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FUZZY SET THEORY APPROACH TO MODEL SUPER ABRASIVE GRINDING PROCESS USING WEIGHTED COMPENSATORY OPERATOR

Bhagwan Kumar Mishra [1], Baidyanath Yadav [2], S.K.Jha [3] and A.P.Burnwal [4]

[1 2 3] *Department of Production Engineering, B.I.T. Sindri, Dhanbad-828123, Jharkhand, India,*
[1] *bhkmishra.me@gmail.com*, [2] *baidyanathoec@gmail.com*, [3] *skjha63@rediffmail.com*
[4] *Department. of Mathematics, GGSESTC, Bokaro-827013, Jharkhand, India, apburnwal@yahoo.com*

Abstract: - This paper deals with application of fuzzy set theory in grinding process as various parameters such as cross sectional area, density, speed are not defined precisely. Decision maker may use the weighted compensatory operator to model the super abrasive grinding problem and a better solution decided by him is obtained by interactive approach also.

Keywords: Grinding parameter, Fuzzy set theory weighted compensatory operator, threshold value.

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1. Introduction

Of all the machining process, grinding is undoubtedly the least understood and the most involved in practice. The complexity of grinding process is due to its complex tooling structure, high cutting speeds, and small depth of cut that varies from grain to grain. Grinding is a chip removal process in which the cutting tool is an individual abrasive grain. Chip formation during grinding process consists of three stage, sliding stage ploughing stage and cutting or chip formation stage. This basis types of operations-surface, cylindrical, internal, and canter less grinding. The relative movement of the wheel may be along the surface of the work piece (traverse grinding, through feed grinding, cross-feeding), or it may be radially into the work piece (plunge grinding). Fuzzy logic ([1], [2]) is a part of artificial intelligence. It is based on the theory of fuzzy sets, where an objects membership of a set is continuing rather than just member or not a member. Fuzzy logic uses the whole interval of real numbers between zero (false) and one (true) to develop logic as a basis for rules of inference. Particularly the fuzzified version of the modus ponens rule of inference enables computers to make decisions using fuzzy reasoning rather than exact. Fuzzy logic has great capability to capture human common sense reasoning, decision making and other aspects of human cognition. It can be performed in hardware or software or by combination of both oh them. Medicine was one of the first field in which it was applied. Many Authors [3], [4], [5], [6]& [7] used fuzzy logic in different fields. M.Saleem et al. [8] deals with a time control grinding and mixing system as a fuzzy time control discrete model. The system consists of four controlled variables measurement through its sensing mechanism for feed- back control. Y.M. Ali et al [9] deal with a three-layer fuzzy model to correlate variables used in surface roughness fuzzy rules based on experimental observations from wheel manufacturers. Faran Baig et al. [10] deals with the designing and simulation of fuzzy logic based elid grinding control system .This work provide useful information and predicted data to develop fuzzy logic based control system for enhancement of the surface quality and MRR in real time application. A.Di Illio et al [11] developed a relationships for modelling force components, cutting energy and work piece surface roughness in grinding of metal matrix composites, are proposed. To develop a experimental data obtained from test carried out on a horizontal surface grinder are employed. Ahmad A.D.Shrhan et al. [12] developed a fuzzy logic model to predict the surface roughness of a machined surface in glass milling operation using CBN grinding tool. Four membership functions are allocated to be connected each input of the model. The result demonstrated settlement between the fuzzy model experimental results with the 93.103% accuracy. P. M. Jones et al.[13] This project work describes the application of two multi-objective optimization techniques to the high efficiency deep grinding process. The paper concerns the high efficiency deep grinding process. The objectives are simultaneously minimized the surface temperature and specific grinding energy. Mandeep Ravish et al. [14] this project work deals with the modelling and simultaneous optimization of multiple performance characteristics such as material removal rate and surface roughness of hard and tough materials using the fuzzy logic and taguchi's quality loss function has been done. K. Wegener et al [15] dealt with description and monitoring of the abrasive layer. For optimization of the dressing process, prediction of the grinding wheel topography and the ground surface are emerging scientific topics.

2. Design algorithm

This system is designed for four fuzzy input variables whose membership functions are shown in Table 1:

Membership Function-MF	**Cross sectional area (in m^2)**	**Density (in Kg/m^3)**	**speed (revo/sec)**	**Item selection norm (in % of total)**
Low	0-30	0-30	0-30	0-30
Medium	30-60	30-60	30-60	30-60
High	60-90	60-90	60-90	60-90

We have a different value of feed rate according to the given select item scheme shown in Table 2, considering different value of feed rate for materials

The crisp value output of feed rate selection defuzzifier is converted into digital signal using analog to digital converter ADC and decoded for the selection of specific feed rate.

Table 2: Feed rate selection

Linguistic variable	**Range**	**Level**
Low	0-30%	F_1
Medium	30-60%	F_2
High	0-90%	F_3

The plots of membership functions for each input fuzzy variable are shown in figure.1(a), 1(b), 1(c)& 1(d) are given below

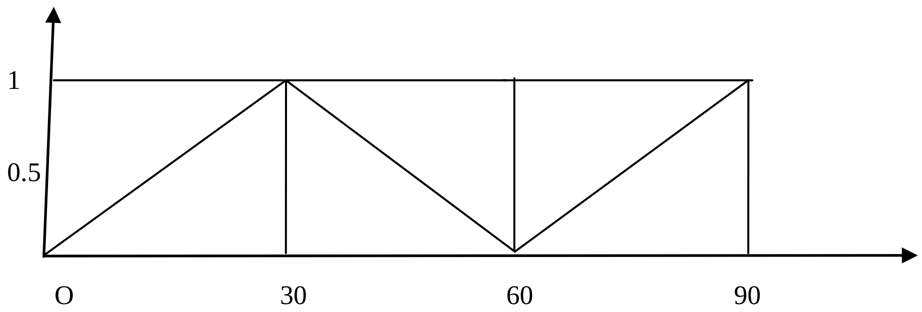


Fig.1 (a) Membership Function vs. crosses sectional area.

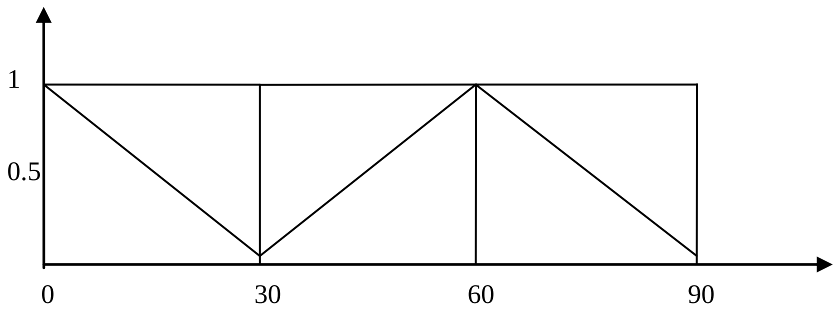


Fig. 1 (b) Membership Function vs. Density

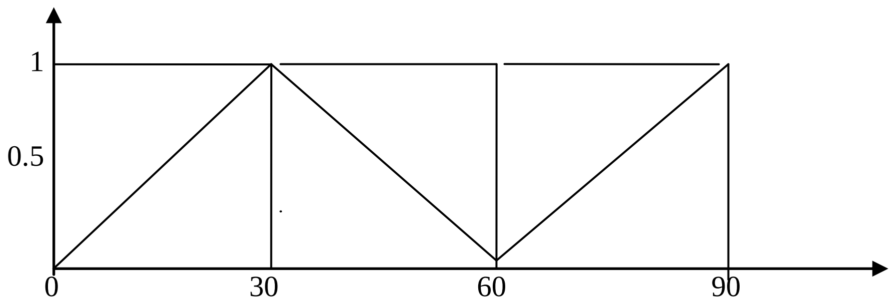


Fig. 1 (c) Membership Function vs. speed

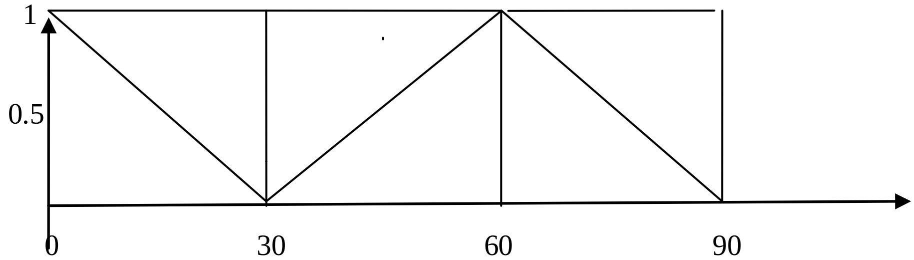


Fig. 1 (d) Membership Function vs. Select item

3. Mathematical Description:

The super abrasive grinding system is designed for four fuzzy input variables. The membership functions for the four variables such as cross sectional area, density, speed and item selection are given below

Different values of cross sectional area (in m^2):

$$V_{11}\text{-}V_{13}=V_1, V_{13}\text{-}V_{14}=V_2, V_{15}\text{-}V_{16}=V3.$$

Different values of Densities (in Kg /m^3):

V_{21}-V_{22}=$\rho 1$,V_{23}-V_{24}=$\rho 2$,V_{25}-V_{26}=$\rho 3$, V_{27}-V_{28}=$\rho 4$,V_{29}-V_{210} =$\rho 5$, V_{211}-V_{212}=$\rho 6$, V_{213}-V_{214}=$\rho 7$,V_{215}-V_{216}=$\rho 8$,V_{217}-V_{218}=$\rho 9$.

Different values of speed (revo/sec):

V_{31}-V_{32}=$N1$, V_{33}-V_{34}=$N2$, V_{35}-V_{36}=$N3$, V_{37}-V_{38}=$N4$,V_{39}-V_{310}=$N5$

Solution procedure:

Let us consider that Xi, Yi and Zi denote different values of cross sectional area, density and speed which belong to

$X_i \in [V_{1i}, V_{12}]$, $Y_i \in [V_{2i}, V_{22}]$, $Z_i \in [V_{3i}, V_{32}]$ &s_1, s_2 ……denote corresponding solution given by weighted compensatory operators as

$X_1p_1+Y_1q_1+Z_1r_1=S_1$

$X_1p_1+Y_1q_1+Z_2r_1=S_2$

$X_1p_1+Y_1q_1+Z_3r_1=S_3$

$X_1p_1+Y_2q_1+Z_1r_1=S_4$

$X_1p_1+Y_2q_1+Z_2r_1=S_5$

$X_1p_1+Y_2q_1+Z_3r_1=S_6$
$X_1p_1+Y_3q_1+Z_1r_1=S_7$
$X_1p_1+Y_3q_1+Z_2r_1=S_8$
$X_1p_1+Y_3q_1+Z_3r_1=S_9$
$X_2p_1+Y_1q_1+Z_1r_1=S_{10}$
$X_2p_1+Y_1q_1+Z_2r_1=S_{11}$
$X_2p_1+Y_1q_1+Z_3r_1=S_{12}$
$X_2p_1+Y_2q_1+Z_1r_1=S_{13}$
$X_2p_1+Y_2q_1+Z_2r_1=S_{14}$
$X_2p_1+Y_2q_1+Z_3r_1=S_{15}$
$X_2p_1+Y_3q_1+Z_1r_1=S_{16}$
$X_2p_1+Y_3q_1+Z_2r_1=S_{17}$
$X_2p_1+Y_3q_1+Z_3r_1=S_{18}$
$X_3p_1+Y_1q_1+Z_1r_1=S_{19}$
$X_3p_1+Y_1q_1+Z_2r_1=S_{20}$
$X_3p_1+Y_1q_1+Z_3r_1=S_{21}$
$X_3p_1+Y_2q_1+Z_1r_1=S_{22}$
$X_3p_1+Y_2q_1+Z_2r_1=S_{23}$
$X_3p_1+Y_2q_1+Z_3r_1=S_{24}$
$X_3p_1+Y_3q_1+Z_1r_1=S_{25}$
$X_3p_1+Y_3q_1+Z_2r_1=S_{26}$
$X_3p_1+Y_3q_1+Z_3r_1=s27.$

Where p_i, q_i and r_i €[0,1] & $p_i+q_i+r_i=1$.

Results

We have finite number of solution out of which some are less useful some are more useful this can be categorized according to threshold value. A threshold value is consider according to choice of decision maker suppose its value is θ .If any solution Si > θ , than result will be accepted otherwise result will be rejected. The sequence <Si> of accepted solution will be given in descending order of their values. The set of solutions is $\{S_1, S_2, S_3, \ldots, S_{27}\}$ and <Si>may contain less than 27 accepted solutions in which first solution is inferior and last is most superior.$\{S_{i1}, S_{i2}, S_{i3} \ldots Si_{27}\}$

Sample problem

The system is designed for fuzzy input variables .The valueof triangular membership functions for the four variables namely as cross sectional area, density, speed and item selection criteria are given below
Linguistic values of cross sectional area (m^2):
V_{11}-V_{12}=20, V_{13}-V_{14}=40, V_{15}-V_{16}=60.
Linguistic values of Densities (Kg/m^3 in %):
V_{21}-V_{22}=10, V_{23}-V_{24}=20, V_{25}-V_{26}=30, V_{27}- V_{28}=40,V_{29}-V_{210}=50, V_{211}-V_{212}=60, V_{213}-V_{214}=45,V_{215}-V_{216}=55,V_{217}-V_{218}=70.
Linguistic values of speed (m/sec):
V_{31}-V_{32}=10,V_{33}-V_{34}=20,V_{35}-V_{36}=30, V_{37}-V_{38}=40,V_{39}-V_{310}=45,V_{311}-V_{312}=50, V_{313}-V_{314}=35, V_{315}-V_{316}=50,V_{317}-V_{318}=55, V_{319}-V_{320}=60, V_{321}-V_{322}=65,V_{323}-V_{324}=70, V_{325}-V_{326}=35, V_{327}-V_{328} =40,V_{329}-V_{330}= 45, V_{331}-V_{332}=45,V_{333} V_{334}=55, V_{335}-V_{336}= 60, V_{337}-V_{338}=20,V_{339}-V_{340}=30,V_{341}-V_{342}=40, V_{343}-V_{344}=30,V_{345}-V_{346}=40,V_{347}-V_{348}=50, V_{349}-V_{350}=40,V_{351}-V_{352}=45,V_{353}-V_{354}=60.

Solution of problem

The set of different values of normalized weights used in weighted compensatory operator is given by:
$\{p_1=.3, q_1=.5, r_1=.2\}, \{ p_2=.4, q_2=.5, r_2=.1\},\{ p_3=.2, q_3=.3, r_3=.5\}$
$X_1 \in [V_{11}, V_{12}]$, $Y_1 \in [V_{21}, V_{22}]$, $Z_1 \in [V_{31}, V_{32}]$
$X_1p_1+Y_1q_1 +Z_1r_1=20x0.3+10x0.5+10x0.2=11.2=S_1$
$X_1p_1+Y_1q_1+Z_2r_1=20x0.3+10x0.5+20x0.2=15=S_2$
$X_1p_1+Y_1q_1+Z_3r_1=20x0.3+10x0.5+30x0.2=17=S_3$
$X_1p_1+Y_2q_1+Z_1r_1=20x0.3+20x0.5+40x0.2=24=S_4$
$X_1p_1+Y_2q_1+Z_2r_1=20x0.3+20x0.5+45x0.2=25=S_5$
$X_1p_1+Y_2q_1+Z_3r_1=20x0.3+20x0.5+50x0.2=26=S_6$
$X_1p_1+Y_3q_1+Z_1r_1=20x0.3+30x0.5+35x0.2=28=S_7$
$X_1p_1+Y_3q_1+Z_2r_1=20x0.3+30x0.5+50x0.2=31=S_8$

Vol.3 Issue.5, Pg.: 62-68
May 2015

$X_1p_1+Y_3q_1+Z_3r_1=20x0.3+30x0.5+55x0.2=32=S_9$
$X_2p_1+Y_1q_1+Z_1r_1=40x0.3+40x0.5+60x0.2=44=S_{10}$
$X_2p_1+Y_1q_1+Z_2r_1=40x0.3+40x0.5+65x0.2=45=S_{11}$
$X_2p_1+Y_1q_1+Z_3r_1=40x0.3+40x0.5+70x0.2=46=S_{12}$
$X_2p_1+Y_2q_1+Z_1r_1=40x0.3+50x0.5+35x0.2=44=S_{13}$
$X_2p_1+Y_2q_1+Z_2r_1=40x0.3+50x0.5+40x0.2=45=S_{14}$
$X_2p_1+Y_2q_1+Z_3r_1=40x0.3+50x0.5+45x0.2=46=S_{15}$
$X_2p_1+Y_3q_1+Z_1r_1=40x0.3+60x0.5+45x0.2=51=S_{16}$
$X_2p_1+Y_3q_1+Z_2r_1=40x0.3+60x0.5+55x0.2=53=S_{17}$
$X_2p_1+Y_3q_1+Z_3r_1=40x0.3+60x0.5+60x0.2=54=S_{18}$
$X_3p_1+Y_1q_1+Z_1r_1=60x0.3+45x0.5+20x0.2=44.5=S_{19}$
$X_3p_1+Y_1q_1+Z_2r_1=60x0.3+45x0.5+30x0.2=46.5=S_{20}$
$X_3p_1+Y_1q_1+Z_3r_1=60x0.3+45x0.5+40x0.2=48.5=S_{21}$
$X_3p_1+Y_2q_1+Z_1r_1=60x0.3+55x0.5+30x0.2=51.5=S_{22}$
$X_3p_1+Y_2q_1+Z_2r_1=60x0.3+55x0.5+40x0.2=53.5=S_{23}$
$X_3p_1+Y_2q_1+Z_3r_1=60x0.3+55x0.5+50x0.2=55.5=S_{24}$
$X_3p_1+Y_3q_1+Z_1r_1=60x0.3+70x0.5+40x0.2=61=S_{25}$
$X_3p_1+Y_3q_1+Z_2r_1=60x0.3+70x0.5+45x0.2=62=S_{26}$
$X_3p_1+Y_3q_1+Z_3r_1=60x0.3+70x0.5+60x0.2=65=S_{27}$

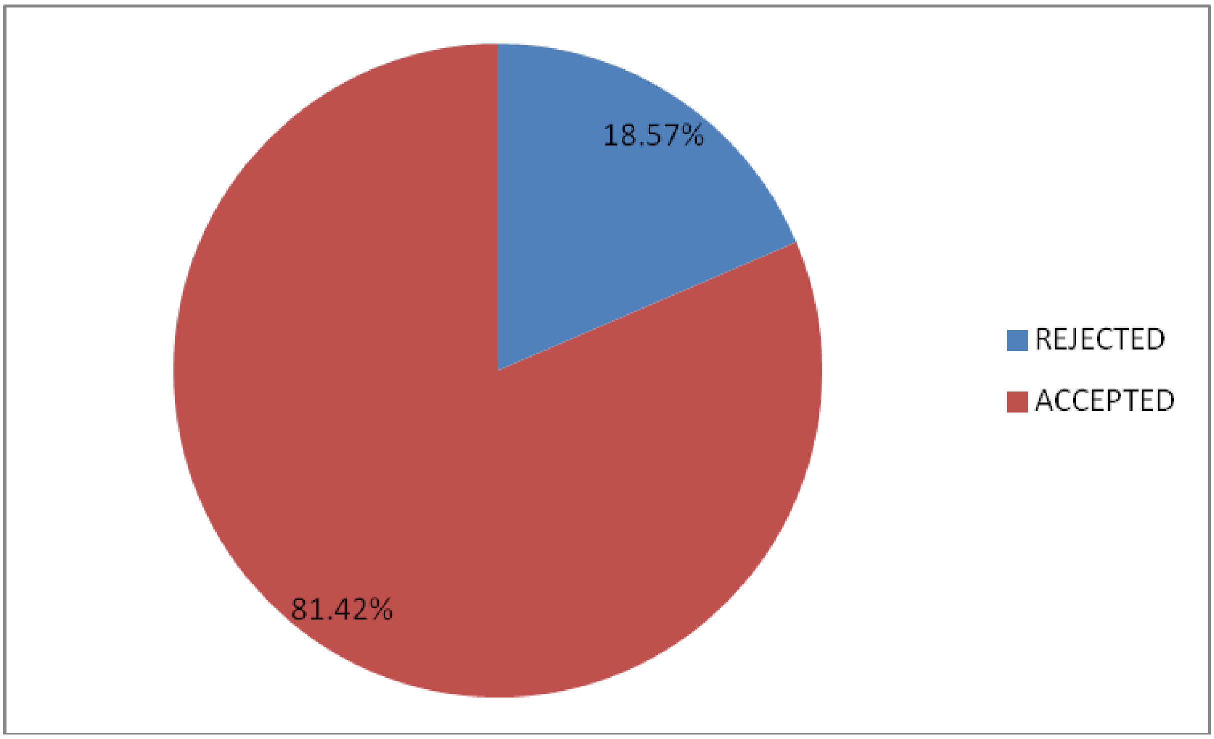
Result

The set of solution in ascending order is given below:
$\{S_1,S_2,S_3,S_4,S_5,S_6,S_7,S_8,S_9,S_{10},S_{13},S_{11}, S_{14},S_{19},S_{12},S_{15},S_{20},S_{21},S_{16},S_{22},S_{17},S_{23},S_{18},S_{24},S_{25},S_{26},S_{27}\}$

Use of threshold value

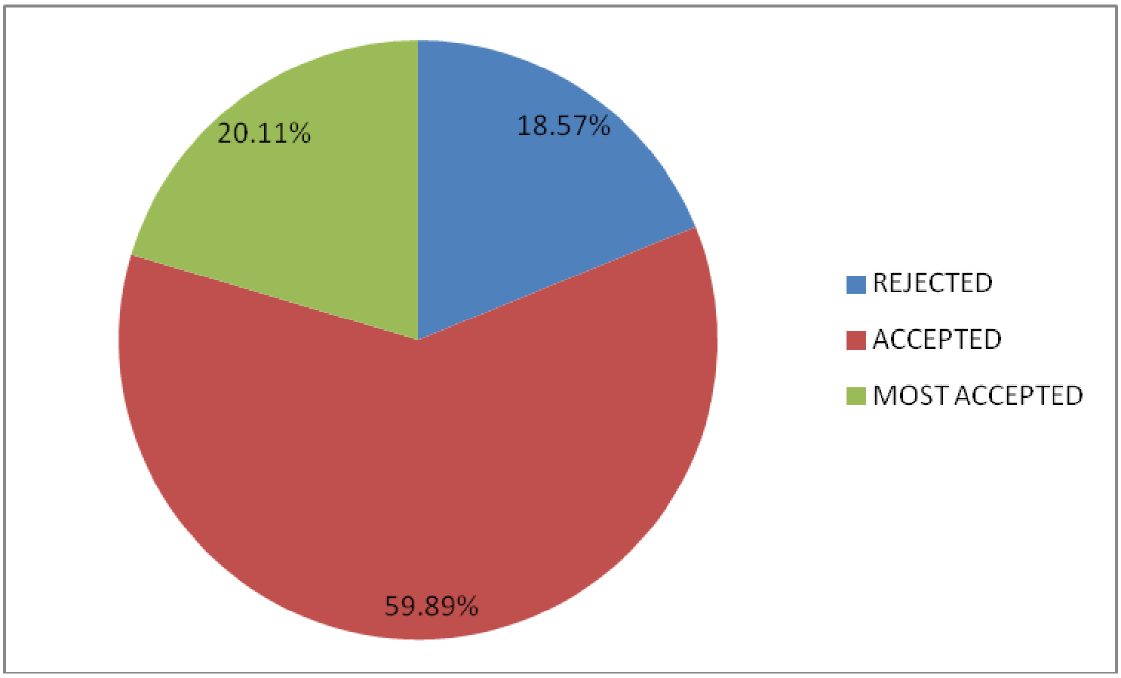
A threshold value denoted by θ, is considered according to choice of decision maker. Suppose its value is 38. if any solution is > 38 than result will be accepted otherwise result will be rejected.

The sequence of accepted solutions will be given in ascending order of their values. The sequence of solutions is$\{ S_{13},S_{11},S_{14},S_{19},S_{12},S_{15},S_{20},S_{21},S_{16},S_{22},S_{17},S_{23},S_{18},S_{24},S_{24},S_{25},S_{26},S_{27}\}$.



If the user is not satisfied with the above result then he/she should take most acceptable asresult given below

A threshold value denoted by θ, is considered according to choice of decision maker. if any solution is >55 result will be most accepted .



4. Conclusion

The result of design model is the same as the simulation result. This system can be extended for any time control system to overcome time control issues and achieve better performance without the burden of extra load for time control. In this super abrasive grinding process we use four linguistic variables cross sectional area, density, speed and selection criteria is used time depend on the amount of linguistic variable selected .Grinding fuzzy time control system depend on the values of linguistic variables such as cross sectional area, density and speed. The values of each selection criteria depend on item-select input variable. The Grinding time control fuzzy system approach makes the system efficient and completely under time control. The fuzzy time control model needs to be developed using super abrasive grinding system with its large number of industrial applications. The work on it is being carried out and in future it will help to design state of the art fuzzy logic time control discrete event systems in industrial environment.

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