Original Research

Effect of the Epoxy-Based Specimen Movement Rate on the Wear Rate in an Abrasive Mass

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Received: 15 April 2021/ Accepted: 27 June 2025 / Published online: 27 June 2025

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Abstract
The conducted experiments have enabled the establishment of a straight-line relationship between wear and testing time; wear intensity therewith changes in a self-organised manner with a decline early in the experiment and subsequent stabilisation. It has been found that the specimen rotation rate during accelerated tests should not exceed 850 min^{-1}.

Keywords - Wear, Wear rate, Accelerated tests, Wearing time, Wear self-organization

Introduction

Using epoxide compounds has led to creation of technologies that influenced profoundly the development of various industrial sectors [1,2,3]. Epoxy-resin-based materials are of vital importance when used as coatings of working surfaces. At the same time, there are few, fragmentary, and sometimes contradictory data about the behaviour of such compounds when the abrasive wear is highly intensive [4,5], what precludes the use of these polymer self-hardening materials and composites based thereon.

Hence, laboratory studies of wearing are necessary since the use of composite coatings with various fillers and compositions offers extensive prospects in increasing service life of parts operated in abrasive media [6,7]. Moreover, these studies make it possible to pre-estimate tribomechanical parameters of employed compositions.

Problem Statement

The work has aimed at identifying the effect of the movement rate of an epoxy-based specimen on the wear intensity and determining a minimum possible testing time in a specified abrasive medium with assured reliability of experimental data when conducting accelerated tests. The nature of wear (Δh) and wear intensity (i) over time (T) at various rates (V) of specimen movement; function-wise variation in i; the effect of movement rate on testing time have been examined.

Materials and Test Procedure

Epoxy-resin-based composition ED-20 (100 parts) and polyethylene polyamine (hardening compound) (7 parts) were used in the research studies [10]. A mixture of mortar sand and granite chips in 70/30 percentage terms served as the abrasive medium. The average size of sand particles was 0.21mm, of granitic inclusions – 9.2 mm. An abrasive substance was selected based on the presence of gravel-like inclusions in soils. The volume of abrasive medium in the container, which had a form of a truncated cone, was 0.02 m^3. Tests were carried out using the unit, designed in the Bryansk SAA (figure 1), where on frame 1 the specimens of like composition are formed to ensure the reliability of tests. It is therewith observed that the tests are identical for all 4 specimens at any moment. The frame movement is given by rotation using a drilling machine with various numbers of revolutions (n) 500 min^{-1}; 710 min^{-1}; 1000 min^{-1}. The frequency of specimens' rotation, that ensures a minimum time for carrying out tests, can be found experimentally. Wear was controlled using a known method of "hollows".

FIGURE 1
GENERAL VIEW OF TESTING DEVICE: 1- SPECIMEN WITH FORMED COATINGS; 2 – ABRASIVE MATERIAL; 3 – CONTAINER; 4 – MACHINE STAND; 5 – WORK SPINDLE; 6 – MANDREL.

TEST RESULTS AND THEIR DISCUSSION

As it follows from the graphs (figure 2), wear increases in a straight-line manner for all n, i.e. it occurs much the same, irrespective of variation in the frame displacement rate, what was noted in work [11] and proved theoretically. Nevertheless, the previous studies belong to testing on metal alloys and were conducted as a real experiment directly in the field conditions. The obtained relationships indicate the commonness of wear processes in the abrasive medium for both metal alloys and polymers. Although wearing-out follows a single law ($\Delta h = k \cdot T$), coefficient k can be regulated by different factors (body movement rate, medium abrasiveness, state of studied material) or their complex. In the given experiment, the compositions of abrasive medium and prototype polymer remained constant; the movement rate of a studied body changed.

An increase in n causes reduction in T. 640 min testing time ensures wears of 0.45 mm and about 2 mm for 500 min^{-1} and 710 min^{-1} revolutions, respectively. In its turn, at n=1000 min^{-1} Δh=2 mm is reached within 40 min. Value Δh of 2mm at 500 rpm can be obtained over an extremely long period of time, what fits in no way in the concept of accelerated tests.

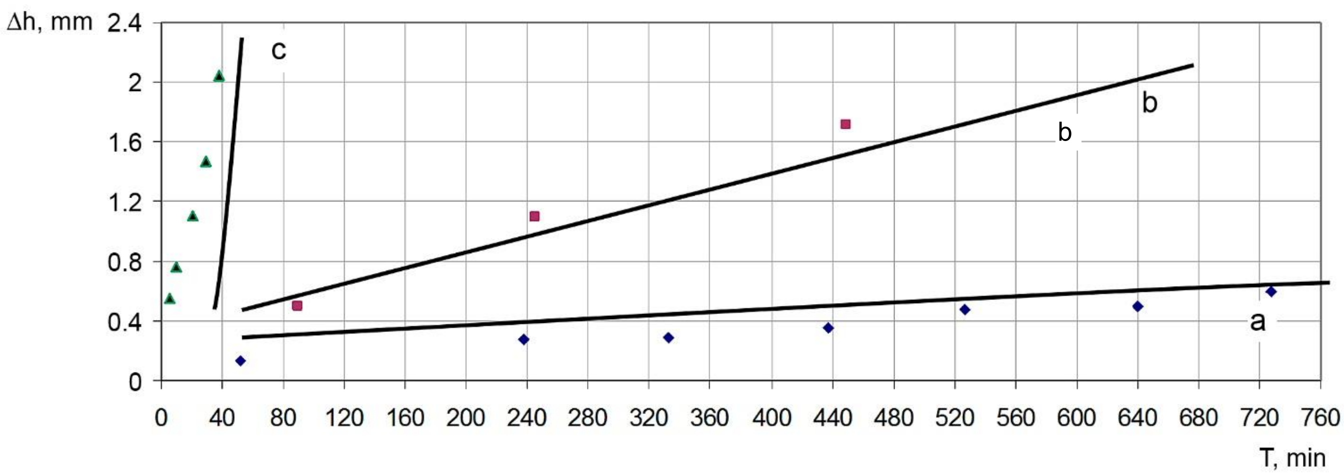

FIGURE 2
NATURE OF EPOXIDE COMPOUND WEAR OVER TIME AT VARIOUS RATES OF MOVEMENT OF PROTOTYPE SPECIMENS: A N=500 MIN^{-1}; B – N=710 MIN^{-1}; C - N= 1000 MIN^{-1}

Constructing a graph of the relationship between testing time and number of revolutions for wear Δh = 0.6 demonstrates a sharp decrease in T in the 500-800 min^{-1} range of n, then the wearing process can be considered stable (steady-state), almost independent of variations in the movement rate (figure 3). 0.6 mm wear was chosen based on the real test conditions – at n=500 min^{-1} this value reaches its maximum, further tests with such n are inexpedient. Furthermore, at this Δh in all cases break-in ceases to occur.

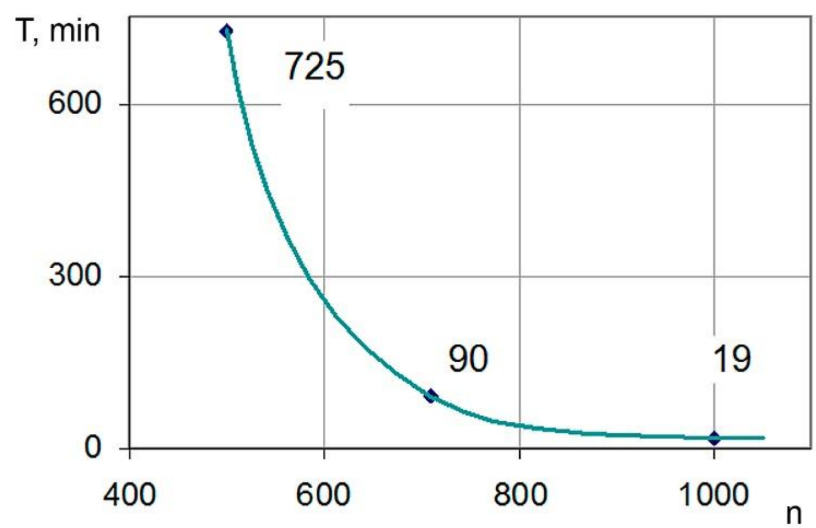

FIGURE 3
DEPENDENCE OF TESTING TIME ON THE NUMBER OF REVOLUTIONS AT THE HOLLOW DEPTH ΔH = 0.6 MM

Thus, conducting accelerated tests for such an abrasive medium is defined by the number of the specimen revolutions 1000 min^{-1} and the time of about 20 min.

The intensity (i) of wearing-out characterises it to the fullest extent possible since it is independent of test parameters under specific conditions. As evidenced by Fig.4, the curves have two strongly pronounced regions (figure 4 a,b,c). The first (1) – the area of specimen break-in, and the second (2) - abrasion of the specimen with virtually complete match between abrasive medium and surface of a tested body. It is customary to consider i as a constant value, and break-in processes are usually not analysed. However, recently they have come to be given serious attention to [12] since in the real conditions of abrasive wear, the cases are often seen when the value of wear at the break-in moment is so high that the items are withdrawn from further operation.

Minimum i is inherent in the lowest movement rate of those used in the experiment (n=500 min^{-1}), maximum for n=1000 min^{-1}. Wear intensity therewith rises asymptotically when n increases (figure 5). It should be supposed that the rate growth will disproportionately affect shock impacts of abrasive particles, impact force, and frequency of bombarding the surface by the abrasive mass components.

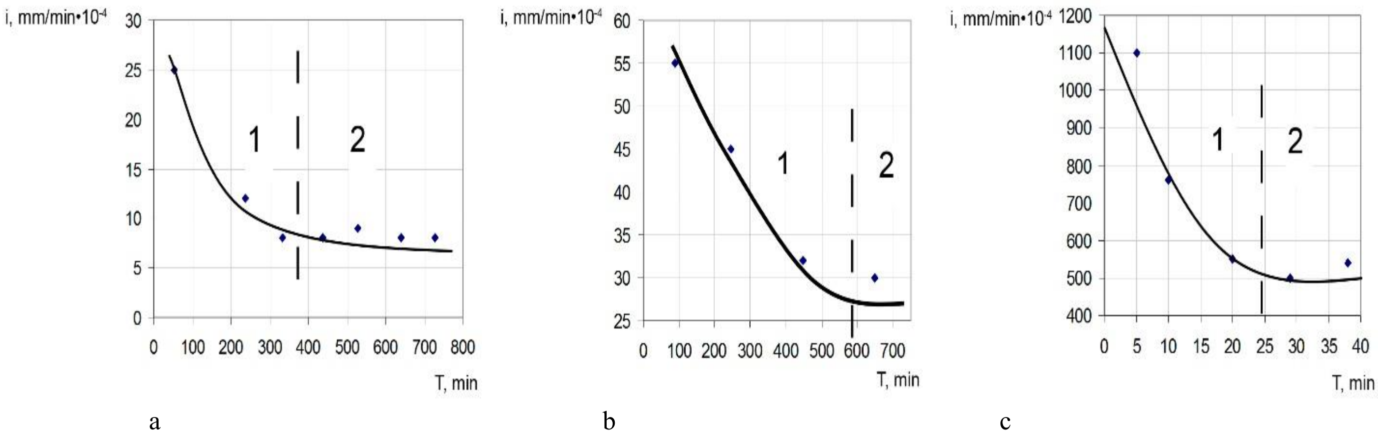

FIGURE 4
WEAR INTENSITY OF EPOXIDE COMPOUND OVER TIME FOR MOVEMENT RATES OF A PROTOTYPE SPECIMEN: A – N=500 MIN^{-1}; B – N=710 MIN^{-1}; C - N= 1000 MIN^{-1}

Wear intensity (figure 5) increases sharply since force action on the surface of abrasive inclusions occurs exponentially. Growth in shock loads results in a rapid increase in contact stresses and destruction of the surface layer. It must be noted that the fracture mechanism for polymers will be other than for metal materials.

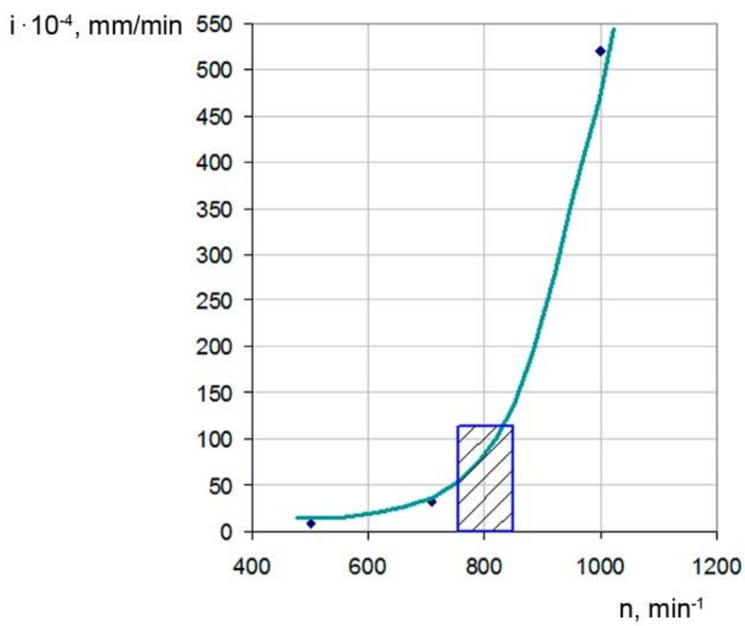

FIGURE 5
GROWTH OF WEAR INTENSITY DEPENDING ON THE NUMBER OF REVOLUTIONS

It follows from analysing the experimental data, that the wear intensity of epoxide compound over time at various movement rates changes according to a single pattern: break-in and subsequent stabilisation. Growth i=f(n) proceeds exponentially. According to the graph (figure 5), 750-850 min^{-1} range (boundaries are crosshatched) will be the optimum rotation frequency. When an increase in n surpasses the specified values, it causes an excessive effect of shock impacts, distorting the picture of wearing-out.

CONCLUSIONS

1. Wear changes over time in a straight-line manner irrespective of the movement rate of a prototype specimen.
2. Wear intensity changes according to a pattern "break-in – stabilisation" with a decline in i early in the experiment irrespective of the rotation frequency of a test body.
3. Optimum rate of specimen movement during accelerated tests is 750-850 min^{-1}, testing time is 40 min.

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