# Abstract

Powder injection moulding (PIM) is one of the new near net-shape manufacturing technologies for economical production of small intricate components out of metal or ceramic in large quantities. The quality of the PIM product depends on feedstock characteristics, process parameters of injection moulding stage as well as debinding and sintering stage. Injection stage is most important as many defects such as phase separation, weld line, voids etc. may occur during injection stage due to improper selection of injection moulding parameters and these defects cannot be repaired in the subsequent debinding and sintering stages.  Numerical simulation is very important for any product or technology development. In this thesis work attempts have been made to develop a non-isothermal multiphase flow numerical model to simulate the injection stage of PIM process in a view to address the phase separation phenomenon and to validate the numerical model with experimental results.

The dissertation is divided into six chapters. The first chapter deals with introduction, stament of the prolem. The send chapter contains detailed literature review and this chapter is divided in eight sections. The first section deals with powder, binder and feedstock attributes. Second section deals with tooling for injection moulding. Third section deals with injection moulding stage. Fourth and fifth sections deal with debinding stage and sintering stage respectively. Problem and defects occur in the injection stage and simulation of injection moulding stage are dealt with in section six and section seven respectively. The last section of this chapter i.e. section eight contains the scope of the work in the present investigation. The third chapter deals with experimental part related to this investigation. Chapter four contains detail mathematical formulation, discretization and solution procedure of the discrtized governing equations to simulate the injection stage. Chapter five deals with results and discussion of the work and is divided into four sections. First section contains the characterization of powder, binder and feedstock. Second section contains validation of numerical model i.e. comparison of simulated results with experimental results. Section three and four contains results related to debinding and sintering of tensile specimens. Chapter six deals with concluding remarks of the investigation.

The present study provides,

1) A non isothermal 3D multiphase flow numerical model based on Eulerian approach to simulate the injection stage of powder injection moulding (PIM) in a view to predict the powder-binder separation phenomenon known as phase segregation. In this numerical model, feedstock has been treated as mixture of two separate fluid phases *viz.* powder phase and binder phase. Another fluid phase, air is assumed to be present inside the mould before feedstock enters into the mould and goes out as feedstock fills the cavity. All the three phases are characterized by their own properties. The non Newtonian behavior of the binder phase has been incorporated through Power Law model and non Newtonian behavior of the powder phase has been incorporated through the model due to Ishi and Zuber (1979) and rule of mixture.

Interaction between the phases is taken care by introducing momentum exchange and heat exchange coefficients in the momentum and energy equations. During solidification, a modified temperature recovery scheme has been introduced taking into account of the latent heat release of the binder. In the solidification range, the temperature in a cell is continuously modified depending of the fraction of liquid of binder phase in that cell. On the other hand liquid fraction of the binder in a cell is tracked by solving a scalar transport equation.

2) Comparison of Simulated injection parameters such as injection pressure and mould filling time with that of experimentally measured injection pressure and mould filling time. Similarly, simulated results of the phase segregation have been compared with experimentally measured results. Simulated data matches in general with experimental results. It indicates that the developed model can simulate the injection stage of PIM and predict phase segregation. The results show that as the injection temperature increases, phase segregation increases and injection temperature has larger effect on phase segregation than the injection speed and the mould temperature.

3) Debinding of the binder requires two stage debinding to maintain the shape of the compact *viz.* solvent debinding followed by thermal debinding.

4) Around 95% of theoretical density has been achieved in the sintered tensile specimens with UTS 433.5 MPa.