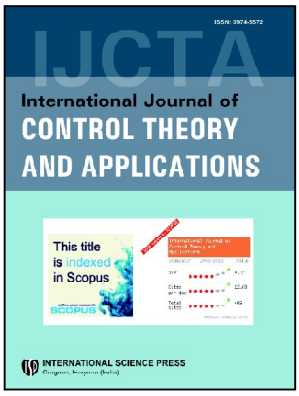

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Acceptance of Quality Characteristics using Fuzzy Inference System

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***Abstract*:** Quality is a significant criterion which customers expect at the end of any product that they purchase. If the product does not function up to the intended period, then the producer will not get any more orders again. Within the shop floor, at each process step, the quality of the component must be ensured. This can be done by online inspection. Mostly it is done by the operator. The online inspection is a difficult task as it depends on equipment as well as the inspector. Quality inspection is critical to any product check, it is difficult to check almost all the quality characteristics of a product 100% within the given time, without compromising the delivery due date. So, this can be overcome by using Fuzzy logic. Fuzzy logic helps to overcome the uncertainty and vagueness of data. In this work, a fuzzy inference system is used in accepting the quality characteristics of a SG Iron, they are dimensional accuracy of a drilled hole, surface roughness and Material removal rate. The result of simulation using MATLAB gives the considerable reduction in inspection time and helps to find the acceptance range very quickly.

Keywords: Quality characteristics, Acceptance level, Fuzzy inference system

1. INTRODUCTION

The customers seek that their product should have the quality as expected. If the product does not meet their expected level, then there won't be any further business with the manufacturer again. In the machine tool industry, sophisticated, highly advanced and rapid machines have improved the metal removing operations with higher accuracy and tolerances. This could lead to better results. But it is also required to ensure the quality of the machined component at the end of machining with precise measuring devices. Even highly accurate measuring devices are prone positional errors. When go for 100% inspection, these errors could affect the inspection. It is not possible for the machine tool operator to inspect every workpiece 100%, so, there is a chance of misconception to occur which may cause some defective products to be permitted for the next stage of production and so on.

2. LITERATURE REVIEW

Machining is a process of removing material from the work piece. The purpose of machining is to bring the material into required shape and size as prescribed by the customer. Machining can be classified into several operations such as turning, milling, drilling and shaping etc. Drilling is a machining process used to make hole

of required dimensions. Drilling a hole in the work piece helps to fit the shaft in it. Making hole to the required dimension is a critical process. It involves various factors like speed, feed, depth of cut, flank radius and flank angle, cutting fluid etc. These parameters are optimized by using design of experiments to bring the required parameters setting to drill a hole of required dimensions. Dimensional accuracy of the hole diameter is a quality characteristic depends upon the machining parameters.

Similarly, Surface roughness and material removal rate are the quality characteristics which customers preferred along with the dimensional accuracy of a drilled hole. Surface roughness is a component of surface texture having peaks and valleys at the micro level. It can be seen using a surface roughness comparator. It is a desirable output in any machining process. Material removal rate the volume of material removed/min and it depends on input parameters like speed, feed and depth of cut. Smith, William F. *et. al.* [1] explained that the Spheroidal Grey Cast iron (S.G Iron) is a type of Cast iron in which the graphites in the form of nodules rather than flakes. Rounded nodules create crack which gives ductility. It has much more impact and fatigue resistance due the presence of graphite in it. The chemical compositions of S.G iron apart from iron as it contains major shares of iron are as follows.

Table 1
Showing the chemical composition of S. G iron

Elements	*C*	*Si*	*Mn*	*Mg*	*P*	*S*	*Cu*
Min %	3.2	2.2	0.1	0.03	0.005	0.005	<0.4
Max %	3.6	2.8	0.2	0.04	0.04	0.02	

Debanshu Bhattacharya[2] clarified the % of sulphur improves the machinability of steel.

S.V. Alagarsamy *et al.* [3] had conducted an experiment on Aluminium alloy 7075 for measuring surface roughness and material removal rate in drilling process. In this work, the considered machining process parameters were Speed, Feed and Depth of Cut of the drill. The Taguchi's experimental design and Analysis of Variance (ANOVA) techniques have been developed to understand the effects, contribution, significant and optimal machine settings of process parameters namely, spindle speed, feed rate and depth of cut.

H. Prakash [4] found that the drilling of SG Iron components produced using the drilling process has high rejection, because of surface roughness in drilled hole. This was observed when the Taguchi method is used to find the effects of cutting parameters on the surface finish in the drilling process of SG Iron. It Shows that the type of shank, Feed rate, Cutting speed, Drill tool, Spindle speed and Type of coolant affect the surface finish for the drilling of SG Iron. Statistical Results revealed that Type of shank, Feed rate, Cutting speed, Drill tool, Spindle speed and Type of coolant affect the surface finish by 44%, 41.64%, 5.24%, 8.94%, 1.32%, and 14.3% for the drilling of SG Iron.

3. QUALITY INSPECTION

Quality inspection is a post-production check of products. It doesn't have direct impact on production process [5]. Inspecting the quality of a machined component is critical to permit the component to pass through the next operation. It involves visual inspection and inspection using measuring devices. The instruments must be calibrated to test the quality of the component. Mostly, 100% inspection is carried out after machining a component. But it is cumbersome process for the operator to do both testing as well as machining. So, it could lead to errors in measuring of dimensions. The quality characteristics are the factors representing the quality of a component. Some operations required to check more number of quality characteristics. So, it is required to check all of them to ensure the quality of the machining operation.

In this work, S.G iron is drilled in a case study industry, which was tested for three quality characteristics namely dimensional accuracy of hole diameter, surface roughness and material removal rate. But it was found that the acceptance of a component is mainly depending on the experience of the operator. Roughly speaking, the acceptance level of a drilled component is vague and uncertain in nature. It brings the scope for fuzzy inference system.

Table 2
Showing the machining parameters and quality characteristics of S.G iron

Material	S.G.Iron
Tool	Carbide
Feed rate in	110 mm/min
Cutting speed	60 m/min
Spindle speed	910 rpm
Surface Roughness	7.70 +/- 0.1 μm
Material removal rate	250 +/-10 cm^3/min
Hole diameter Dimensional accuracy	15 +/-0.5 mm

4. FUZZY LOGIC

Fuzzy logic is derived from fuzzy set theory based on reasoning that is approximate rather than precisely deduced from classical predicate logic. It was first presented by Lotfi Zadeh in 1965 at the University of California, Berkeley. Fuzzy set theory has been used to model systems that are hard to define precisely. As a methodology, fuzzy set theory incorporates imprecision and subjectivity into the model formulation and solution process.

5. FUZZY LOGIC METHOD

The three steps involved in fuzzy logic are as follows [6].

1. Selection of appropriate family of membership function.
2. Interview with humans familiar with the target system.
3. Refining the parameters of membership function using regression and optimization techniques.

6. FUZZY INFERENCE SYSTEM

It is a system used to map the inputs with output. This can be of conditional type. For instance, If dimensional accuracy is poor, surface roughness is low and material removal rate is low then acceptance level is very low.

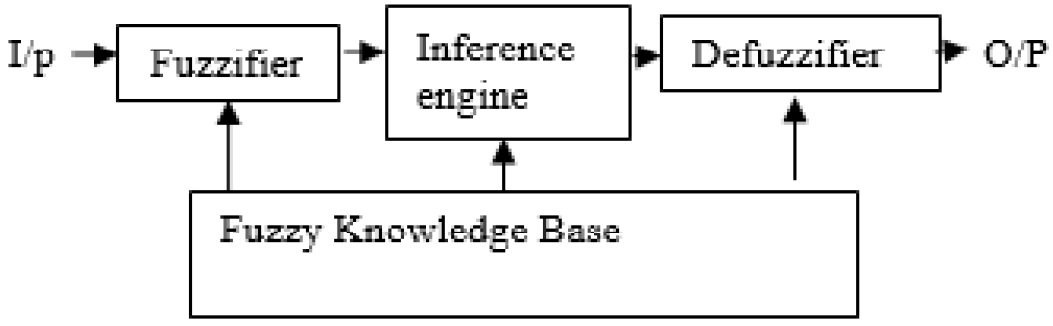

Figure 1: Showing the architecture of Fuzzy inference system

Both input and output values are crisp values. The fuzzy inference system takes an input in the form of crisp value, converts it into a fuzzy form and then a defuzzifier called centroid method is used to produce the output in the form of crisp value, in MATLAB. Mamdani inference system is used here to find the different resultant parameters. The selected membership function is Gaussian in nature for both input and output variables.

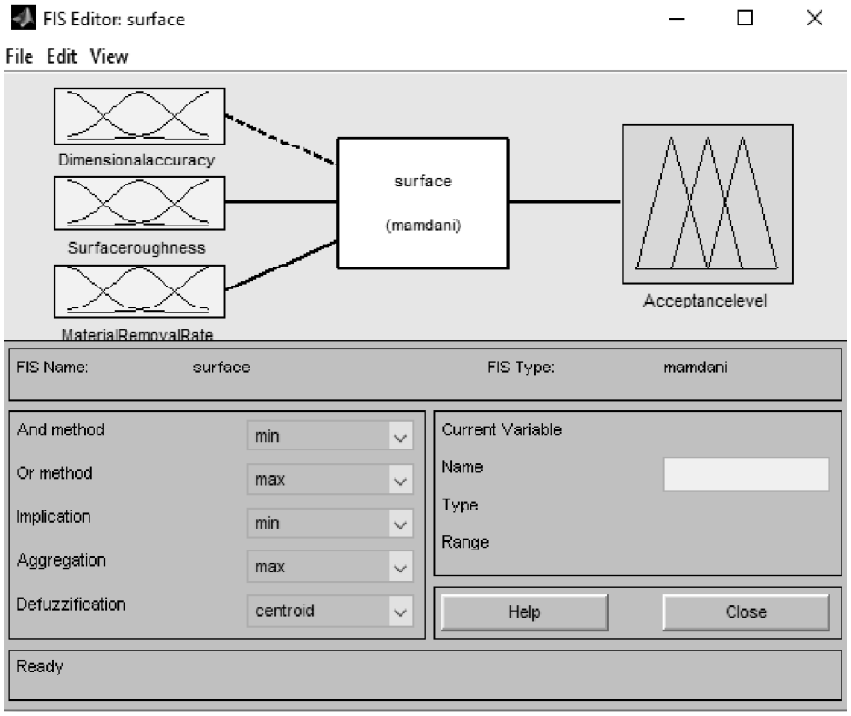

Figure 2: Showing the fuzzy inference system

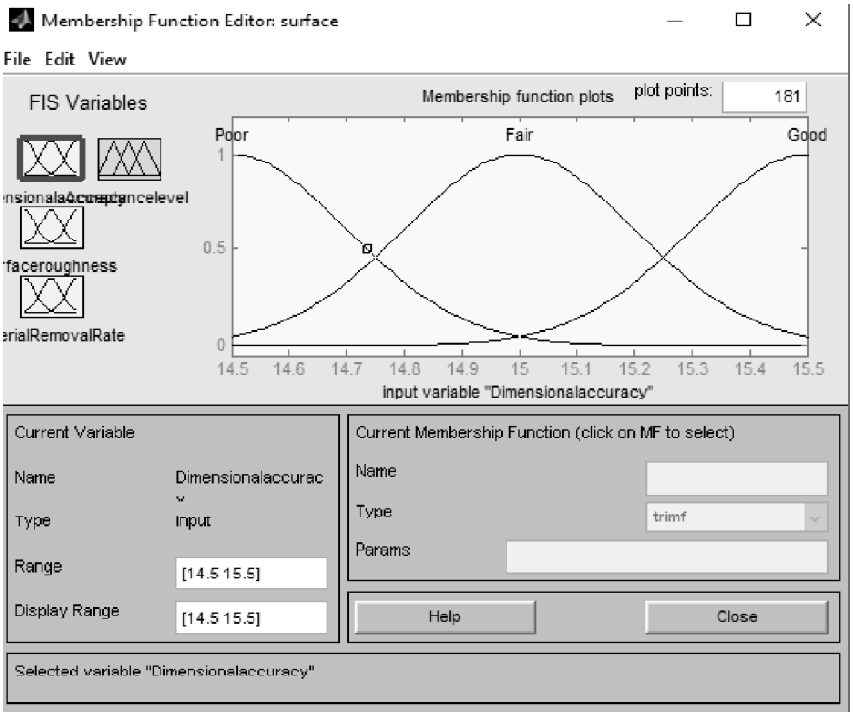

Figure 3: Showing membership function of Dimensional accuracy

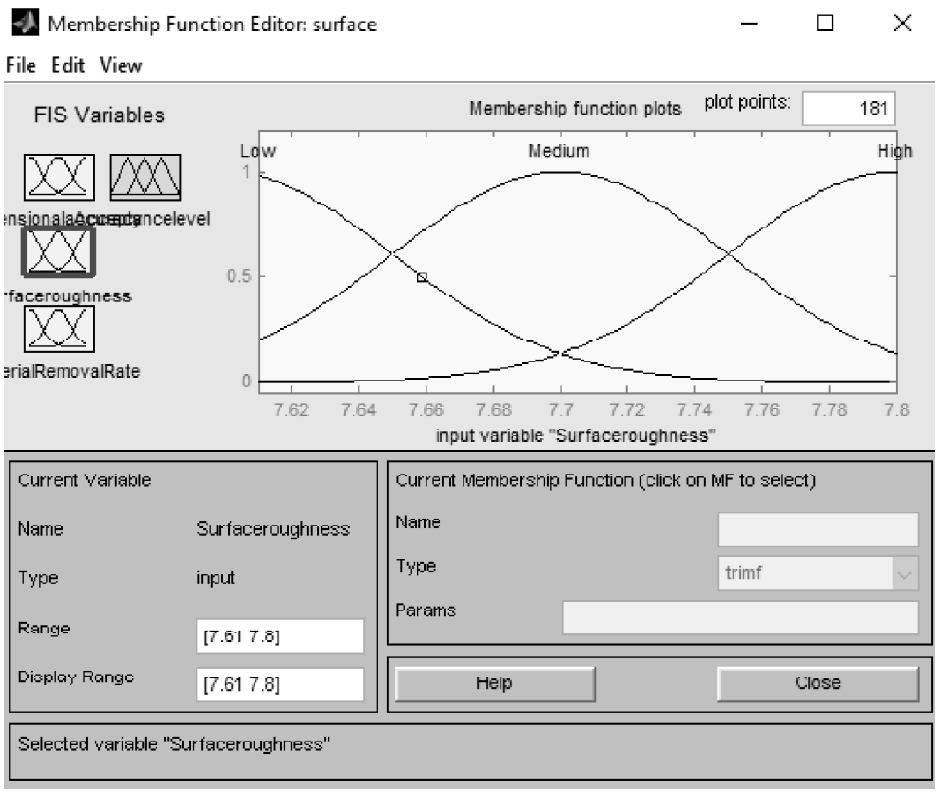

Figure 4: Showing membership function of Surface roughness

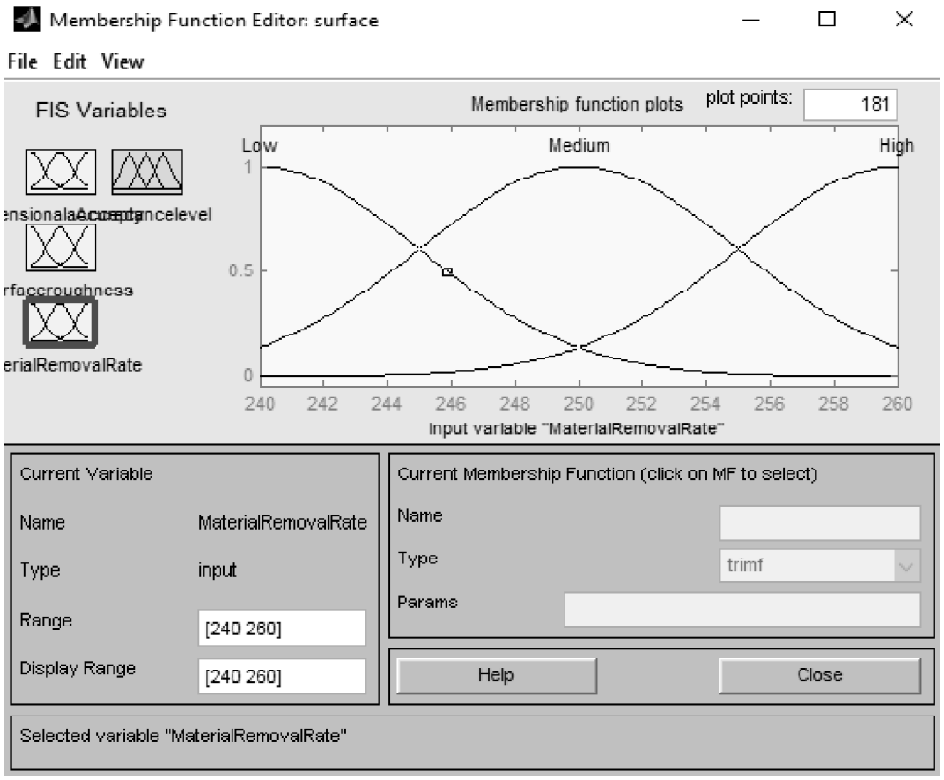

Figure 5: Showing membership function of material removal rate.

Figure 3 to figure 5 represent the member ship function values and ranges for the quality characteristics in membership function editor of MATLAB.

Table 3
Showing the linguistic variables of quality characteristics

Quality Characteristics	*Linguistic variables*	*Range*
Dimensional accuracy (Input variable)	Poor	14.5-15
	Fair	15-15.5
	Good	<15.5
Surface roughness (Input variable)	Low	7.6-7.7
	Medium	7.7-7.8
	High	<7.8
Material removal rate (Input variable)	Low	240-250
	Medium	250-260
	High	<260
Acceptance level (Output variable)	Very Low	0-20%
	Low	20-40%
	Medium	40-60%
	High	60-80%
	Very High	80-100%

7. FUZZY IF THEN RULES

The Rules for Acceptance level depends on input variables such as dimensional accuracy, surface roughness and material removal rate. The three input variables having 3 linguistic variables each made, 27 if then rules. By using the expert opinion who involved in inspecting the quality characteristics helped us to frame the rules for fuzzy inference system.

Table 4
Showing the Fuzzy If then rules

Dimensional accuracy	*Surface roughness*	*Material removal rate*	*Acceptance level*
Poor	Low	Low	Very low
Poor	Medium	Low	Very low
Poor	High	Low	Low
Fair	Low	Low	Low
Fair	Medium	Low	Medium
Fair	High	Low	Medium
Good	Low	Low	Low
Good	Medium	Low	Medium
Good	High	Low	High
Poor	Low	Medium	Low
Poor	Medium	Medium	Low
Poor	High	Medium	Medium
Fair	Low	Medium	Medium

contd. table 4

Dimensional accuracy	*Surface roughness*	*Material removal rate*	*Acceptance level*
Fair	Medium	Medium	Medium
Fair	High	Medium	High
Good	Low	Medium	Medium
Good	Medium	Medium	Medium
Good	High	Medium	High
Poor	Low	High	Low
Poor	Medium	High	Medium
Poor	High	High	Medium
Fair	Low	High	Medium
Fair	Medium	High	High
Fair	High	High	Very High
Good	Low	High	Medium
Good	Medium	High	High
Good	High	High	Very high

8. FUZZY IN ACCEPTANCE QUALITY LEVEL

Acceptance sampling is a sampling method for acceptance or rejection of part based on quality characteristics. Though classical acceptance sampling plan was studied by numerous researchers, the application of the classical method has some vagueness. Vagueness in decision making can be overcome using Fuzzy systems.

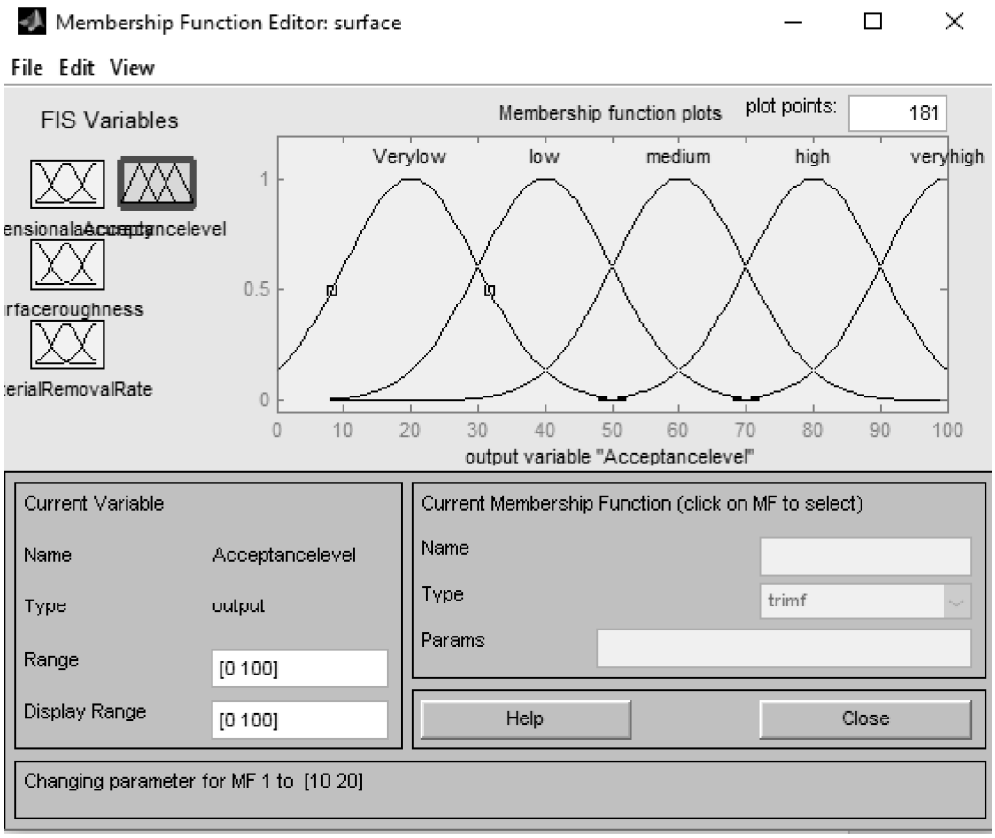

Figure 6: Showing the membership function of output variable, acceptance level

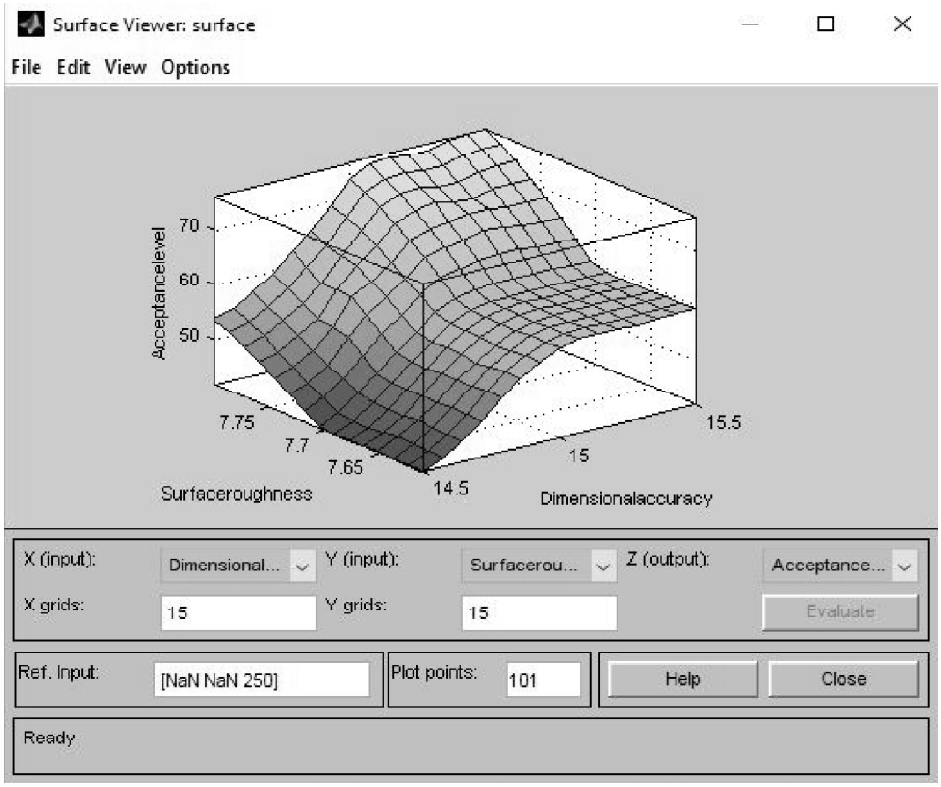

Figure 7: Showing the 3D plots of quality check in surface viewer

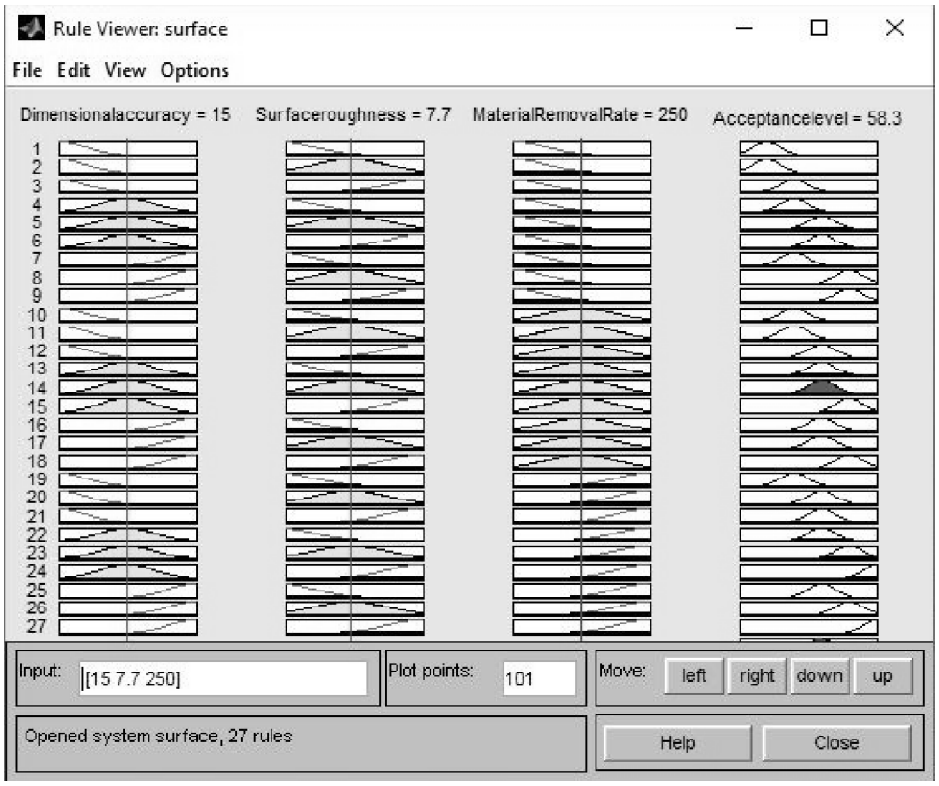

Figure 8: Showing the rule viewer on Quality check

Acceptance quality level depends upon accepting a component which meets the quality standards. The fuzzy logic concepts were also considered for accepting the quality characteristics. Ohta and Ichihashi [7] present a fuzzy design methodology for single stage, two-point attribute sampling plans. Chakraborty [8] investigates the problem of imprecision exists in finding the sample size and critical value of a single sample attribute sampling plan during the declaration of producer and consumer risk. Ezzatallah Baloui Jamkhaneh et.al. [9] studied the application of fuzzy parameter using Poisson distribution. Grzegorzewski [10] investigated the sampling plan by variables with fuzzy requirements.

9. RESULTS AND DISCUSSION

In this work, the quality characteristics such as dimensional accuracy, surface roughness and material removal rate were taken as input variables in accepting the quality of a drilled hole. Instead of depending upon the experience of the quality inspector, a fuzzy logic based system was developed. In the case study industry, accepting a quality of hole is very crucial, so it is necessary to adopt a system which works better than the existing one. Surface viewer of figure 7 showed the 3D plots of the input and output variables. Rule viewer of figure 8. Showed the level of input and output variables. If the dimensional accuracy = 15mm, surface roughness = 7.70 µm and Material removal rate = 250cm3/min, then the acceptance level becomes 58.3%. This value lies between 40-60%.whose linguistic variable is Medium. It means, the component acceptance level is medium.

The minimum permissible level of acceptance is 50%. and this is the requirement of the customer who orders the drilled hole in the S.G Iron, having quality characteristics close to the mean values. The acceptance level increases as the quality characteristics move to higher level of tolerances.

CONCLUSION

Quality of a machined component depends upon the material properties and machining parameters. It is vital to check the component after every process steps in online inspection. It is carried out by the operator himself. Quality characteristics are inspected using measuring devices for acceptance. If the values of quality characteristics are not coming within the permissible level, it is rejected as scrap or reworked. By using fuzzy logic, the quality characteristics can be checked for accepting the machined component. Simulation using MATLAB yields good results for finding the level of acceptance within the given period.

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