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OPTIMIZATION OF WORKING PARAMETERS OF INJECTION MOULDED RUBBER BUSH

B. Prasad Kumar[1], P. Venkataramaiah[2]
[1]Research Scholar, Department of Mechanical Engineering, S.V. University, Tirupati-517502, India.
[2]Professor, Department of Mechanical Engineering, S.V. University, Tirupati-517502, India.

ABSTRACT

Injection Moulding is a versatile manufacturing technique for forming of plastics. Present work focused on optimizing the process parameters of Nylon 66/graphite Mixer coupler Bush for better performance. Rubber bushings are effective in reducing the transmissions of shock and vibration between parts. The input parameters such as time, speed, Load which influence the performance of characteristics of Rubber Bush such as Temperature, Shear Stress, Shear Strain are studied. Experiments are conducted on jar mixer with coupler according to Taguchi's experimental design (L27) and the response values are recorded. This data is analysed and optimum levels for input put parameters are identified by using Fuzzy Logic and Genetic Algorithm.

Keywords: Mixer Rubber Bush, Nylon 66/graphite , Parameters, Temperature, Shear Stress, Shear Strain, Taguchi, Fuzzy Logic, Genetic Algorithm.

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1. Introduction

Plastic injection moulding is the most widely used components manufacturing process for a variety of reasons like cost-effectiveness, efficiency and component quality, due to this many industries choose to use injection moulded parts for their products. Injection moulding is a widely used manufacturing process for producing various components with complex shapes and precise dimensions. One such component is the mixer rubber bush, which plays a crucial role in machinery and equipment by providing cushioning, vibration isolation, and noise reduction. The injection moulding process involves injecting molten material, typically a rubber compound, into a mould cavity under high pressure. The material then cools and solidifies, taking the shape of the mould. This process allows for mass production of rubber bushes with consistent quality and dimensional accuracy. A mixer jar coupler is the base of the mixer grinder [13,14]that connects the unit to the grinding jar**.** After some time of working, the coupler mostly stops functioning. In case of grinding of frozen food items regularly at high speeds, the chances of breakage or damage of coupler, it leads to its replacement.

Chin. J. et.al [1] studied on the conformal cooling system which is applied for the production of bowl-shaped product made of PP AZ564. Optimization is done to initiate machine setup parameters such as melting temperature, injection pressure, holding pressure and holding time. The genetic algorithm method and Moldflow were used to optimize the injection process parameters at a minimum cycle.

Ramkumar Ramakrishnan1 et al. [3] investigated the effect of various injection moulding process parameters on volumetric shrinkage of a acetal polymer gear part and optimized the process parameters through Taguchi method. Further, the ANOVA method is used for determining the most significant moulding process parameter that effect volumetric shrinkage.

B Prasad Kumar et.al[8] investigated the influence of Process Parameters in Injection Moulding of PMC Cam Bush and optimize the Process parameters to improve the quality of the Cambush. The quality characterstics such as Shrinkage, Warpage and Surface Roughness are crucial in Injection Moulding as it negatively impacts the dimensional stability and accuracy of the product. The experiments are conducted according to Taguchi L27 Orthogonal Array and the response data are analysed and optimized by using GRA.

Gennaro Salvatore Ponticelli et.al [2] investigated on Combined Fuzzy and Genetic Algorithm for the Optimisation of Hybrid Composite-Polymer Joints Obtained by Two-Step Laser Joining Process.

Based on literature, in view of failures of rubber bush, present paper focussed on optimization of working parameters of mixer grinder using fuzzy logic and genetic algorithms.

2.Methodology

The injection moulding [4,9]process may seem simple, there are many parameters which need to be tightly controlled to ensure the overall quality of the plastic components produced. Understanding the process and parameters in some depth will help manufacturers to identify plastic components producers who can provide the quality and consistency they need.

A Prototype model of Mixer rubber bush (Fig.1) and Mixer grinder has taken for experimentation. Design of experiments (Taguchi's L27 OA) is developed based influential parameters and their levels as given in Table.1. The Nylon 66/graphite [10] coupler has been taken for experimentation.

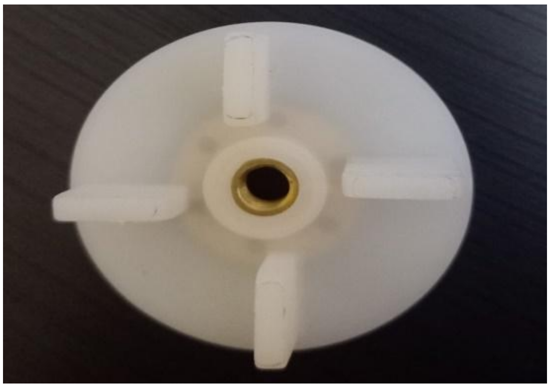

Figure.1. Mixer Rubberbush

Figure.2. Infrared pyrometer

Experiments are conducted according to the design of experiments (Table.2) and the output parameters (Table 3) are known as Temperature, which is measured using Infrared pyrometer (Fig.2) and Shear stress (Fig.3.a), Shear strain (Fig.3.b) are found on ANSYS software.

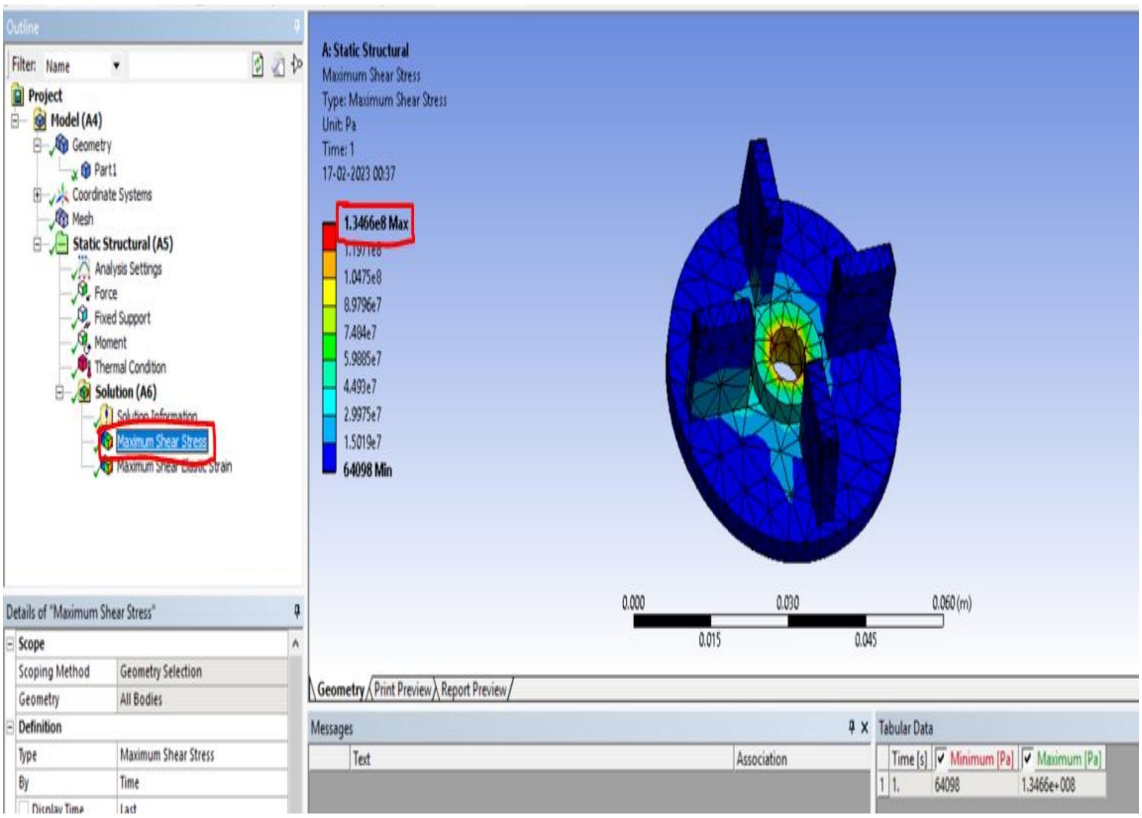

Figure.3.a Shear stress

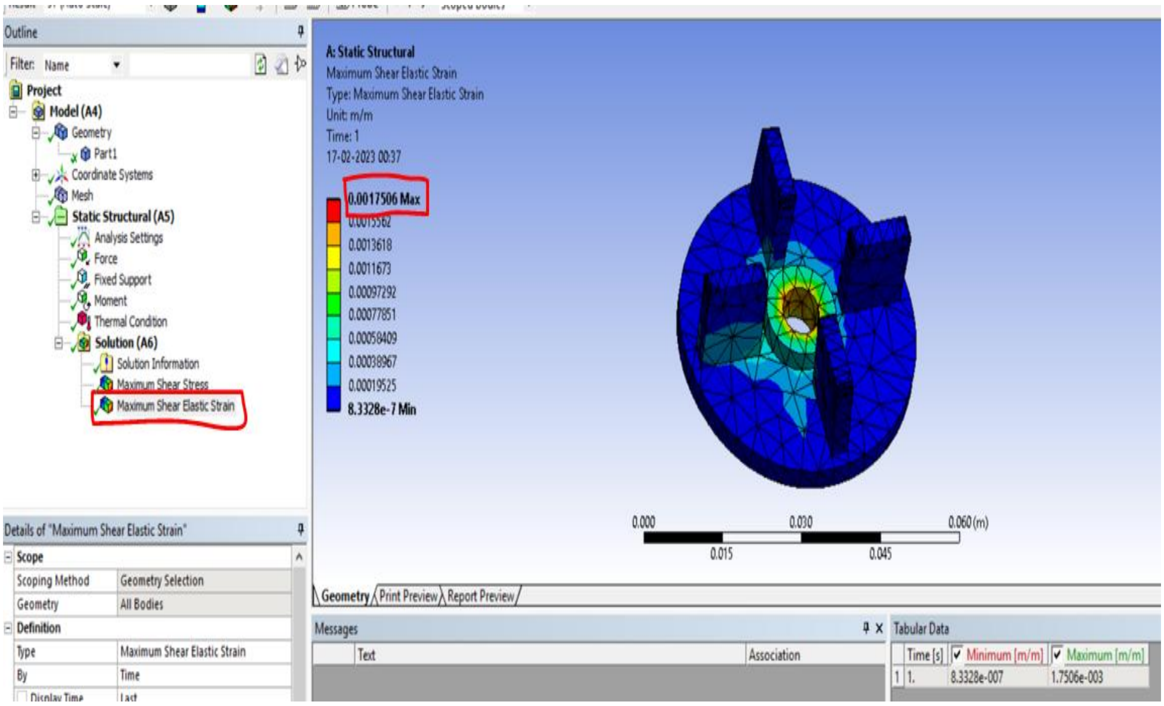

Figure.3.b Shear strain

Table 1. Influential parameters and their levels

Sl. No	Influential factors	Level-1	Level-2	Level-3
1	Time (min)	1	1.5	2
2	Speed (rpm)	2	4	6
3	Load (grm)	50	100	150

Table 2. Experimental Design

Sl. No	Time (Min)	Speed (Rpm)	Load (gm)
1	1	2	50
2	1	2	100
3	1	2	150
4	1	4	50
5	1	4	100
6	1	4	150
7	1	6	50
8	1	6	100
9	1	6	150
10	1.5	2	50
11	1.5	2	100
12	1.5	2	150
13	1.5	4	50
14	1.5	4	100
15	1.5	4	150
16	1.5	6	50
17	1.5	6	100
18	1.5	6	150
19	2	2	50
20	2	2	100
21	2	2	150
22	2	4	50
23	2	4	100
24	2	4	150
25	2	6	50
26	2	6	100
27	2	6	150

Table 3. Experimental Results

Sl.No	Temperature (°C)	Shear stress (MPa)	Shear strain
1	35	56.2	0.0007316
2	37	60.9	0.0007929
3	39.4	70.6	0.0009180
4	40.5	63.3	0.0008233
5	43.5	71.7	0.0009330
6	45.9	79.2	0.0010298
7	47.4	110.3	0.0014344
8	50.3	124.5	0.0016196
9	52.6	136.4	0.0017736
10	43.1	56.1	0.0007303
11	44.8	60.9	0.0007918
12	46.7	66.1	0.0008600
13	49.5	71.1	0.0009251
14	53.1	80.3	0.0010445
15	55.9	87.6	0.0011392
16	58.2	101.6	0.0013218
17	61.6	111.9	0.0014547
18	64.9	122.1	0.0015875
19	55.4	83.9	0.0010907
20	57.1	88.3	0.0011490
21	59.3	88.8	0.0011544
22	63.6	103.7	0.0013482
23	67.4	113.2	0.0014722
24	69.7	119.1	0.0015491
25	71.1	125.3	0.0016297
26	72.9	130.6	0.0016979
27	74.2	134.6	0.0017506

3.Optimization of parameters using Fuzzy Logic method

Using Fuzzy logic[5], the test results are analysed and optimum influential factor combination is identified as in the following.

3.1 Calculating S/N ratios for experimental results

For different data sequences, the data is normalized and it depends upon the type of the response, whether it is to be minimized or maximized or a normal value (smaller the better or larger the better or nominal the better). In the present work, the “lower is better” characteristic is applicable for Temperature, Shear stress, Shear strain, because these are to be minimized and hence S/N values are calculated and values are recorded (Table 4).

3.2 Determination of the Comprehensive Output Measure using fuzzy logic

The fuzzy logic unit consist a fuzzifier, membership functions, a fuzzy rule base, an inference engine and a defuzzifier. In the fuzzy logic analysis, the fuzzifier uses membership functions to fuzzify the normalized values first. Next, the inference engine performs a fuzzy reasoning on fuzzy rules to generate a fuzzy value. Finally, the defuzzifier converts the fuzzy value into a Comprehensive Output Measure (COM). The structure built for this study is three input-one-output fuzzy logic unit as shown in Fig.4. The input variables of the fuzzy logic system in this study are the S/N ratios of responses: Temperature, Shear stress, Shear strain. They are converted into linguistic fuzzy subsets using membership functions of the triangle form, as shown in Fig.5. and uniformly assigned into three fuzzy subsets Low(L), Medium(M), High(H). The output variable of this analysis is the comprehensive output measure (COM). The output variable is assigned into relatively six subsets i.e, very low (VL), low (L), medium (M), medium high (MH), high (H), very high (VH) grade. Then, considering the conformity of three for input variables, 27 fuzzy rules (Fig.6) are defined. In this analysis, the max-min compositional operation of Mamdani is adopted to perform evaluation of COM (Fig.7).

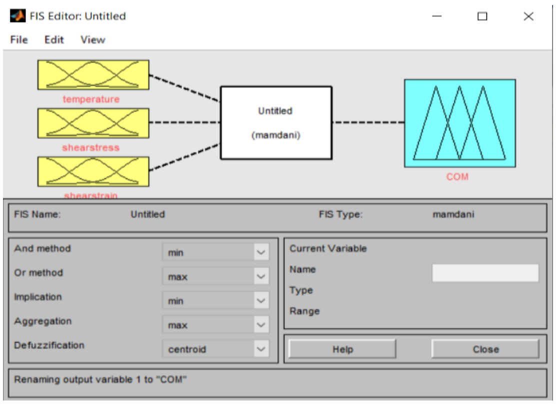

Fig.4 Three input-one-output fuzzy logic unit

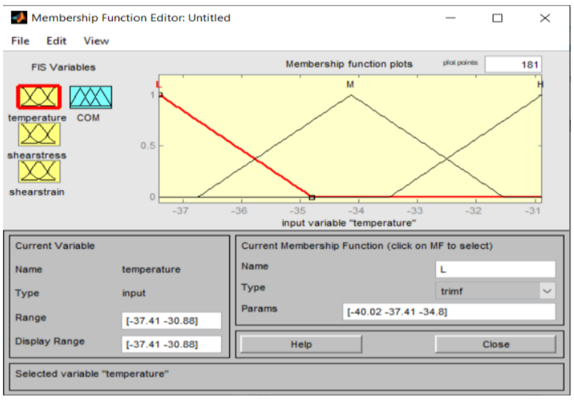

Fig.5(a).Membership functions of inputs

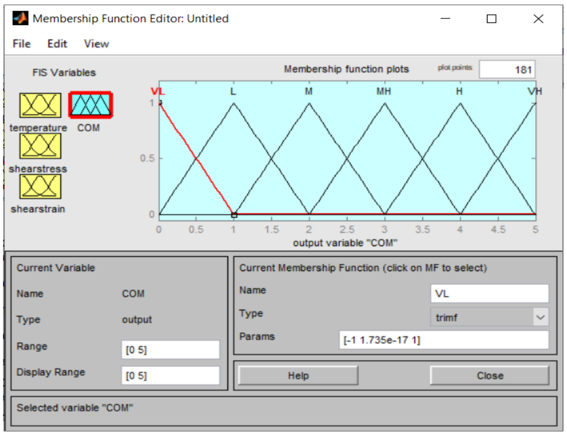

Fig.5(b) Membership functions of COM

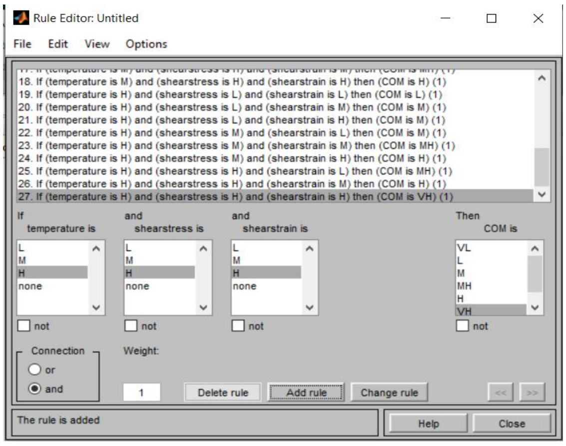

Fig.6. Fuzzy rules

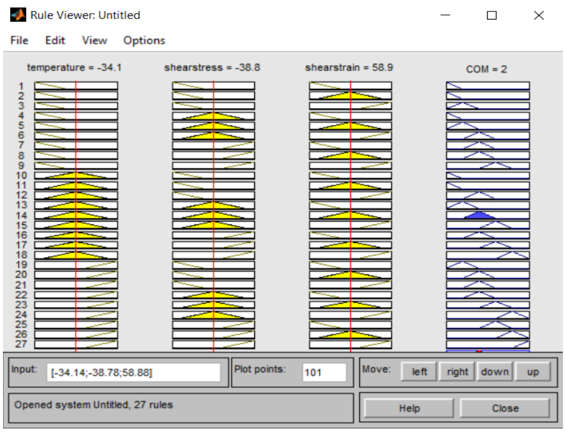

Fig.7. Evaluation of COM

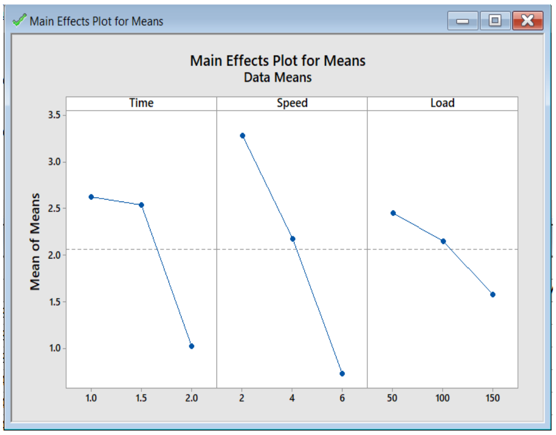

Fig.8.COM for each parameter at each level

Table 4. S/N Ratios and COM values

Exp. no	S/N Ratios			COM
	Temperature	Shear stress	Shear strain	
1	-30.8814	-34.9947	62.7148	4.68
2	-31.3640	-35.6923	62.0162	4.67
3	-31.9099	-36.9761	60.7434	3.32
4	-32.1491	-36.0281	61.6890	3.76
5	-32.7698	-37.1104	60.6020	2.93
6	-33.2363	-37.9745	59.7449	2.22
7	-33.5156	-40.8515	56.8666	1.35
8	-34.0314	-41.9034	55.8118	0.337
9	-34.4197	-42.6963	55.0229	0.322
10	-32.6895	-34.9793	62.7302	4.07
11	-33.0256	-35.6923	62.0271	4.02
12	-33.3863	-36.4040	61.3096	3.33
13	-33.8921	-37.0374	60.6763	2.91
14	-34.5019	-38.0943	59.6218	3.0
15	-34.9482	-38.8501	58.8680	1.91

16	-35.2985	-40.1379	57.5767	1.69
17	-35.7916	-40.9766	56.7445	1.33
18	-36.2449	-41.7343	55.9857	0.559
19	-34.8702	-38.4752	59.2459	1.96
20	-35.1327	-38.9192	58.7936	1.81
21	-35.4611	-38.9683	58.7529	1.65
22	-36.0691	-40.3156	57.4049	1.31
23	-36.5732	-41.0769	56.6407	0.949
24	-36.8647	-41.5182	56.1984	0.556
25	-37.0374	-41.9590	55.7578	0.335
26	-37.2546	-42.3189	55.4018	0.323
27	-37.4081	-42.5809	55.1363	0.318

3.3 Identification of the optimal combination of influential factors

The COM values are calculated for each factor at each level (Table 5) and the optimal level for each factor is identified based on their COM values. The optimal level of most influential factor is the highest COM value among their considered levels. From the analysis (Fig.8.), the best combination of parameters is: T3 S3 L3, **it** means

T3 :Time at level 3 (2 min)

S3 :Speed at level 3 (6 rpm)

L3 :Load at level 3 (150 grms)

Hence, the best optimal input parameters are Time (T3), Speed (S3), Load (L3).

Table.5 COM for each parameter at each level

Level	Time	Speed	Load
1	2.6210	3.2789	2.4517
2	2.5354	2.1717	2.1521
3	1.0234	0.7293	1.5761
Delta	1.5976	2.5496	0.8756
Rank	2	1	3

From the analysis(Table.5), it is revealed the speed is most significant factor follows time and load

4. Genetic Algorithm:

For further refinement of solution, the output data of fuggy logic (COM) is processed with Genetic algorithm[6,7]. The objective function is obtained by giving weightage for each individual objective function of responses, and is as follows.

$$F(x) = w_1 f_1 + w_2 f_2 + \dots \dots\dots + w_n f_n$$

Where

w_k = is the weighting factor of individual response function,

f_k = is objective function for response k

n = is no.of responses(n=1)

In the present work, weighting factor of 1 for each of the responses is considered, which gives equal priorities for all responses to simultaneous minimization objective function. Each input parameter has upper bound and lower bound. A regression equation is developed for COM data(Table.4) which is taken as objective function(Y). The constraints(Eq 2.1,2.2,2.3) are formed by these bound values and the objective function(Eq.1) is subjected to these constraints. Regression equation is solved under constraints using GA tool of Matlab software, as shown in Figure.9

Minimize Y= F(x) -------(1)

(COM)^0.5 = 3.477 - 0.555 Time – 0.2445 Speed – 0.00331 Load**:**

Subject to

Time(x1)	:	$1 \leq T \leq 2$	(2.1)
Speed(x2)	:	$2 \leq S \leq 6$	(2.2)
Load(x3)	:	$50 \leq L \leq 150$	(2.3)

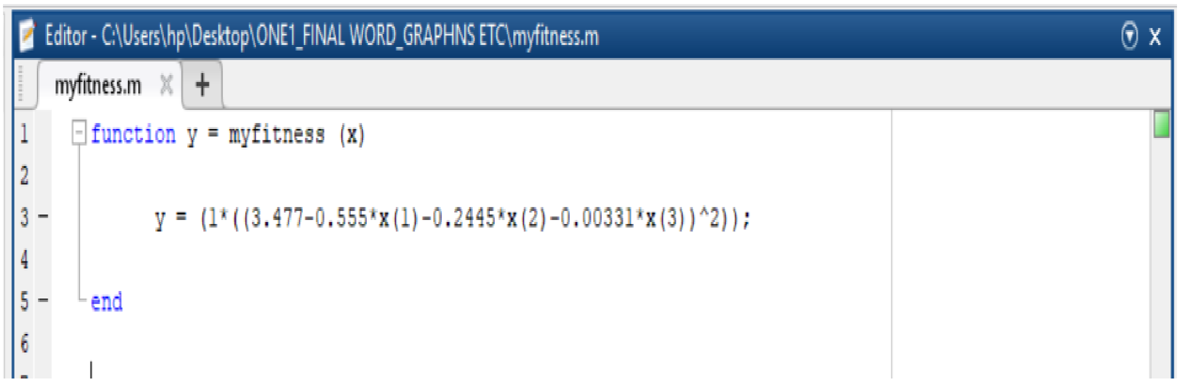

Figure.9 Matalb code

```
function y = rubberbush(x)                                    y =
(1*((3.477-0.555*x(1)-0.2445*x(2)-0.00331*x(3))^2));
        end
```

By selecting the Fitness function and enter the number of variables and bounds. Afterwards, select the population size, crossover and pareto graph, rank histogram, Distance, Distance of individuals, Average spread etc., check the final optimization value (Fig.10)

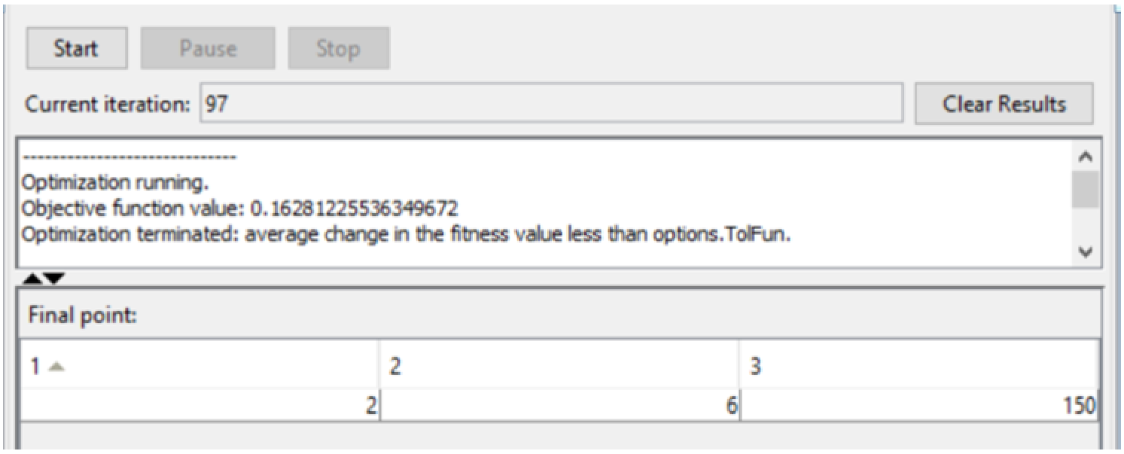

Fig 10. Objective function value and optimum parameters

Selecting best influencing parameters, the optimum solution(Fig 10) is obtained from GA: optimal influencial factor combination is T3, S3, L3, which is same as obtained from Fuggy logic.

T3: Time at level 3 (2 min)

S3: Speed at level 3 (6 rpm)

L3: Load at level 3 (150 gr)

A conformation experiment is conducted at above optimal levels of working conditions which gives lower temperature of 36^{0} centigrade in grinder.

5. Conclusion

In this work, performance of injection moulded Mixer rubber bush is analysed by varying input parameters time, speed, load. The responses of temperature, shear stress, shear strain are studied successfully. This methodology is more useful for evaluation of working parameters of grinder. The optimum parameters that can give better results are identified and the following conclusions are derived from the analysis.

- The S/N ratio values for temperature, shear stress and shear strain are given as input to the fuzzy system, and corresponding COM values are calculated. Based on COM, the optimal level for each parameter Time at level 3 (2), Speed at level 3(6), Load at level 3(150) are identified.
- The regression equation of COM data is solved using genetic algorithm, the obtained optimum parameters are Time at level 3(2), Speed at level 3(6), Load at level 3(150). It is observed that genetic algorithm gave same results as by Fuzzy logic, revealed that fine solution is obtained from Fuzzy logic without need of further process.

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