

New Metal/Polymer Composites for Fused Deposition Modelling Applications

By

Mostafa Nikzad

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Australia

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Abstract

Fused Deposition Modelling (FDM) has been a leading rapid prototyping process but it has been mostly limited to use in making prototypes for design verification and functional testing applications. The commercial process can currently fabricate parts only in limited types of thermoplastics such as ABS and Polycarbonate. Very little efforts have been made to increase the range of FDM materials to include metals or metal based composites for wider application domain beyond just design and verification. This thesis presents new research in this direction by developing novel metal based composites for use in FDM technology.

The principal objective of this research is to develop new metal/polymer composite materials for direct use in the current Fused Deposition Modelling rapid prototyping platform with long term aim of developing direct rapid tooling on the FDM system. Using such composites, the direct rapid tooling will allow fabrication of injection moulding dies and inserts with desired thermal and mechanical properties suitable for using directly in injection moulding machines for short term or long term production runs. The new metal/polymer composite material developed in this research work involves use of iron particles and copper particles in a polymer matrix of ABS material, which offers much improved thermal, electrical and mechanical properties enabling current Fused Deposition Modelling technique to produce rapid functional parts and tooling. Higher thermal conductivity of the new metal/polymer composite material coupled with implementation of conformal cooling channels enabled by layer-by-layer fabrication technology of the Fused Deposition Modelling will result in tremendously improved injection cycles times, and thereby reducing the cost and lead time of injection moulding tooling.

Due to highly metal-particulate filled matrix of the new composite material, injection tools and inserts made using this material on Fused Deposition Modelling, demonstrate a higher stiffness comparing to those made out of pure polymeric material resulting in withstanding higher injection moulding pressures. Moreover, metallic filler content of the new composite allows processing of functional parts with electrical conductivity and in case of using ferromagnetic fillers, namely as fine iron powders, it introduces magnetic properties, which will make FDM-built components suitable for electronic applications specifically whereby electro-magnetic shielding is of high interest.

In this research project, a full characterization of the newly developed metal/polymer composites including rheological, thermal, mechanical and electrical properties has been investigated. Mathematical models have been employed in order to predict and optimize the viscous behaviour of metal/polymer composite during the course of deposition through the FDM nozzle.

In order to predict the main flow parameters of the metal/polymer composites including pressure, temperature, and velocity fields through the FDM liquefier head, 2-D and 3-D numerical analysis of melt flow behaviour of acrylonitrile-butadiene-styrene (ABS) and Iron composite as a representative metal/polymer material has been carried out using ANSYS FLOTRAN and ANSYS CFX commercial codes. Results of numerical analysis have been verified by the developed empirical mathematical models.

A variety of advanced techniques have been employed to fully characterize the newly developed metal/polymer composites in order to successfully process filaments for fabrication of injection mould tooling inserts. Morphological effects of metallic fillers and surfactants as well as variation of volume fractions of constituents on the viscoelastic properties of the new composite material

have also been investigated. Filaments of the filled ABS has been fabricated and characterized to verify the possibility of prototyping and direct tooling using the new material on the current FDM machine.

Major contributions of the thesis include:

- Development of a new metal/polymer composite material for functional parts and rapid tooling solutions on Fused Deposition Modeling platform.
- Development of mathematical models for predicting viscous behavior of three-component composite flow through capillary extrusion process.
- Full rheological, thermal, mechanical and electrical characterization of the new metal/polymer composites.
- Combining experimental and numerical methodology (tools) to predict melt flow behavior of metal/polymer composite through Fused Deposition Modeling.
- Fabrication of stiff and flexible filaments of the metal-polymer composites as feedstock material for direct rapid tooling via Fused Deposition Modeling.
- Fabrication of functional parts and inserts of new metal/polymer composites successfully and directly on the FDM3000 system.
- Production of plastic parts using injection moulding tools made by Direct FDM-based Rapid Tooling Process.

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Thank You!

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