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Methods of preparing polymeric gradient composites

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ABSTRACT

Purpose: The goal of this work is to introduce basic methods of preparing polymeric gradient materials, which allow to join two different components to ensure the required properties and structure of the functionally gradient materials.

Design/methodology/approach: In this paper few of methods of preparing functionally gradient polymeric materials are briefly described which were successful employed in many investigations performed during last few years.

Findings: It was noticed that the knowledge about polymeric gradient materials is still developing what can allow to manufacture new products characterized by unique properties.

Research limitations/implications: Most of methods presented in this paper are also used for conventional products, the difference between conventional products and products with gradient are quantity of components, shape and size of reinforcements, and properties of ready materials.

Practical implications: Presented methods can be applied in preparing FGMs for future research programmes and also in industrial processes.

Originality/value: Techniques are presented that can be useful in future scientific work concerning functionally gradient materials containing polymer materials.

Keywords: Casting; Functionally gradient materials; Polymeric gradient materials; Corona discharge; Pressing

1. Introduction

Functionally Gradient Materials (FGMs) are a unique generation of composite materials, characterized by spatial and continuous distribution of composition and/or microstructure of materials components (two or more) in the definite direction (Fig.1). The cause of searching such materials is modification of mechanical and thermal properties by interchanging the roles of matrix and reinforcement of product. It can be obtain by using differences in properties, size and/or shape of reinforcement [1-5].

For the first time Functionally Gradient Materials (FGMs) were manufactured by Academician S.A. Vekshinskii in 1944 [6]. From 1987 scientists have been developing knowledge about FGMs. Since that time there were many investigations to produce materials for which is not possible to distinguish frontiers between individual layers. The basic problem which appears during the planning of composites with gradient is preparation the manners for controlling gradient of definite properties.

Gradient Materials have different functions, which characterize various distribution of properties for instance hardness, Young's modulus, wear resistance, thermal expansion coefficient etc. It is possible owing to use of different mixtures of engineering materials such as metals, ceramics, and polymers. PGMs (Polymeric Gradient Materials) are inhomogeneous composites containing at least one polymer. In the case when are more than one component, usually the first one is considered as matrix and the second component is a reinforcement (from 5 to

45% - particles or fibres) [7-10].

In prior works it was found that PP/PA-6 [9], PVC/PMMA [10], PP/EVA [11], alumina/epoxy [12], SiC/epoxy [13], UHMWPE/epoxy [14], PMMA/glass fibre [15], glass-fibre mat/PP [16], epoxy/carbon fibre [17], PP/carbon fibre/glass fibre [18] were applied as PGMs. There are few methods that allow to make effectively PGMs for example hot isostatic pressing [13], gravity casting [19], centrifugation [13,20-22], corona discharge [23,24], UV irradiation [7,25], selective laser sintering (SLS) [26,27], and compression moulding [28,29]. Some of them are described in this paper.

Fig. 1. Gradual distribution of components of FGMs

Till now scientists have been making researches with the aim to reach better properties of the materials, which can allow to find new interesting applications. They can be used for tools, coatings, aircraft, space science, and automotive industry. Unusual structure and properties of these materials are obtained by using appropriate methods.

2. Methods of preparing PGMs

2.1. Casting

Gravity casting

Gravity casting method is one of the methods relying on gravity without applying pressure. It is possible to produce spatially distribution of component materials by casting step-by-step two or more melts. First of all one of melts is poured and when is partially solidified or crosslinked then the second melt is poured (Fig .2)[19].

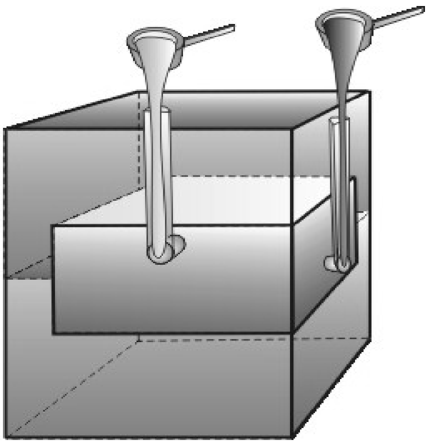

Fig. 3. Schematic diagram of gravity casting

Centrifugal casting

One of the effective methods applied in production of FGMs is the centrifugal technique. The casting method depends upon type of forming material which can be in form of paste or powder. The material is located close to heated mould's wall. Mould with processed mixture is rotated around one or two perpendicular axis. Mixture during the process is heated inside the mould. As a consequence of applied centrifugal force one of the components sediments gradually on the form's walls. Next the form is cooled and moulding is took out [30]. In previous works described in literature it was shown that this method could be successfully used for FGMs. The gradation of properties can be controlled for instance by changing rate and time of centrifugation but also by size, shape and amount of particles [20-22,31]. This way diverse density distribution was obtained in searched materials (Fig.3).

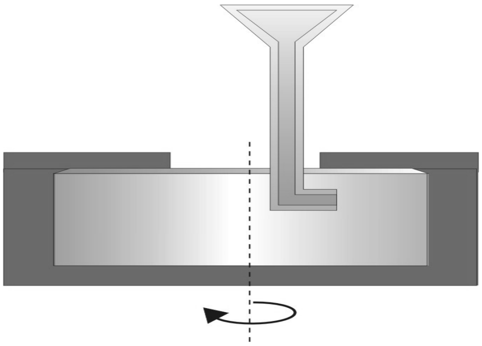

Fig. 2. Schematic diagram of rotation casting

2.2. Corona discharge

Gradient materials can be also produce by using the corona discharge method. There were made a number of investigations with this method [23,24]. Corona discharge can be use for modification of surface layer of flat products (for instance plate, film), but also for products with complex shape (e.g. pipe, container). Figure 4 shows the schematic diagram of corona-discharge apparatus with a radio frequency (RF) for the preparation of the gradient surface layer. Usually the apparatus consists of: generator, high voltage transformer and two electrodes. One of them is ground-down covered with dielectric layer and the second electrode, so-called knife-electrode, (usually made from aluminium) is connected to the RF generator. Applied power increases gradually by means of motorized drive [32].

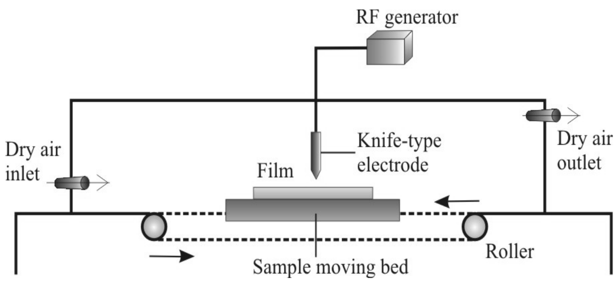

Fig. 4. Schematic diagram showing the corona discharge apparatus

The cleaned film is placed on the movable sample bed and dry air purges through the apparatus. During bed movement the corona from the electrode discharges onto the sample.

2.3. Selective laser sintering (SLS)

In Selective Laser Sintering (SLS) process 3-dimensional objects with CAD aid can be created. Parts are formed by fusing polymer (PA, PS), metal or ceramic powder materials. SLS processing requires special properties of material's particles, first of all, the powder should be in the form that can flow freely. This method consist of deposition and consolidation layer-by-layer, what means that the layer of material is selectively fused by applying laser beam. After that the next layer is applied on the top, and the process is repeated [26,27].

2.4. Pressing

Materials characterized by gradient properties are manufactured by pressing (uniaxially pressing, hot pressing, HIP – hot isostatic pressing) [16,33].

Uniaxial pressing (Fig 5) fabrication is a very common forming process performed in rigid forms which consist of matrix and punch.. Pressing is realized under suitable pressure and only in vertical direction. In prior investigations described by other authors [16] density gradient was achieved. In future, authors of this paper are planning to apply this method to produce PGMs with gradient of various properties.

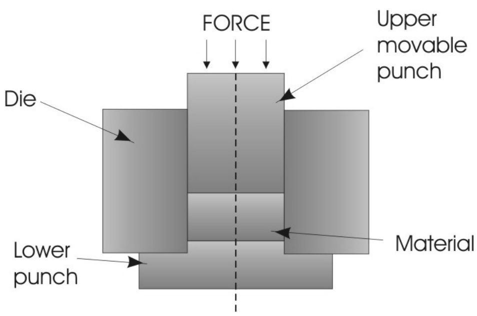

Fig. 5. Schematic diagram of uniaxially pressing

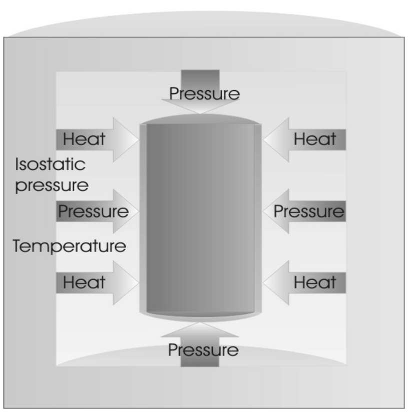

Fig. 6. Schematic diagram of hot isostatic pressing

Hot pressing is also a forming technique with a simultaneous application of pressure and temperature to enhance densification. Pressure is applied statically or dynamically to heated component in one or two directions along a single axis. In case of Hot Isostatic Pressing, technique combining high temperature and isostatic forming , pressure is applied to consolidate components. Material is situated in elastic form that is surrounded by gas under isostatic pressure. It assure that pressure is applied uniformly in all directions (Fig.6) [34].

2.5. UV fotopolymerization

Reaction of monomers to produce polymeric structures by light-induced initiation is defined as a photopolymerization. This reaction has several advantages over other methods, for example low temperature conditions, light can be focused onto a desired place. Depending on irradiation wavelength, light intensity and properties of monomer, induction, dissociation or ionisation of monomer can occur [35]. Photopolymerization applied for gradient materials production can be divided into two steps. First one relating to absorbance variation of UV in the medium in order to obtain gradient material. The second step comprises thermal cross-linking reaction. In most researches samples are treated by vapour lamp [7,25].

3. Conclusions

The development of methods for preparing PGMs has opened new opportunity for engineered materials. The concept of functionally gradient polymeric materials and techniques were briefly described. Unfortunately up till now, comparing polymers with ceramics and metals, knowledge on processing methods for polymer gradient materials is limited. All of described methods can be used to obtain connection between two materials with various properties. Authors have begun research programme on properties of PGMs formed using casting and pressing techniques. Results will be published in near future.

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