ISSN 1068-798X, Russian Engineering Research, 2022, Vol. 42, No. 11, pp. 1189–1191. © Allerton Press, Inc., 2022.
Russian Text © The Author(s), 2022, published in STIN, 2022, No. 9, pp. 16–19.

Restoration of Machinery by Means of Nonwoven Polymer Composites

Yu. V. Trofimenko[a], * **and A. G. Timofeeva**[a], **

[a] *Moscow Automobile and Road Construction State Technical University (MADI), Moscow, Russia*

**e-mail: ywtrofimenko@mail.ru*

***e-mail: atimofeevan@rambler.ru*

Received April 25, 2022; revised April 25, 2022; accepted April 25, 2022

Abstract—Traditional repair technologies for machine parts are analyzed. New restoration methods using polymer composites with nonwoven filler are proposed. Types of polymer materials are considered in the light of the life cycle of machine parts.

Keywords: machine parts, recycling, environmental impact, recycled nonwoven polymer materials, polymer composites

DOI: 10.3103/S1068798X22110223

On account of recent political and financial constraints imposed by developed nations, which mainly affect import-dependent sectors of Russia's economy (including mechanical engineering), Russian enterprises will find it difficult to organize the production of competitive cars, road-building and construction equipment, or systems satisfying current and prospective standards regarding productivity, reliability, safety, and environmental protection, within a compressed time frame.

In that context, it is a priority to extend the life and maintain the performance of the existing stock of imported or Russian high-efficiency machinery and technical equipment for machine-building plants, by improving repair and servicing systems for machine tools, machines, and machine parts.

In our view, it is expedient to turn to existing repair and restoration technologies during the current reorganization. On the basis of accumulated experience and the undoubted interchangeability of foreign production processes at Russian enterprises, the technological and financial stability of enterprises in the mechanical-engineering sector may certainly be ensured in the short term [1].

In addition, this approach has clear environmental benefits, since restricting the use of components that are of poor quality and cannot be repaired will slow the consumption of natural resources and decrease environmental pollution over the cycle from the production of machine parts to their disposal.

THEORETICAL ASPECTS

In the production of machinery, enterprises rely on machine tools and machines to create machine parts and assemblies. As it operates, production equipment experiences high statistical, vibrational, and dynamic loads. The loads are greatest on the frames, drives, shafts, and gears of metal-working machinery. Failure of those components leads to production problems and downtime. To prevent fracture, production systems today are equipped with sensors to detect component wear, so as to warn of the need for repair.

Traditionally, components are repaired by welding and subsequent thermomechanical surface treatment so as to obtain the required dimensions. Welding is a universal, rapid, and inexpensive repair method even for complex and critical components. However, there is a risk of stress concentrators at the weld, which, in turn, shorten the working life.

MATERIALS AND METHODS

To extend the working life, manufacturers have begun to use polymer composite components [2]. Their benefits include better tolerance of loads and lower density. In addition, the physicochemical properties of the material rule out stress concentrators, even after welding.

Because most polymer composites are less dense than metals, the mass of the machines produced is decreased, and so the energy and operational costs in the course of the machine's life cycle are also decreased. Table 1 presents the energy consumption

Table 1

Material	Energy consumption, kW/h	
	per kg of material	per kg of product
Carbon fiber	33–35	72–74
Aluminum	48–50	390–395
Steel	35–37	220–225
Titanium	188–190	1540–1550

(kW/h) in the production of components from different materials [3].

Thanks to their structure and production, polymer composites permit less expensive disposal at the end of their life cycle. Note that, in the manufacture of machine parts from polymer composites, the production wastes account for only 10–30% of the initial material. By contrast, for high-strength aluminum and titanium alloys, wastes in aviation exceed the final production mass by a factor of 4–12 [4].

Expansion of the use of polymer composite in manufacturing also meets safety and environmental requirements. For example, personal protection equipment (single-use medical masks) against COVID-19 infection in crowded places is made from polymer materials [5]. After use, the masks are medical waste and are a source of environmental contamination, especially where waste processing and disposal infrastructure is poorly developed, for woven or nonwoven material [6].

According to data collected during the coronavirus pandemic, globally, 129 billion masks and more than 65 billion disposal gloves were used each month [7]. According to UN estimates, about 75% of plastic products will not be recycled and are likely to end up in landfills and bodies of water [8].

Nonwoven material usually consists of individual fibers or thread that are randomly intertwined, but not in an orderly pattern, as in the case of knitted fabric. Nonwoven materials or cloth are produced by different methods: for example, by aerodynamic methods from melt; by spinning melt; by spraying melt; and by fastening cord aggregations [9]. Nonwoven polypropylene cloth is produced from granules of polypropylene (international symbol PP) and used in applications such as the textile industry, medicine, construction, and agriculture.

Polypropylene sheet produced from fibers is highly elastic, stable under double flexure, and hypoallergenic. It resists the action of acids, alkalis, and organic solvents. It may be assigned hydrophobic or hydrophilic properties.

RESULTS AND DISCUSSION

The use of secondary nonwoven polymer material as filler in polymer composites may be an effective means of preventing environmental contamination with consumer wastes. Their use at different stages of the product life cycle—in particular, the repair stage—is of great environmental significance [10].

Recently, polymers and polymer composites with different types of matrices have been used increasingly in machine parts [11]. The processing of polymer composites based on a thermosetting plastic matrix is accompanied by an irreversible chemical reaction in which infusible and insoluble material is formed.

On the other hand, this material is ideal for repair purposes, since it increases the working life of machine parts in the event of damage and so prolongs product life. Obviously, research on combining reactive plastic with secondary nonwoven polymer filler to repair damaged and defective machine parts is of great economic and engineering interest. The filler consists of individual fibers, which have reinforcing properties. It may strengthen the matrix, assigning the required properties to the part and decreasing its cost.

Research on the combination of polypropylene granules and individual fibers of secondary nonwoven polymer material is of great importance, since both materials have a thermoplastic matrix capable of reversibly passing to a highly elastic or highly fluid state on heating. That permits repeated recycling of such components, with economic and cost benefits.

CONCLUSIONS

According to preliminary estimates, the development and introduction of polymers filled with secondary nonwoven fibers for use in repair increases the working life of machine parts, decreases the final product cost, and minimizes the environmental impact.

REFERENCES

1. Trofimenko, Yu.V., Vorontsov, Yu.M., and Trofimenko, K.Yu., *Utilizatsiya avtomobilei: Monografiya* (Car Recycling: Monograph), Moscow: AKPRESS, 2011.
2. Timofeeva, A.G., Investigation of properties of secondary abs-plastic modified with organic-silicon compound and used in automobile and mechanical engineering industries, *Remont. Vosstan. Modern.*, 2021, no. 4, pp. 28–33.
3. Baurova, N.I. and Zorin, V.A., *Primenenie polimernykh kompozitsionnykh materialov pri proizvodstve i remonte mashin: Uchebnoe posobie* (Application of Polymeric Composite Materials in Mechanical Engineering: Manual), Moscow: Infra-M, 2018.
4. Kosenko, E.A., Baurova, N.I., and Zorin, V.A., *Prirodopodobnye materialy konstruktsii v mashinostroenii: Monografiya* (Nature-Like Materials of Construction in Mechanical Engineering: Monograph), Moscow: Mosk. Avtom.-Dorozhn. Inst., 2020.
5. *Advice on the Use of Masks in the Context of COVID-19.* World Health Organ., 2020.

6. Saberian, M., Li, J., Kilmartin-Lynch, Sh., et al., Repurposing of COVID-19 single-use face masks for pavements base/subbase, *Sci. Total Environ.*, 2021, vol. 769, p. 145527.
https://doi.org/10.1016/j.scitotenv.2021.145527
7. Prata, J.C., Silva, A.L.P., Walker, T.R., et al., COVID-19 pandemic repercussions on the use and management of plastics, *Environ. Sci. Technol.*, 2020, vol. 54, no. 13, pp. 7760–7765.
8. *Roads, Fuel and Chairs: What Masks are Recycled into in Different Countries*, Moscow, Recycle. https://recyclemag.ru/article/dorogi-toplivo-stulya-raznih-stranah-pererabativayut-maski?utm_source=yxnews&utm_medium=desktop
9. *Spunbond*, Moscow, Plastinfo. https://plastinfo.ru/information/glossary/119/1388/
10. Graedel, T E. and Allenby, B.R., *Industrial Ecology*, Englewood Cliffs, NJ: Prentice Hall, 2003, 2nd ed.
11. Timofeeva, A.G., Application of modifiers for secondary polymer materials used in mechanical engineering, *Remont. Vosstan. Modern.*, 2020, no. 12, pp. 40–44.

Translated by B. Gilbert