

An Investigation of Thin Epoxy Resin Layers Curing Using Microwave Energy

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Abstract

This thesis documents the experimental application of producing thin epoxy resin layers cured by using microwave radiation. Applying thin layers upon each other leads to a tridimensional model. In principle this operation is similar to current methods of tridimensional modelling such as Stereolithography (SL), Laminated Object Manufacturing (LOM), Selective Laser Sintering (SLS) or Fused Deposition modelling (FDM). In contrast to methods utilising a high-powered laser to polymerise light sensitive liquid polymers or fuses ceramic or polymer particles, the concept of thin epoxy resin/amine layer cured by using microwaves has been investigated in this thesis. In this context, we see the microwave heating technology as an alternative cost-effective and technically superior process for thermal activated polymerisation of layers. Moreover, because microwaves have a volumetric heating capability, the layer material is cured within seconds to a dimensionally stable condition. Therefore additional work such as post curing under UV-light or waxing of a partly completed model to improve the strength is not required.

In this investigation the layer consisted of a liquid mixture of epoxy resin with aluminium particles. The intention was to implement a new technique of fast curing the material mixtures using microwave heating. A modified industrial microwave oven was used as a resonant cavity with a speed controlled turntable as a modelling platform. The microwave energy was supplied by a specially designed applicator to enhance the electric field strength. The epoxy resin was sprayed onto a rotating platform close to the microwave applicator. Curing of the epoxy layer was performed while the layer was exposed to the microwave electromagnetic field shortly after application.

Microwave curing was used to support fast curing in order to prevent changes to the form and shape of a selective applied layer. To reach the state of dimensional

stability, the curing temperature of the layer material was controlled using two options. First, the curing temperature was controlled through the reduction of the microwave power and second, through altering the turntable speed so that the microwave exposure time of the layer could be monitored. This operation was controlled using appropriate computer software.

A major part of this thesis focused on determining the optimal material combination to enable fast curing. To this end it was important to generate an extensive experimental data set in order to understand the relationship between microwave power, exposure time and the material for fast curing. Therefore, a special waveguide was designed to cure samples of epoxy resin/amine mixtures. In order to understand and to specify the curing state of microwave exposed samples, samples were analysed using Dynamic Scanning Calorimetry (DSC). In line with the curability of epoxy resin/amine layers, the material properties of layer mixtures were investigated by conducting tensile and hardness tests.

The issue of statistical modelling of the fast curing process of thin epoxy resin layers using microwave heating is addressed also in this study. The modelling by a linear regression method is based on information available from the curing process as well as from data collected performing the DSC analysis.

The major objective of this thesis was to investigate a new manufacturing process for microwave curing of thermoset polymers producing thin epoxy resin/amine layers. The aim was to investigate the feasibility of fast curing of thermoset material layers by using microwave energy. The newly developed fast curing technique proves an advantage in reduced curing time and delivers benefits to the manufacturing industries due to reduction in modelling time for non-stoichiometric mixture of thermoset material of epoxy resin /amine.