Application of Grey Taguchi based Response Surface Methodology (GT-RSM) in Injection Moulding of Polypropylene/E-glass Composite

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ABSTRACT

Strong non-linearity combined with the complicated rheological behaviour of polymers makes the quality characteristics of products unpredictable in plastic injection moulding. The purpose of this work is to study the mechanical properties of injection moulded polypropylene/E-glass composites. The process parameters like the melt temperature, injection pressure, packing pressure and cooling time were found to influence the quality characteristics of the produced parts. These four parameters were varied at three levels and a L18 orthogonal array was used for designing and conducting the experiments. Tensile and impact strength (Charpy-notched) were observed as the responses and a new integrated technique of grey Taguchi based response surface methodology (GT-RSM) was disclosed to predict the optimal operating condition. A confirmation test was conducted to demonstrate the accuracy of GT-RSM approach. Injection and packing pressure were found to have statistical significance in influencing the strength of injection moulded polypropylene/E-glass composites.

Keywords: *ANOVA, Desirability Analysis, Grey Taguchi, Injection Moulding, Optimization, Orthogonal Array, Polypropylene/E-glass, Response Surface Methodology*

INTRODUCTION

Polypropylene based composites are generally used for interior applications in automotive designs, food containers, reusable products etc. Particularly those reinforced with E-glass have good durability combined with the ease of fabrication and temperature tolerance. High production rates of these polymer composites with close tolerances are made possible by plas-

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tic injection moulding (PIM). It is a common manufacturing process for reinforced plastics with precision and hence efficient usage of the PIM process becomes essential as these equipment and moulds are costly. PIM can be used to form complex profiles with good surface finish and the process involves four stages viz. melting of raw material, injecting through a nozzle, applying packing pressure and cooling the mould (Chiang & Chang, 2006). From the existing literature it was found that process parameters like melting temperature, injection pressure, injection speed, injection time, packing pressure, packing time along with the cooling temperature and cooling time play a vital role in affecting the quality of the injection moulded parts (Wu & Liang, 2005; Kuo-Ming Tsai et al., 2009). Selecting the correct injection moulding conditions was always a major concern in plastics industries. The fibre orientation in these composites was also found to play a vital role in affecting the mechanical strength of the moulded components (Sadabadi & Ghasemi, 2007). PIM was generally characterized by the presence of shrinkage phenomena but selection of proper mould temperature and packing pressure could be a solution for avoiding shrinkage and warping (Sanchez et al., 2012). It was also found that the flexural modulus of the parts was affected greatly by the mould temperature (Ozcelik et al., 2010). The quality characteristics of PIM products could be studied through the dimensional properties, the surface properties and the mechanical or optical properties (Yang & Gao, 2006). Accelerated injection rate was observed to be an utmost essential parameter while moulding ultra-thin components. Enhanced injection rates were found to bring a great increase in filling ratio (Song et al., 2007). The cooling time was also found to affect the mechanical properties of injection moulded plastics and its interaction with the packing pressure was observed to play a vital role in reducing the shrinkage (Karasu et al., 2014).

Taguchi's optimization approach involving signal to noise ratio and orthogonal arrays was an accepted methodology for improving productivity. Taguchi method was used to identify the optimal setting of input parameters for good mechanical properties, surface finish and reduced shrinkage in polymers processed by PIM (Li et al., 2007; Ozcelik, 2011). Taguchi orthogonal design was used to optimize the roughness of machined surface effectively (Das & Sahoo, 2011). However most researches based on this technique were concerned with single response optimization while a practical situation demands simultaneous optimization of multiple responses. Techniques for handling

Figure 1. Plastic injection moulding machine