705. Influence of erosive particles impact energy on epoxy coatings wear intensity

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(Received 11 September 2011; accepted 4 December 2011)

Abstract. The paper describes an examination method of polymer coatings erosive wear and the results of the examination carried out using this method. It consist in free falling of erosive material onto examined coating and measurement of wear scar. Intensity of coating erosive wear is, among others, proportional to erosive particles impact energy in the moment when they hit the coating. The different impact energies can be obtained differentiating the height of free fall. The examination concerned influence of coating modification with nanofiller on its resistance to erosive wear. Obtained results clearly reveal that this kind of modification gives positive effect decreasing coating erosive wear intensity.

Keywords: epoxy coating, erosive particle, erosive wear, wear intensity.

Introduction

Erosive wear process of a polymer coating occurs as a result of multiple impacts of hard particles on the coating surface in condition of their elastic or plastic contact. Characteristics of coatings erosive wear process essentially depend on coating physical-chemical properties as well as on erosive particles characteristics like their material kind, shape, velocity and impact angle [1-8, 18, 19, 25-28]. Intensity (velocity) of coating wear may be treated as a criterion of coating resistance to erosive action of environmental factors [9-12]. Intensity of coating erosive wear is directly proportional to the value of elasticity modulus and inversely proportional to the coating breaking stress [21-23, 28]. The increase of polymer coating hardness causes the decrease of its wear intensity, in the case of plastic contact between the hard particle and the coating surface [1, 17]. Increasing of erosive particles velocity leads to increase of erosive wear intensity and this relationship is nonlinear [7, 19]. Erosive wear intensity of polymer coating essentially depends on an angle these particles hit at the coating surface. The impact angle α value determines the depth of particle intrusion into coating surface layers [4, 8]. An extremum of an erosive wear intensity characteristic is determined by the coating hardness. In the case of coatings made of plastic materials of low elasticity modulus the highest value of wear intensity is observed for low values of impact angle. However, for the majority of coatings the highest intensity of erosive wear is observed for impact angles in the range from 10º to 50º. For these angles a micro-cutting is dominating wear process instead of material fatigue process which is characteristic for higher impact angles. Increase of friction coefficient (of erosive particles on coating surface) shifts the extremum of erosive wear intensity characteristic of polymer coatings in the lower angles direction [7, 17].

The intensity of polymer coating erosive wear is proportional to the energy of erosive particles hitting the coating surface. The impact energy depends on velocity (v) and impact angle (α) of erosive particles. The coating wear is commonly examined using apparatuses implementing free fall of erosive particles. In this case the velocity of free fall depends, of course, on the height of particles free fall and this way of testing is the case of presented paper.
The erosive wear intensity of polymer coatings may be decreased by adding nanofillers to their composition [13-16, 20, 24, 29].

Characteristic of Examined Coatings

Three layer epoxy coatings and three layer epoxy coating with surface layer modified with nanosilica were subject matters of examination described in the paper. The coatings were air-sprayed on steel substrates. First, two priming layers made of epoxy primer were deposited and subsequently, after curing period, the top epoxy coat was sprayed.

Modification of top coat epoxy resin consisted in addition of 3.5% (wt) nanofiller in the form of silica (silicon dioxide) nanoparticles of 16 nm average size and 110 ± 20 m^2/g specific surface area. The paint material before application was mixed with silica nanoparticles for 18 hours to obtain effective covering of nanoparticles by epoxy resin.

As steel substrates sheets of dimensions 170×90×1.5 mm made of S235JR steel were used. The sheets were at first abraded in special drums filled with small ceramic rollers and then, directly before application, degreased. The coating after application was acclimatised for the period of 10 days at temperature 20±2ºC and relative humidity 65±5%. Mean thickness of the three-layer epoxy coatings was equal 175 μm and the top coat 55 μm thick.

Examination Method of Polymer Coatings Erosive Wear Intensity

Examinations of epoxy coatings erosive wear were executed using the testing device recommended in Polish Standard PN-76/C-81516. In this device erosive particles fall free from the determined height. The erosive particles move down in the pipe of internal diameter equal 19 mm and target a specimen (steel plate) with investigated coating which is declined at α angle to the pipe axis. Hitting the specimen particles produce wear of the coating in the elliptic shape.

In order to evaluate the intensity of polymer coating erosive wear the I criterion was proposed in this paper expressing the ratio of the coating thickness *G*, [μm] to the total mass *M*, [kg] of erosive particles inducing coating wear in the tested area (i.e. wear causing substrate exposure of the shape similar to ellipse of minor diameter *d*=3.6±1 mm).

As erosive material particles of granulated alundum 99A (acc. to PN-76/M-59111) were used of grain number 30 (acc. To PN-ISO 8486-2) and grain size equal 0.60÷0.71 mm. Aluminium trioxide is the main constituent of this erosive material (min. 99%), and others constituents are silicon dioxide, iron trioxide, calcium oxide, and sodium dioxide.

During each test examined specimen with the coating were inclined at angle α=45º. Examination were carried out at ambient temperature equal 20±2 ºC and relative humidity equal 65±5%.

Examination Results

Examination results are comprised in Fig. 1. They describe the influence of erosive particles impact energy (presented as height of their free fall) on intensity of erosive wear of two kinds of coating: epoxy three layer coating and epoxy three layer coating with top coat modified with 3.5% addition of silica nanoparticles of 16 nm mean size.

It is clearly visible in the Fig. 1 that application of top coat modified with nanoparticles decreases erosive wear intensity of epoxy coating i.e. increases resistance of epoxy coating to erosive wear.

Conclusions

On the basis of carried out tests it can be stated as follows:

1. When the impact energy of free falling erosive particles (which is directly proportional to fall height) is higher the intensity of erosive wear is higher too. Progressive increase of erosive wear intensity is observed within the free fall height range from 665 mm to915 mm while in the subsequent range from 915 mm to 1415 mm stabilisation of erosive wear occurs.
2. Coating modification method consisting in addition of silica nanoparticles to the coating composition induces lower wear intensity of modified coatings in comparison with unmodified ones. It is effect of lower roughness of modified coatings as well as improvement of their mechanical properties. Filling of coating structure with silica nanoparticles contributes thus to coating hardness increase as well as to decrease of micro- and nanocracks development what lead to decrease of coating tendency to fatigue chipping.

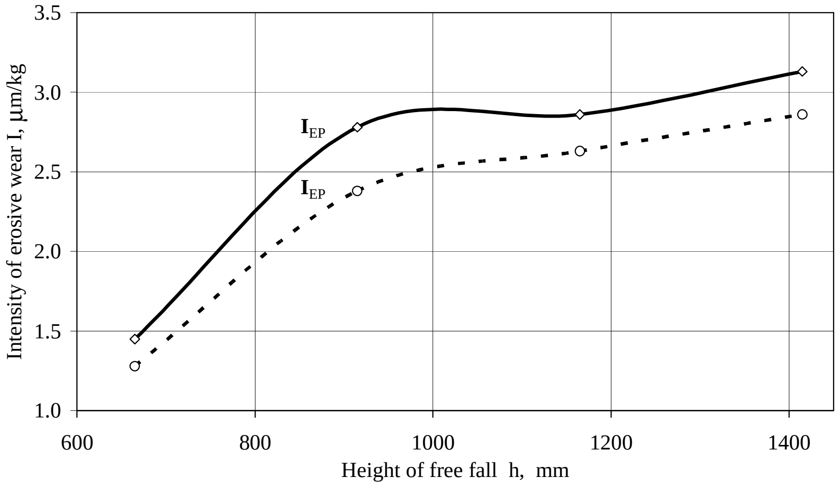

Fig. 1. Intensity of erosive wear of three layer epoxy coating (I_{EP}) and three layer epoxy coating with top coat modified with silica nanoparticles (I_{EPn}) vs. height of erosive particles free fall

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