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Mechanical Properties of Composite Materials under Conditions of Impact Loads Action

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Abstract
This paper describes how the impact loads act on the composite materials applied for equipment repairs and reports on the results of the dedicated studies. This paper also deals with the damping capabilities of the polymeric materials with respect to their repairing techniques. The practical need for this study is illustrated through revealing how the repairing techniques are able to influence the damping properties of the composite materials while the use of composite materials for the equipment working under conditions of impact loads could be of scientific interest as it is the new approach to the indicated problem. In the course of the research, we subjected the composite materials placed by various techniques to the impact loads.
Key words: EQUIPMENT, REPAIRING TECHNIQUES, IMPACT LOAD

Introduction

Currently, metallopolymer materials find their wide applications in repairs and maintenance of industrial equipment, as they allow reduction in time to be spent on the mentioned activities. However, the industries limit the inherent opportunities with repairs at nodes and machines, operated under conditions friendly for equipment where both impact loads and vibratory loads are eliminated. This is explained by insufficient knowledge of how this kind of materials reveals its bearing capabilities at dynamic loads.

Problem Area. Since the specific feature of any metallurgical equipment is non-stop or continuous operational mode and any delay causes the decrease in the production yield, the time requirements for the repairs in the metallurgical sphere should be minimized and this leads to the search for new methods and materials to carry out the repairs. Nowadays, the composite materials are not used for this purpose. Moreover, regarding the materials for the repairs and maintenance for the metallurgical sphere, we cannot neglect the requirement for the metallurgical equipment nodes and machines to be commonly operated under hard conditions with impact loads and vibratory loads. The consequences of such operation in most cases are observed as early failures of bearings assemblies of machines. These destructions of the bearings primarily are caused by the dynamics of their loading and are accompanied with their shafts failures and those of their mounting seats.

Further, the quite different conditions of the work exist for the equipment operating in quarries and involve the operations of granite grinding and crushing. However, such kind of equipment also operates under severe conditions of vibrational and impact loads effect on the major components. This results in most cases in premature failures of the bearing units of the machines. The fracture of bearings occurs primarily due to the dynamic nature of their loading and is accompanied by a failure of the shaft and the seat, in which these bearings are set. This allows wear and deformation of the seat necks under the bearings.

Background and Current Research Target. The problem how to protect and to repair the components of metallurgical equipment has always been within the interest circle of metallurgists. One of the problems related to the repairs in the area of the mounting seats of the bearings is described in [1…10], the authors solve the problem of the bearing contacting with the bearing assembly surface in order to determine the maximum value in the mounting seat of the bearing. The problem with the inner contacts under loads was solved by I.Ya. Shtaerman [1] for two circular cylinders with the small differences in their radiuses, it was suggested as osculatory circle with annular excision in the infinite thrust plane. The solution is based on the dependency of radial elastic displacements on concentrated force for the circle and for infinitely rigid body with annular cylindrical excision, according to S. P. Timoshenko.

V. M. Aleksandrov and his team solved the problem of annular layer of fine thinness. Further, the physical model for bearing mounting seat repaired with composite material could be shown as the analog of the model used in the publication by A. A. Staroselskiy and A. B. Kleyner. The latter was the attempt to obtain the picture of pressures in metallopolymer layer of the materials within the repaired rolling bearing and to develop the engineering solution for the calculations embracing the design parameters. However, their publication provides no recommendation concerning the method to repair the bearing mounting seats or to determine the impact load.

The recent years have seen more and more practical applications of metallopolymer materials for repairing various kinds of equipment. In the current publication we regard metallopolymer materials as the plastic masses with powder metallic or fibrous filling. The bonding substances for these materials can be as follows: thermoplastic polymers (polymethylene, polypropylene, polyamide, polytetrafluorethylene or fluoroplastic, polyvinyl chloride, etc.) and thermosetting material (phenol-formaldehyde, polyester, epoxide resin, organic-silicon, etc.) The fillings could be powders, fibers and tapes obtained from metals and alloys and metallized powders and fibers. Moreover, a polymer bonder within metallopolymer composition can be made of metallic, mineral, organic constituents, stabilizers, pigments, paints, cold binders and capillary active substance. The type and the quantity of the indicated additions are determined by the chemical nature of the polymer bonder.

Currently, the application of the above-mentioned materials is limited by the repairs of the nodes and the machines, which operate under friendly conditions without impact and vibrational loads.

The aim of the current work is to study and analyze damping capacity of bearing units repaired with the use of metallopolymer materials.

Research Equipment. The research on the load being tolerated by the bearing support was carried out on a specially designed and modified machine in the laboratory of the Department of Mechanical Equipment for Ferrous Metallurgy of the Pryazovskyi State Technical University. The machine allows measuring impact accelerations in the repaired bearing unit. The kinematic scheme of this machine is shown in Figure 1.

The impact machine consists of the cantilever beam 4 (channel in cross section), set into oscillatory motion by the cam 3. The cam engages the roller 9 on the beam fixed. The beam swings on the supports 10. The roller 9 is fixed on one arm of the beam while on the other one is the load 5. The cam is set into rotation by means of the electric motor 1, through the worm-gear speed reducer 2, the motor clutch 6, and the lead spindle 7 of the flexible bolt coupling type. The suitable load 5 is fastened at the end of the beam. In addition, a force closure in the form of the spring 8 is installed into the impact machine. During the work of the impact

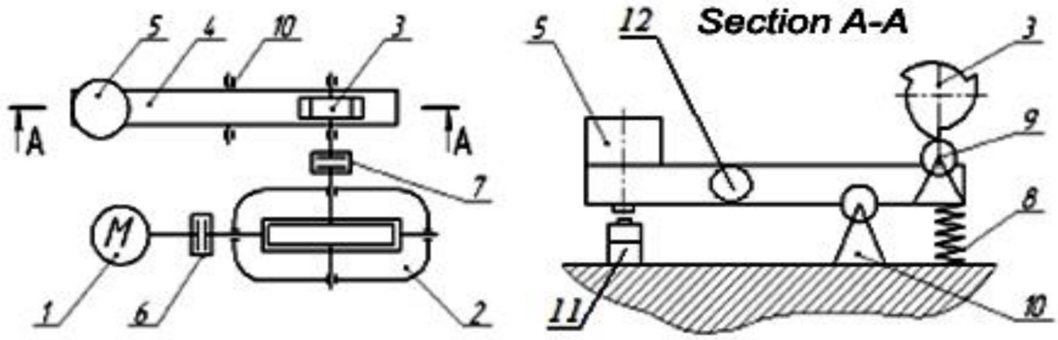

Figure 1. Kinematic Scheme of the Impact Machine

machine, the sample 11 percepts the blow, and value is set using the accelerometer 12. The impact machine itself is mounted on the supporting structure, which is a massive steel slab with the size of 1210x500x250 mm. The technical data of the impact machine are given in table 1.

Table 1. Technical Data of the Impact Machine

Indicator Name	Measurement Unit	Value
1. Oscillation frequency of the cantilever beam	min^{-1}	114
2. Range of the loads, attached to the beam	kg	to 20
3. Electric engine type		4A71B2
4. Rated rotational speed of the shaft	min^{-1}	1500
5. Power rating	kW	2
6. Reducing gear type		RChU-63
7. Gear ratio		40

The sample testing was performed in the special service tool for testing, the basic diagram of which is shown on Figure 2.

This equipment consists of the understructure 1 and the strip 2. The strip is the model of the bearing outer ring to be aligned in the hole, made in centering bar 3. The centering bar is aligned by the pins 4, the clamping bar 6 and clamped with the bolts. In the understructure 1, there are the holes 7 made for fixing on the foundation. The understructure is a model of the repaired seat of the bearing, a groove has been made there for putting the polymeric repairing material “Multimetal-steel 1018”. The shock accelerations are registered with the accelerometer, which is mounted on the impact machine. For testing to determine the load acceleration during the impact, an AD XL 150AQC inertia sensor by Analog Device (USA) has been used.

Research Materials. In the course of the experiment, we have tested the materials which are used for repairing of bearing assemblies. These materials are Multimetal and Diamant Metallkleber Y (hereinafter referred as Y-adhesive). Since dynamic loads occur in the bearing assembly, in this experiment we have determined how the repaired materials withstand the impact loads. The properties of the materials used are shown in Table 2.

The adhesive used for the studies is Diamant Metallkleber Y designed for bonding metal, stone, glass, wood, etc. This Y-adhesive material is a two-component pasty mass widely applied in industries. Its properties provided by the manufacturer are shown in Table 3.

Method Applied. The first method is the free placement of the metal-polymer material layer into the support being repaired. Its state can be considered as plane stressed. The results of the experiment are shown in the graph of Figure 3.

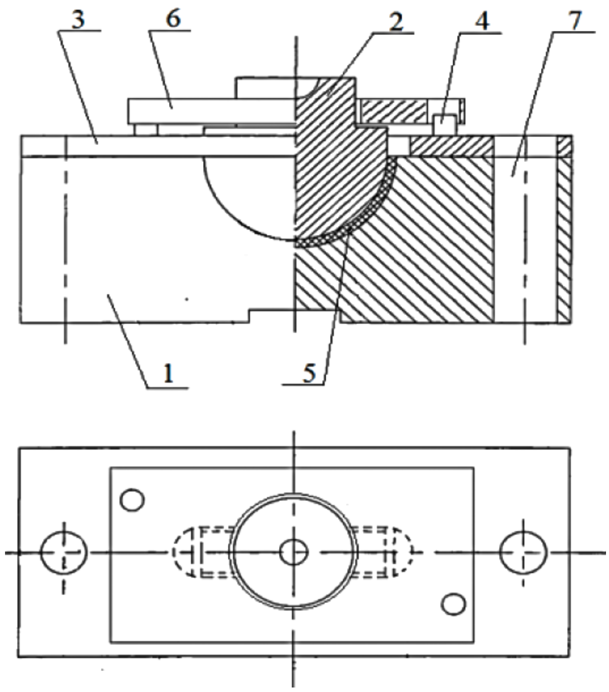

Figure 2. Diagram of the Tool for Measuring of Distortion in the Bearing Seat

Table 2. Properties of Multimetal

	Steel	
	P	F1
Ultimate compressive strength, mPa	160	156
Ultimate tensile strength, mPa	76	76.6
Ultimate bending value, mPa	89	87
Impact toughness, n/mm2	5.2	5.0
Thermal resistance, C^0		
Short time	-32 +350	
Long time	-32 +200	
Specific weight g/cm2	2.1	2.1
Operation time, min	60	60
Light load, after an hour	5-6	5-6
Full load, after an hour	24	24
Shrinkage after solidification	0.004	0.005
Storage time, year	2	2

Table 3. The Properties of Diamant Metallkleber Y

Components ratio	1:1 in volume units
Thermal resistance	$-20^0 \ldots +150^0$
Ultimate tensile-shear strength	3-3.5 kgf/mm at hot solidification 1.7-2.3 kgf/mm at cold solidification
Solidification Time	150^0C -15-20 min 80^0 C - 2-3 hours 20^0C -24 hours
Consumption rate	100-150 g/m^2 if one-sided painting

The acceleration values of the strip were measured during the impact and by these values we estimated the polymer layer ability to compensate the dynamic load by the elastic properties of the composite material layer. To do this, the following solutions for repairing the support surface with the polymer have been implemented. They are compared to the surfaces repaired by conventional methods, i.e., padding on and subsequent machining:

- the support surface repaired with Multimetal layer of 2.0 mm thick.

- the support surface contains two “indicators” defining the design position of the bearing and the surface repaired with Multimetal material, which layer thickness is 2.0 mm.

- the support surface repaired with Y-adhesive material with the layer of 0.5 mm thick.

- the supporting surface repaired with Y-adhesive material with the layer of 0.5 mm thick and connected by this adhesive with the strip (0.2 mm thick layer).

Results and Analysis. The obtained acceleration values for 15 test impact for the given above alternatives of the bearing surface repairings are presented in Figure 3.

The results presented allow us to note that the most rigid system of the strip contact with the metal gives the highest value of load on bearing surface in case of traditional method of repairing. As reflected by Figure 3, the application of the composite material reduces the acceleration value by 15% on average irrespectively of the indicators application or their absence. The use of the Y-adhesive material with the strip put into the bearing surface allows the acceleration value to be significantly reduced by 50% while the use of Y-adhesive layer alone without any strip fixation within Y-adhesive brings about the same results as the application of the polymeric layer from Multimetal. This suggests a number of conclusions concerning reasonability of the polymeric materials application for repairing the bearing surfaces located under the rolling bearings. First and foremost, the application of the composite material gives the opportunity to repair the bearing surfaces of the large-scale equipment

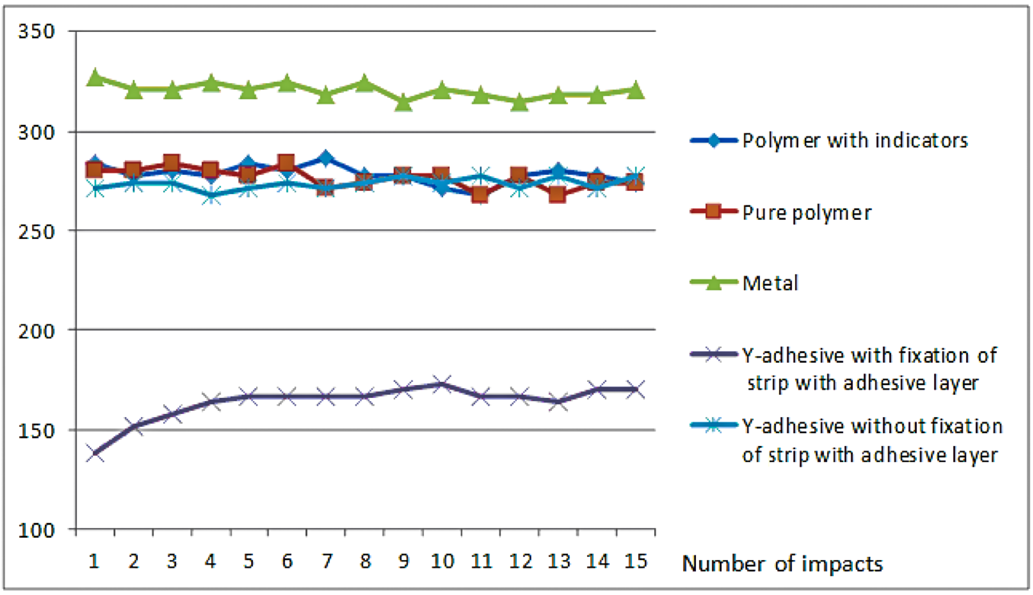

Figure 3. Changes in Values of Maximum Impact Accelerations during the Set of 15 Impacts

directly at the sites where they are operated without their dismantlement. This is a big advantage over the traditional technology in case when the equipment dismantlement and its transportation into a mechanical shop with the consequent repairs pose the risk to violate the time limits scheduled for the maintenance of a continuously operated metallurgical shop. Moreover, the application of the release agents enabling us to exclude the adhesive connection of the bearing with the repaired layer just slightly (15%) reduces the impact loads accepted by the bearing surface. Therefore, there is no point in expecting the significant improvement of the service conditions for the bearing or the decrease in the breakdown probability caused by the impact loads.

However, quite different result is achievable if the outer ring of the bearing is fixed in the seat by Y-adhesive when repairing of the bearing surface with the composite material. The fixed connection of the outer ring with the bearing surface (rigid fixation with respect to the composite material but excluding the emergence of the additional stress in the outer ring) has some advantages in comparison with an unfixed outer ring, which can move within the micro gaps with the load application point on it. The latter is certainly the negative factor but it does not determine the durability of the bearing as the impact loading value is reduced almost twice and only the industrial experiments can give the definite answer about predominance of this or that factor in the bearing service life.

Conclusions. The experiments have proved that the problem how to extent the service lives of bearings under conditions of considerable impact loads can be solved by repairing their outer rings by the composite material. It can give the opportunity to increase the resistance of the bearing outer ring to impact almost twice.

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