Chapter 11

Multi-Objective Evolutionary Algorithms:
Application in Designing Particle Reinforced Mould Materials

A. K. Nandi
CSIR – Central Mechanical Engineering Research Institute, India

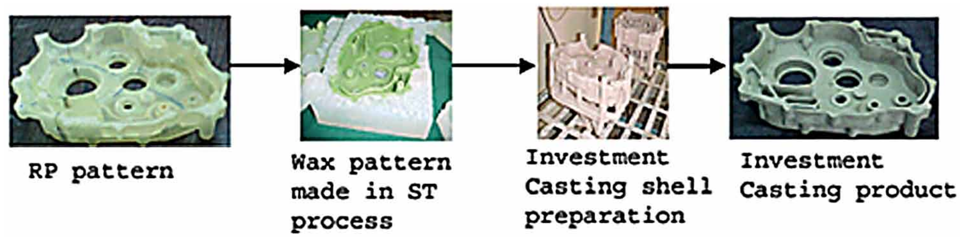
K. Deb
Michigan State University, USA

ABSTRACT

The primary objective in designing appropriate particle reinforced polyurethane composite which will be used as a mould material in soft tooling process is to minimize the cycle time of soft tooling process by providing faster cooling rate during solidification of wax/plastic component. This chapter exemplifies an effective approach to design particle reinforced mould materials by solving the inherent multi-objective optimization problem associated with soft tooling process using evolutionary algorithms. In this chapter, first a brief introduction of multi-objective optimization problem with the key issues is presented. Then, after a short overview on the working procedure of genetic algorithm, a well- established multi-objective evolutionary algorithm, namely NSGA-II along with various performance metrics are described. The inherent multi-objective problem in soft tooling process is demonstrated and subsequently solved using an elitist non-dominated sorting genetic algorithm, NSGA-II. Multi-objective optimization results obtained using NSGA-II are analyzed statistically and validated with real industrial application. Finally the fundamental results of this approach are summarized and various perspectives to the industries along with scopes for future research work are pointed out.

DOI: 10.4018/978-1-5225-0290-6.ch011

Figure 1. Development of metal components through RP-ST-wax pattern -investment casting



INTRODUCTION

Soft tooling (ST) is a rapid tooling process where polymeric flexible materials are used for making mould (Rosochowski, 2000). ST process is particularly suitable to produce wax patterns in small batch by vacuum assisted or gravity casting method based on RP (Rapid Prototype)/others pattern. This wax component is used in investment casting process as pattern to make ceramic slurry and finally metallic components are produced by fusing the wax pattern. The method of making metal component through different processes (rapid prototyping (RP)-soft tooling-investment casting) is illustrated in Figure 1.

The common polymeric flexible mould materials used in soft tooling process are polyurethane (PU), silicone rubber, etc. However, these mould materials in general possess poor thermal conductivity (TC). For this reason, solidification time of wax/plastic pattern produced in ST process is significantly long because of poor heat flow rate through the mould wall. As a result the rapidity of soft tooling process is reduced to a great extent.

Previous experimental studies (Nandi, Datta, & Orkus, 2012) reveal that similar to other composites (Agrawal et al., 2000; Boudenne et al., 2004; Iqbal, Frormann, Saleem, & Ishaq, 2007; Ishida & Rimdusit, 1998; Keith, King, Lenhart, & Zimny, 2007; Kim, Choi, Lee, & Kang, 2008; Lopes & Felisberti, 2004; Mamunya, Davydenko, Pissis, & Lebedev, 2002; Miller et al., 2006; Mu, Feng, & Diao, 2007; Ng, Lu, & Lau, 2005; Oliveira et al., 2007, Razzaq & Frormann, 2007; Subodh, Manjusha, Philip, & Sebastian, 2008; Sundstrom & Chen, 1970; Tsukuda, Sumimoto, & Ozawa, 1997; Vinod, Varghese, & Kuriakose, 2004; Wang, Li, & Su, 2008; Wang, Gao, Wang, & Hua, 2001; Weidenfeller, Hofer, & Schilling, 2004; Wong & Bollampally, 1999; Xu, Chung, & Mroz, 2001; Yu, Hing, & Hu, 2002;) increase of conductive filler loading raises the equivalent thermal conductivity (ETC) of flexible mould materials. Moreover, with enhancing the filler content, the equivalent modulus of elasticity (EME) of particle reinforced SR also increases, which yields to escalating the stiffness of mould box (Nandi et al., 2012).But high stiffness value of the mould box is not suitable for STP because it produces numerous complications especially when the pattern is to be taken out from the mould box. Moreover presence of filler material augments the equivalent viscosity of melt SR composite (Nandi, Vesterinen, Cingi, Seppala, & Orkus, 2010). In STP, elevated viscosity of liquid FMM is not permitted as it creates the problem of filling up the space between the mould box and pattern. The reason is that high viscosity condenses the flow ability of melt mould material. Thus there is a need to appropriately design composite flexible mould materials to improve the soft tooling process by enhancing its solidification time and keeping other inherent advantages. Since, in the present problem the motivation is to increase the thermal conductivity of mould material and simultaneously to restrict the increases of modulus of elasticity and viscosity, it seems that these objectives are conflicting to each other. Therefore, this problem is tackled using a suitable multi-

Related Content