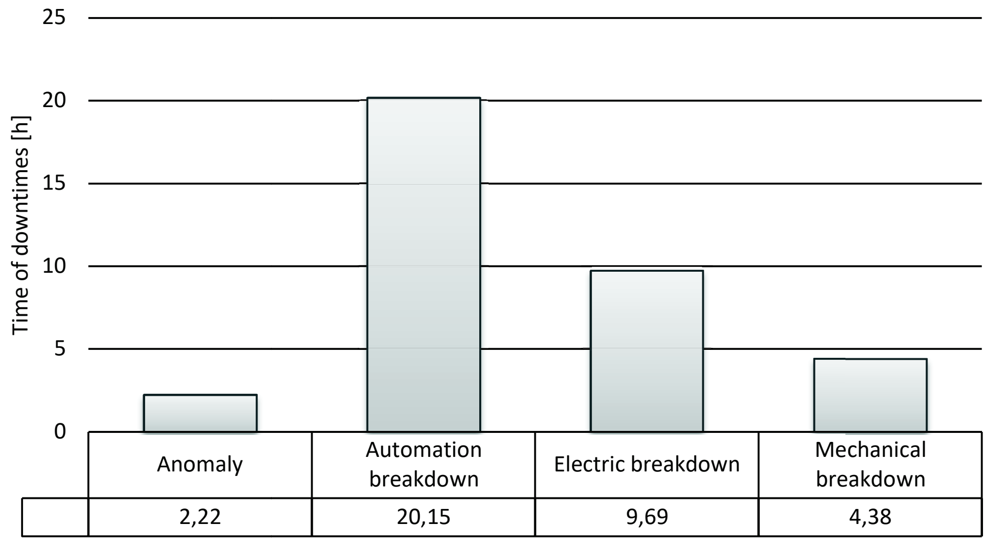


Fig. 6. Downtimes of machines

The longest downtime is observed in the case of automation failures – 20.2 hours; this value is twice as high compared to electric failures – 9.6 hours. The shortest downtimes are caused by anomalies – an average of 2.2 hours and mechanical failures – 4.4 hours.

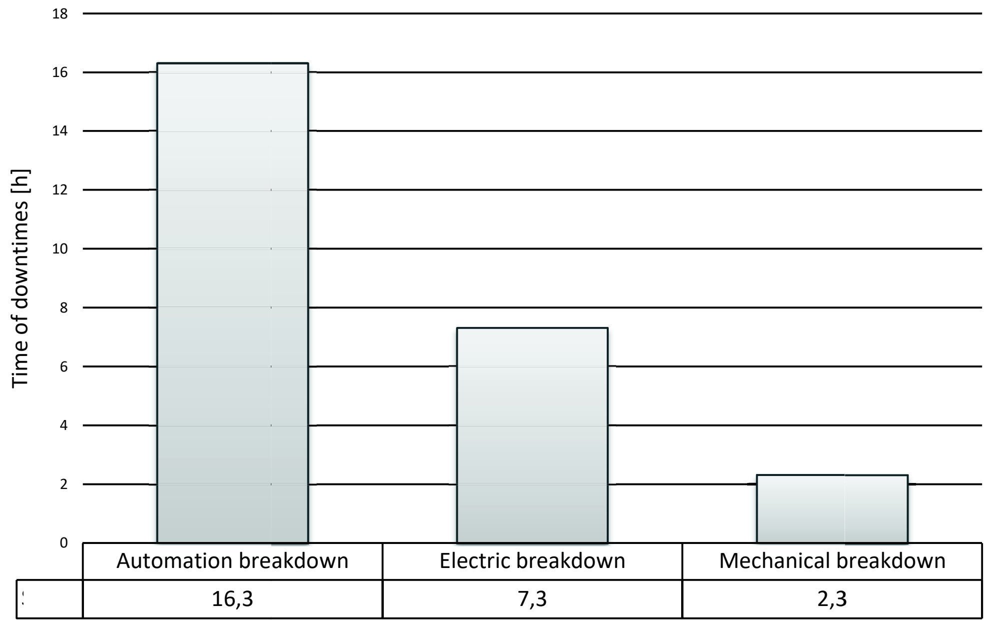


Fig. 7. Time of waiting for spare parts

As shown in Fig. 7, most of the time of downtimes caused by automation and electric failures is connected with waiting for spare parts. Waiting accounts for nearly 80% of the whole duration of downtime, as opposed to mechanical failures, in the case of which the waiting time is approximately 50% of the downtime duration.

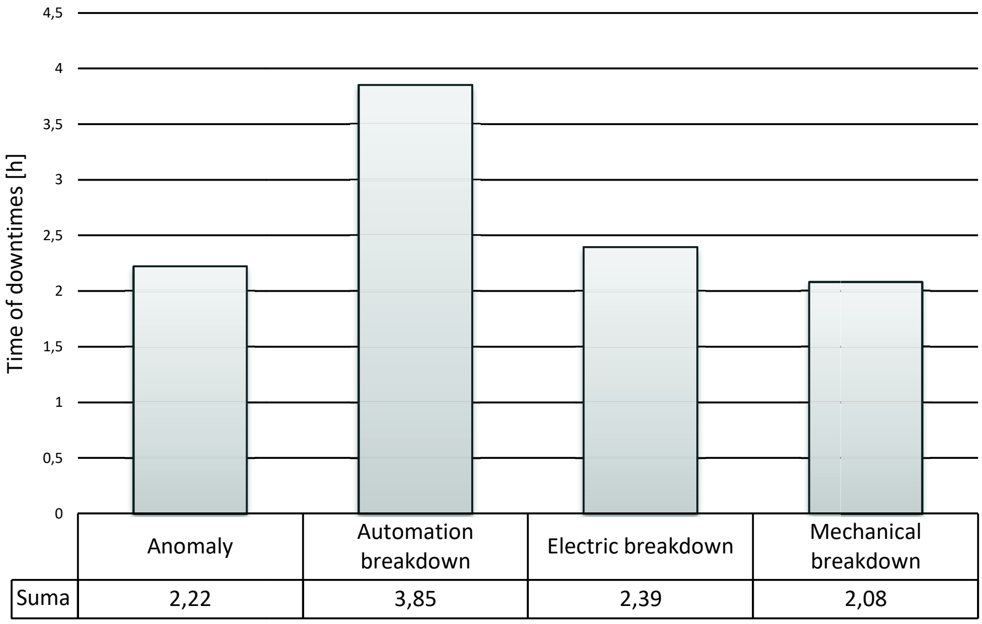
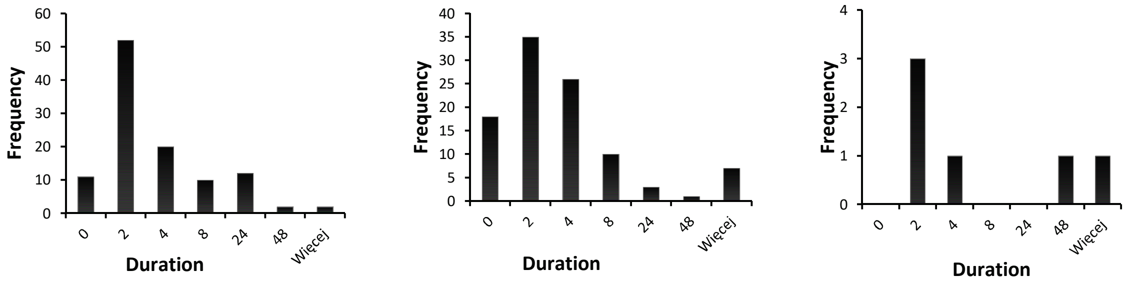


Fig. 8. Mean time of work related to failure removal

The results regarding the time of maintenance service teams' work contained in Fig. 6 demonstrate that the mean time of removing mechanical breakdowns, electric failures and anomalies is the same and reaches more than 2.2 hours, except for automation failures, in which case failure removal takes an average of nearly 4 hours.

The frequency of failures versus their duration has been shown in histograms placed in Fig. 9.



mechanical failures **electric failures** **automation failures**

Fig. 7. Histograms of failures duration

By far the biggest group among the most numerous mechanical and electric failures are breakdowns lasting no more than 2 – 4 hours; longer failures occur sporadically. The exception are automation failures, which occur sporadically, but last much longer.

Conclusion

The conducted analysis allows concluding as follows:

1. The most frequent are mechanical and electric failures – automation failures are very rare.

2. The most reliable machine is Extruder 3 – the failure rate of the other two machines is comparable.

3. The longest downtimes are caused by automation failures – followed by numerous electric failures.

4. Long downtimes result mainly from long waiting for spare parts.
5. The most numerous failures are the ones lasting maximum 2 hours.
6. The above conclusions allow formulating the following recommendation:
   – first the availability of parts for electric systems should be improved by increasing the availability of parts in the warehouse and establishing good contacts with suppliers,
   – as automation failures do not often occur and spare parts storage costs are high, it is necessary to establish very good relations with automation system suppliers and implement predictive/proactive actions,
   – to limit the duration of removing small mechanical and electric failures to minimum, it is necessary to increase the availability of the most frequently used parts in storerooms in the production hall and implement innovative technologies to support the repair process (time-sheets, augmented reality or virtual reality),
   – the number of anomalies should be minimized by providing information and organizing trainings which consolidate good practices in machine operation
   – due to a higher failure rate of Extruders 1 and 2, it is necessary to increase monitoring of these machines' technical condition and engage their operators in the process,
   – due to a very high number of mechanical and electric failures, employment in facility maintenance teams should be increased.

The results of the analysis of the machinery stock allow finding weak points in the facility maintenance process and enable developing improvement actions in work organization and warehouse management, which contributes to shortening the duration of downtimes caused by failures.

PŘEKRAČUJEME HRANICE
PRZEKRACZAMY GRANICE
2014—2020

EVROPSKÁ UNIE / UNIA EUROPEJSKA
EVROPSKÝ FOND PRO REGIONÁLNÍ ROZVOJ
EUROPEJSKI FUNDUSZ ROZWOJU REGIONALNEGO

Projekt jest współfinansowany ze środków Europejskiego Funduszu Rozwoju Regionalnego
oraz z budżetu państwa RP „Przekraczamy Granice"

References

[1] W. Mączyński and T. Nahirny. „Efektywność służb utrzymania ruchu jako składowa efektywności przedsiębiorstwa" in *Innowacyjność procesów i produktów*. R. Knosala, Ed. Opole: Oficyna wydawnicza PTZP, 2012, pp. 203–213.

[2] M. Jasiulewicz–Kaczmarek. „Współczesne koncepcje utrzymania ruchu infrastruktury technologicznej przedsiębiorstwa" in *Koncepcje zarządzania systemami wytwórczymi*. Poznań: Instytut Inżynierii Zarządzania Politechniki Poznańskiej, 2005, pp. 127–134.

[3] S. Legutko. *Podstawy eksploatacji maszyn i urządzeń*. Warszawa: Wydawnictwo Szkolne i Pedagogiczne, 2004

[4] S. Legutko. „Development trends in machines operation maintenance". *Eksploatacja i Niezawodność – Maintenance and Reliability*, vol. 2, pp. 8-16, 2009.

[5] S. Wyciszczok. *Maszyny i Urządzenia Górnicze. Część druga*. Warszawa: Wydawnictwo REA 2011.

[6] Z. Tadmor and C.G. Gogos. *Principles of Polymer Processing*. New Jersey: John Wiley & Sons, 2006.

[7] R. Sikora, Ed. *Przetwórstwo tworzyw polimerowych*. Lublin: Wydawnictwo Politechniki Lubelskiej, 2006.

[8] Qenos Technical Guides. Pipe and Tubing Extrusion, Qenos Pty Ltd 2015.

ANALIZA NIEZAWODNOŚCI WYBRANYCH MASZYN W PRZEDSIĘBIORSTWIE PRODUKCYJNYM – STUDIUM PRZYPADKU

Abstrakt: Artykuł prezentuje wyniki analiz, jakich dokonano na podstawie danych zebranych w jednym z przedsiębiorstw produkujących rury preizolowane dla przemysłu ciepłowniczego. Dane pochodzące z systemu utrzymania ruchu zawierały m. in. długość czasu trwania awarii, czas usuwania awarii i rodzaj awarii dla najważniejszych urządzeń w przedsiębiorstwie jakimi są wytłaczarki rur z polietylenu. Przeprowadzona analiza pozwoliła na wyznaczenie wskaźników niezawodności. Otrzymane wielkości wraz z informacjami na temat rodzaju awarii umożliwiło wyciągnięcie wniosków zawierających zalecenia dla służb utrzymania ruchu w zakresie organizacji pracy techników, zarządzania zasobami ludzkimi i materialnymi oraz planowania przeglądów i remontów.

Słowa kluczowe: niezawodność, utrzymanie ruchu, organizacja, MTBF, awaryjność, awaria