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Evaluation of the Suitability of a Microcapsule-Based System for the Manufacturing of Self-Healing Low-Density Polyethylene

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Abstract : Among self-healing materials, the most unexplored group are thermoplastic polymers. These polymers are used not only to produce packaging with a relatively short life but also to obtain coatings, insulation, casings, or parts of machines and devices. Due to its exceptional resistance to weather conditions, hydrophobicity, sufficient mechanical strength, and ease of extrusion, polyethylene is used in the production of polymer pipelines and as an insulating layer for steel pipelines. Polyethylene or PE coated steel pipelines can be used in difficult conditions such as underground or underwater installations. Both installation and use under such conditions are associated with high stresses and consequently the formation of microdamages in the structure of the material, loss of its integrity and final applicability. The ideal solution would be to include a self-healing system in the polymer material. In the presented study the behavior of resin-coated microcapsules in the extrusion process of low-density polyethylene was examined. Microcapsules are a convenient element of the repair system because they can be filled with appropriate reactive substances to ensure the repair process, but the main problem is their durability under processing conditions. Rapeseed oil, which has a relatively high boiling point of 240ºC and low volatility, was used as the core material that simulates the reactive agents. The capsule shell, which is a key element responsible for its mechanical strength, was obtained by in situ polymerising urea-formaldehyde, melamine-urea-formaldehyde or melamine-formaldehyde resin on the surface of oil droplets dispersed in water. The strength of the capsules was compared based on the shell material, and in addition, microcapsules with single- and multilayer shells were obtained using different combinations of the chemical composition of the resins. For example, the first layer of appropriate tightness and stiffness was made of melamine-urea-formaldehyde resin, and the second layer was a melamine-formaldehyde reinforcing layer. The size, shape, distribution of capsule diameters and shell thickness were determined using digital optical microscopy and electron microscopy. The efficiency of encapsulation (i.e., the presence of rapeseed oil as the core) and the tightness of the shell were determined by FTIR spectroscopic examination. The mechanical strength and distribution of microcapsules in polyethylene were tested by extruding samples of crushed low-density polyethylene mixed with microcapsules in a ratio of 1 and 2.5% by weight. The extrusion process was carried out in a mini extruder at a temperature of 150ºC. The capsules obtained had a diameter range of 70-200 µm. FTIR analysis confirmed the presence of rapeseed oil in both single- and multilayer shell microcapsules. Microscopic observations of cross sections of the extrudates confirmed the presence of both intact and cracked microcapsules. However, the melamine-formaldehyde resin shells showed higher processing strength compared to that of the melamine-urea-formaldehyde coating and the urea-formaldehyde coating. Capsules with a urea-formaldehyde shell work very well in resin coating systems and cement composites, i.e., in pressureless processing and moulding conditions. The addition of another layer of melamine-formaldehyde coating to both the melamine-urea-formaldehyde and melamine-formaldehyde resin layers significantly increased the number of microcapsules undamaged during the extrusion process. The properties of multilayer coatings were also determined and compared with each other using computer modelling.

Keywords : self-healing polymers, polyethylene, microcapsules, extrusion
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