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ScienceDirect

Procedia Structural Integrity 8 (2018) 239–255

Structural Integrity Procedia

www.elsevier.com/locate/procedia

AIAS 2017 International Conference on Stress Analysis, AIAS 2017, 6-9 September 2017, Pisa, Italy

Tribological characterization of modified polymeric blends

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Abstract

The present work reports of a series of experimental tests with two polymeric materials, a thermoplastic polyurethane (TPU) and a polyamide (PA), modified with the inclusion of additives, in terms of their tribological properties of friction and wear. Many thermoplastic materials are in fact used in applications with sliding contact and friction (as in journal bearings, supports…) and, to improve their properties, the polymer is modified with additives having the capacity to change the surface properties.
Used additives are of several types: in this work a comparison is made between graphite, polytetrafluoroethylene, a silicone (siloxane), molybdenum disulfide, and carbon nanotubes. For each additive, different percentage in weight have been considered. All these materials can modify the surface properties of the base material exploiting different physical and chemical phenomena. Moreover, the presence of such additives can alter the mechanical properties of the materials sometimes reducing stiffness, strength, and strain limit.
The work reports of the experimental methods obtained with a typical tribological test (pin-on-disk method) to measure the tribological properties of the compounds in terms of friction and wear, together with mechanical tests. The analysis will show correlations between the composition, in terms of type and quantity of the additive, on the properties of the compounds.

Peer-review under responsibility of the Scientific Committee of AIAS 2017 International Conference on Stress Analysis

Keywords: thermoplastic materials; wear; friction

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Peer-review under responsibility of the Scientific Committee of AIAS 2017 International Conference on Stress Analysis
10.1016/j.prostr.2017.12.026

1. Introduction

Plastic materials are of paramount importance when dealing with the current widespread trend towards *lightweight design.* Their peculiar properties of low density, low cost, and flexibility in terms of both design and manufacturing, make them ideal for the process so-called of *metal replacement*, see Kerns (2016) or Platt (2003). Of course, total metal replacement is nonsense because not always convenient from many points of view. However, there is plenty of examples of efficient replacement of a more conventional material (mainly steel or other alloys) with a special polymer or a techno-polymer, see Lewis (1993). The process is not a straight and simple replacement of material: to exploit the advantage of plastics a re-design of the component is mandatory, together with a re-design of the whole manufacturing process, including assembly. Assembly can be sometimes simplified or even avoided with a smart re-design allowing to introduce internal joints or hinges.

One of the most interesting situations were a partial metal replacement can be efficiently carried out is in journal bearings and other connections where friction, and consequently wear, is involved. In these situations, one of the part, more commonly the shaft, remains made of metal (typically a ferrous alloy) while the other will be in some plastic material with high strength and resistance to wear. Concurrently, reduction in the coefficient of friction is also highly welcome to decrease dissipation of energy that could induce problems due to heating and temperature increase but also losses of efficiency. Among the plastic materials with higher strength and wear properties, Sinha (2002) and Briscoe et al. (2002), there are PTFE (polytetrafluoroethylene), POM (polyoxymethylene or acetal resin), UHMWPE (ultra-high molecular weight polyethylene), PA (polyamide) and TPU (thermoplastic polyurethane), and secondarily, PES (polyester). As is well known, talking of a family of such polymers doesn't mean to represent a set of properties within a relatively small range: most properties (physical, mechanical, optical…) often vary of a large amount depending on the grade from the same manufacturer and between different manufacturers, and can also largely change depending on environmental influences (temperature, moisture…) and processing. Therefore, from selection of a plastic material to design, the freedom to search for a specific property is compensated by the uncertainty about the precise value of each characteristic.

Tribological systems are always very complex, even more when plastic materials are involved. In Zhang S.W. (1998) a review is made about different polymeric materials showing their peculiar problematic including lubrication, timing, frequency, and type of loading, composition and modifications by additives: all of these factors can be of different influence. Myshkin et al. (2005) also examined the influence of surface properties, contact mechanisms, temperature, speed and load, on wear and friction of some of the previously indicated polymers, showing a correlation between wear and strength.

TPU, a block copolymer consisting of alternating sequences of hard and soft segments or domains obtained by the reaction of diisocyanates with short-chain diols and diisocyanates with long-chain diols, is an important class of plastics because of the variable combination of good processability and flexibility that has demonstrated interesting properties of wear resistance, as shown by Yahiaoui et al. (2014). In that paper they examined the influence of load, velocity and temperature in the contact with steel under dry conditions of friction. Martínez et al. (2010) also examined the influence of load on the wear of TPU and correlated with the fatigue strength. The wear mechanisms in TPU were examined by Elleuch et al. (2007) confirming a correlation between friction and wear. The effect of additives has been studied by many authors: Akbarian et al. (2008) concluded that reinforcing with aramid fibers, despite increasing strength, was detrimental for wear resistance; on the contrary Tan et al. (2008) obtained improved abrasion resistance by adding ethylene–propylene–diene monomer rubber; Hill et al. (1996) and Bremner et al. (1996) showed that an increase in wear resistance up to 20% could be obtained with a small concentration of PDMS additive. TPU can also be used as an additive to other polymers such as in Pomali et al. (2008) who examined blends with PMMA, but the result is that TPU was detrimental for abrasion resistance.

Polyamides, the first engineering thermoplastics already used in the 1930s, see Rosato et al (2004), constitute another huge family of polymers with important technological applications. PA6 and even more PA66 are used in applications where load-bearing capacity is important as well as wear resistance, such as journal bearings, Feyzullahoglu et al. (2006). Consequently, the tribological properties of polyamides have been widely studied: Jia et al. (2007) studied the friction properties of PA66 against itself and the influence of some lubricants; Feyzullahoglu et al. (2006) studied the tribological properties of cast PA in contact with steel parts; Zhang Z.-Z et al. (1998) compared PA66 with other polymers in the oil-lubricated conditions against a chromium steel to confirm the interesting