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Multiobjective optimization of injection moulding process parameters using Grey Fuzzy method

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ABSTRACT – Grey fuzzy method is used to find the multiobjective optimization of injection moulding process parameters. Various responses results are calculated by GRA for getting grey relational coefficients. Then values are used as input in MATLAB software by using FIS. It is found that optimum parameters for deflection, volumetric shrinkage, and residual stress are mould temperature at level 1, melt temperature at level 3, injection time at level 1 and cooling time at level 1.

1. INTRODUCTION

Injection moulding is a high-speed moulding of plastic parts. It works by injecting molten thermoplastic into a mould cavity. The advantage of this process is it can produce complex and intricate shapes of plastic products. It well known that factors that most influence injection moulding process parameters such as packing pressure and packing time on the post-moulding shrinkage and warping of parts made from polypropylene filled with calcium carbonate.

Annicchiarico and Alcock [1], critical processing parameters in injection moulding were temperatures, the packing parameters, cooling time, and injection speed, temperatures and packing parameters. In addition, at macro scale, they found that shrinkage was decreased by increasing the critical factors.

For multiple objective optimization, several researchers have implemented grey-fuzzy method in their research. In 2014, Yeh and Tsai [2] optimized copper wire bonding process with multiple quality characteristics using a grey-fuzzy Taguchi method. Pattnaik et al. [3] stated that as the optimal condition determined for each response was different, grey-fuzzy method was used to combine individual objective functions into a single objective function.

In this study, optimization of injection moulding parameters of multiobjective such as deflection, volumetric shrinkage and residual stress can be achieved by using a grey-fuzzy Taguchi method.

2. METHODOLOGY

In previous study, Md Ali et al. [4], optimized injection moulding parameters to get the lowest deflection, volumetric shrinkage at ejection and in cavity-residual stress of family mould part by using Taguchi method. It was found that each response has different optimum parameters. By using Grey-Fuzzy Taguchi method, process parameters optimization of multiobjective can be achieved.

3. RESULT AND DISCUSSION

3.1 *Optimization using Grey Relational Analysis (GRA)*

First of all, measured value of deflection, volumetric shrinkage at ejection and in-cavity residual stress ranging from '0' to '1' are normalized. This is called as Grey relational normalization. For all responses, 'smallest is the best' quality characteristics [4] have been implemented and expressed in Equation (1).

$$x_i\ (k) = \frac{max\ y_i(k) - y_i(k)}{max\ y_i(k) - min\ y_i(k)} \quad (1)$$

Where, $x_i(k)$ is the value after the grey relational generation, min $y_i(k)$ is the smallest value of $y_i(k)$ for the kth response, and max yi(k) is the largest value of $y_i(k)$ for the *kth* response.

After that, from the normalized experimental data, the grey relational coefficient is calculated to represent the correlation between the desired and the actual experimental data. The grey relational coefficient ξ_i (k) is calculated as in Equation (2).

$$\xi_i(k) = \frac{\Delta min + \xi \Delta max}{\Delta 0_i(k) + \xi \Delta max} \quad (2)$$

Here, ξ is a distinguishing coefficient between 0 and 1 which is taken as 0.5, Δ0i(k) the difference in absolute value between y_0(k) and y_i(k), y_0(k) the ideal or reference sequence, Δmin the smallest value of Δ0i and Δmax the largest value of $\Delta 0_i$. Table 1 shows the individual grey relational coefficient values of the responses.

3.2 *Fuzzy Inference System (FIS)*

According to Vasudevan et al. [5], FIS is used to couple grey relational coefficient into single performance index called as multi performance criteria index (MPCI). In this paper, Mamdani type fuzzy system is implemented and the FIS consists of fuzzification, rules evaluation and defuzzification. The calculated MPCI together with their S/N ratio are as given in Table 2.

Table 1 Individual grey relational coefficient values of the responses.

Run	Deflection	Volumetric Shrinkage	Residual Stress
1	0.4034	1.0000	0.3333
2	0.4856	0.4798	0.5723
3	0.7011	0.3402	1.0000
4	0.3537	0.7981	0.3671
5	0.4494	0.4970	0.6253
6	1.0000	0.3333	0.7055
7	0.3333	0.7757	0.3913
8	0.5732	0.4770	0.4752
9	0.7807	0.3347	0.8710

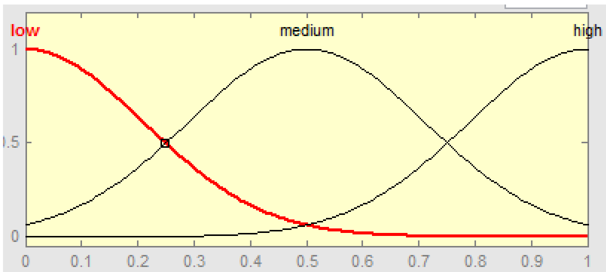

Figure 1 Membership functions of the inputs.

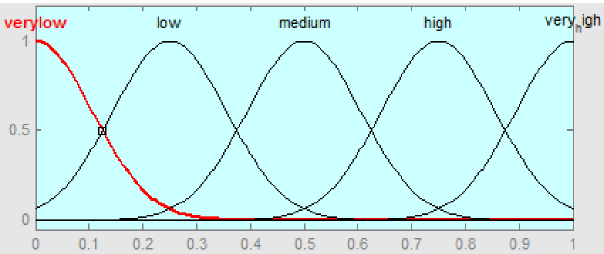

Figure 2 Membership functions of the output.

Table 2 Calculated MPCI and its S/N ratio.

Run	1	2	3	4	5	6	7	8	9
MPCI	0.61	0.52	0.66	0.56	0.53	0.66	0.54	0.51	0.61
S/N (-)	4.34	5.76	3.61	5.07	5.58	3.64	5.32	5.78	4.31

3.3 Taguchi optimization

According to Vasudevan et al. [5], the highest value of MPCI determined the optimal parameter setting. In addition, MPCI optimization was carried out using Taguchi method. By implementing higher-the-better characteristics of S/N ratio, optimal parameters combination can be determined. Table 2 shows the calculated value of MPCI and its S/N ratio.

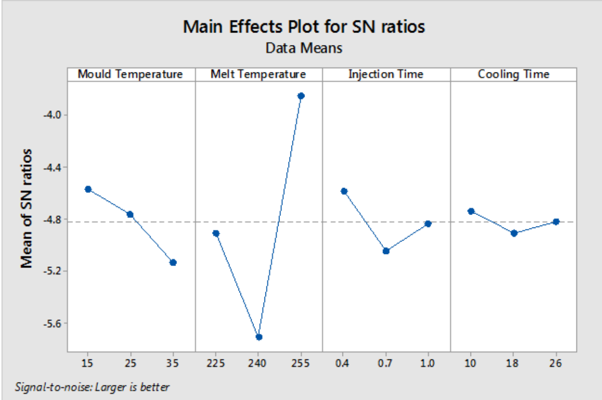

Figure 3 S/N ratio graph of MPCI.

Optimal parametric combination has been evaluated from the plot in Figure 3. The optimum parameter combinations have the highest S/N ratio value represent in the graph. It is found that the grey-fuzzy grade obtained at the optimal condition is 0.680 which is greater than all values obtained for L9 OA.

4. CONCLUSION

In this study, the process parameters optimization of multiobjective of family mould part is studied. The optimum parameter combinations are mould temperature of 15°C, melt temperature of 255°C, injection time of 0.4s and cooling time of 10s. It is found that the grey-fuzzy grade obtained at the optimal condition is 0.68 which is greater than all values obtained for L9 OA.

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