ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 5, Issue 2, February 2018

Determination of general Grooved Chip breaker geometry to enhance the Chip breakability factor for various operations using Fuzzy Logic approach

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Abstract: **-- For every machining operation good chip breakability is desired. Controlling of cutting parameters helps in achieving the desired chip breakability. But many a time there are constraints regarding cutting parameters. Hence we require the help of grooved chip breaker to have a control on chip breakability factor. Therefore the geometry for the grooved chip breaker geometry has to be designed very precisely so as to enhance the good chip breakability. Implementing the fuzzy logic model will helps in predicting of geometries for the grooved chip breaker accurately for different machining operation.**

Keywords **— Chip breakability, Chip breaker, Fuzzy Logic, Chip flow, Grooved.**

I. INTRODUCTION

During the machining specifically with ductile material, longer chip wraps around the work piece and damages the machining surface. Moreover such wrapped chip may strike the operator and may cause injury to the operator. This problem becomes very much serious while machining at higher cutting speed. The early analysis shows that at high speed the heat carried out by the chip is much more compared to heat generated at the tool surface and machining surface. Hence the chance of severe burning accident causes the environment very hazardous to operate. Therefore, it is very much essential to design the machining process so as to break the chip intermittently while machining the work material. Chip breakability is assessed in terms of the ease with which chip breaks. Higher value of chip breakability is necessary both for conventional machining process as well as for unmanned machining system. Controlling of cutting parameters helps in achieving the desired chip breakability. But many a time there are constraints regarding cutting parameters. Chip breakability factor may be enhanced by suitable design of a chip breaker. As a first trial, an attempt was made to incorporate the fuzzy logic using MATLAB software to select proper value of the element of the chip breaker to generate proper chip breakability factor in the type of finishing and roughing operation. In this paper chip breaker is installed for CNMG120408 type insert whereas the type of work material used for simulation work was CSM 4 Steel as steel is widely used material in industrial applications. Further, the same fuzzy logic study on the effect of various element of the chip breaker on chip breakability was explored. This study may help to design proper chip breaker for specific chip breakability. The effect of machining parameter on chip breakability was also verified.

II. BACKGROUND

2.1 Chip breaker

The metal cutting process by a single point cutting tool generates narrow and long chips that lead to problems such as tangling together, difficulty in chip handling, surface damage of products, and safety hazards for the operator. It is necessary to cut chips to the appropriate size. Chips generated during metal cutting form curling, and strike against workpiece or tools, result in chip breaking. Patterns and sizes of broken chips are different depending on deformation mechanism and collision location. The generated chip makes continuous curling and it is known that chip breakability enlarges when we reduce the up curling radius and down curling radius of a chip clearance that is formed at this time (Shaw Milton, 2005). For determining chip pattern, the most important factor is to ensure that appropriate external force is applied to the chip. Doing so decreases the radius of the chip and increases the fracture strain of the chip. A chip breaker is the tool which has a groove or an obstacle placed on the incline face of the tool. A chip breaker can be used for increasing chip breakability that has resulted in efficient chip control and improved productivity. It can also decrease cutting resistance, and improve the tool life and surface condition of a workpiece. A chip breaker is operated for improving chip breakability through the decrease of chip radius. The chip curl radius is expressed as the following equation based on the geometrical relation (Hong-Gyookim

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International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
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et al., 2009).

$$\frac{1}{\rho} = \frac{2}{k}\sin(\alpha + \beta)$$

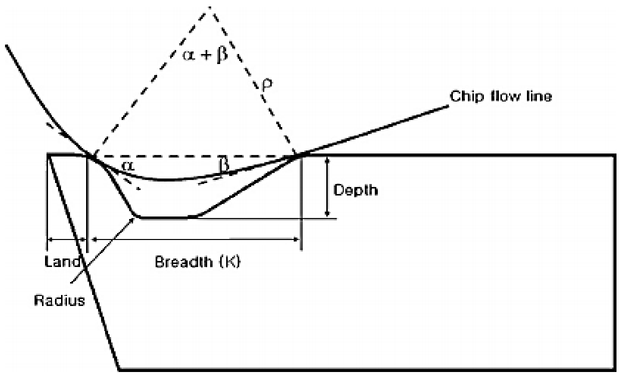

Fig.1. Radius of chip that flows touching chip breaker (Hong-Gyookim et al., 2009)

2.2 Classification of chip pattern

Chip pattern has been classified by CIRP and INFOS, but each classification is very similar. In this study, the INFOS classified chip pattern was used, and chip conditions were evaluated. These patterns are classified again as three categories of linguistic parameters such as stable, usable, and unstable. In this study, these linguistic parameters were used as output variables for Fuzzy logic algorithm.

Table 1Chip pattern evaluation during machining operations (Hong-Gyookim et al., 2009)

1		ribbon chips	unstable
2		tangled chips	unstable
3		corkscrew chips	unstable
4		helical chips	usable
5		long tubular chips	usable
6		short tubular chips	stable / usable
7		spiral tubular chips	stable / usable
8		spiral chips	stable / usable
9		long comma chips	usable
10		short comma chips	usable

III. PREPARATION OF DATABASE FOR FUZZY LOGIC ANALYSIS AND FORMATION OF RULES.

Chip breaker design can be done through experimental trial for the Work material SCM 4 Steel and with the combinations of grooved chip breaker geometry. The purpose of performing experimentation is to establish a set of rules for fuzzy logic implementation. So, knowledge based rules can be implemented to predict the effect of various element of chip breaker on chip breakability. Such prediction through MATLAB software can be useful to design the specific chip breaker for certain machining task so as to yield better chip breakability factor. Studies were made to design various geometry chip breaker elements for different machining types as for example finishing, roughing, and heavy roughing and roughing.

Table 2 Specification for chip breaker geometry data used and results obtained as referred in (Hong-Gyookim et al., 2009)

S.No	Depth	Land	Breadth	Radius	Finishing	Light Roughing	Heavy Roughing	Roughing
1	0.39	0.00	1.52	0.70	Stable	Stable	Usable	Unstable
2	0.21	0.04	1.41	2.00	Stable	Stable	Usable	Unstable
3	0.18	0.00	1.40	3.00	Stable	Stable	Usable	Unstable
4	0.43	0.13	2.07	0.70	Usable	Usable	Usable	Unstable
5	0.72	0.00	2.00	2.00	Usable	Stable	Unstable	Unstable
6	0.24	0.22	1.90	1.08	Unstable	Unstable	Stable	Usable
7	0.35	0.28	1.80	1.05	Unstable	Unstable	Stable	Usable
8	0.45	0.18	1.61	1.07	Usable	Stable	Stable	Usable
9	0.27	0.20	1.85	1.50	Usable	Usable	Stable	Usable
10	0.31	0.11	2.67	2.60	Usable	Usable	Stable	Usable
11	0.27	0.35	2.12	0.80	Usable	Usable	Stable	Usable
12	0.19	0.30	2.15	0.00	Unstable	Unstable	Stable	Stable
13	0.17	0.32	2.50	0.00	Unstable	Unstable	Stable	Stable

Table 3 Experimental conditions and work material composition as referred in (Hong-Gyookim et al., 2009)

Compositions	C	Mn	P	S	Si	Cr	Mo
Wt.%	0.35-0.40	0.70-0.90	0.035(max)	0.04 (max)	0.15-0.30	0.80-1.10	0.15-0.25

Insert Type: CNMG120408

Cutting parameters used-

Cutting speed: 100 m/min; Feed Rate: (0 - 0.40) mm/rev.; Finishing cut doc: (0 - 0.50) mm; Light roughing doc: (0.51 - 0.80) mm; Heavy roughing doc: (0.81 – 3) mm; Roughing doc: (3.01 - 5) mm.

The geometry for chip breaker can be measured for various experiments with the help of Tool Makers Microscope.

ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
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IV. FUZZY LOGIC BASED MODEL TO PREDICT CHIP BREAKER ELEMENTS GEOMETRY FOR DIFFERENT OPERATIONS

4.1 Membership functions for input and output fuzzy variables

In choosing the membership functions for fuzzyfication, the event and type of membership function are mainly depend upon the relevant event. In this model the information regarding input parameters are as follows:

NumInputs = 4;
NumOutputs = 1;
NumRules = 13;
AndMethod = 'min';
OrMethod = 'max';
ImpMethod = 'min'
AggMethod = 'max'.

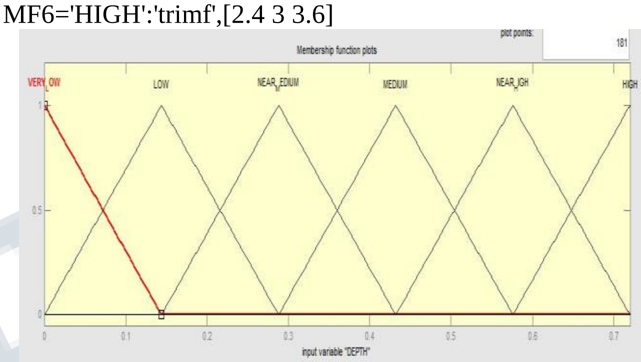
Table 4 Input Membership Functions

[Input1]
Name='DEPTH'
Range=[0 0.72]
NumMFs=6
MF1='VERY_LOW ':'trimf',[-0.14 5.204e-18 0.14]
MF2='LOW' :'trimf',[0 0.14 0.28]
MF3='NEAR_MEDIUM' :'trimf',[0.14 0.28 0.42]
MF4='MEDIUM': 'trimf',[0.28 0.42 0.56]
MF5='NEAR_HIGH':'trimf',[0.42 0.56 0.7]
MF6='HIGH':'trimf',[0.56 0.7 0.84]

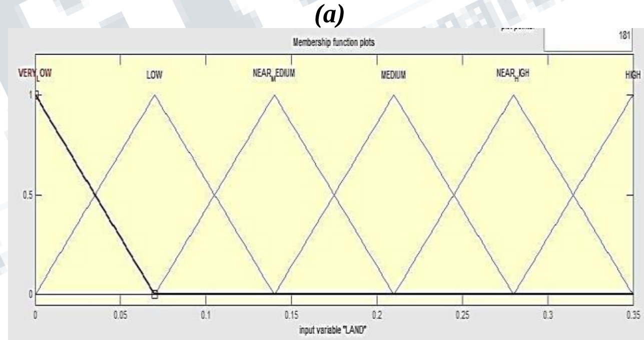
Input2]
Name='LAND'
Range=[0 0.35]
NumMFs=6
MF1='VERY_LOW' :'trimf',[-0.07001 8.674e-19 0.07001]
MF2='LOW' :'trimf',[-8.8e-06 0.07 0.14]
MF3='NEAR_MEDIUM' :'trimf',[0.06999 0.14 0.21]
MF4='MEDIUM' :'trimf',[0.14 0.21 0.28]
MF5='NEAR_HIGH':'trimf',[0.21 0.28 0.35]
MF6='HIGH':'trimf',[0.28 0.35 0.42]

Input3]
Name='BREADTH'
Range=[1.4 2.6]
NumMFs=6
MF1='VERY_LOW' :'trimf',[1.16 1.4 1.64]
MF2='LOW' :'trimf',[1.4 1.64 1.88]
MF3='NEAR_MEDIUM' :'trimf',[1.64 1.88 2.12]
MF4='MEDIUM' :'trimf',[1.88 2.12 2.36]
MF5='NEAR_HIGH':'trimf',[2.12 2.36 2.6]
MF6='HIGH':'trimf',[2.36 2.6 2.84]

[Input4]
Name='RADIUS'
Range=[0 3]
NumMFs=6
MF1='VERY_LOW ':'trimf',[-0.6 1.388e-17 0.6]
MF2='LOW' :'trimf',[-8.147e-06 0.6 1.2]
MF3='NEAR_MEDIUM' :'trimf',[0.6 1.2 1.8]
MF4='MEDIUM' :'trimf',[1.2 1.8 2.4]
MF5='NEAR_HIGH':'trimf',[1.8 2.4 3]
MF6='HIGH':'trimf',[2.4 3 3.6]



(a)



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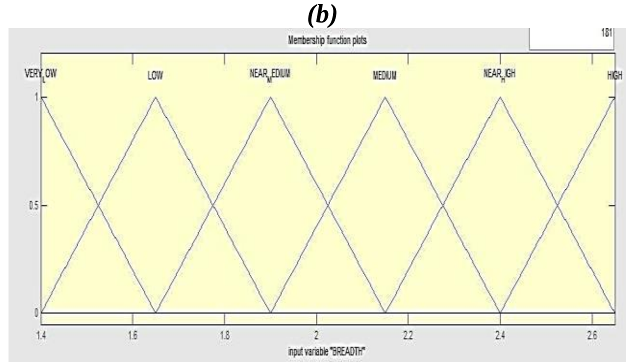

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ISSN (Online) 2394-6849

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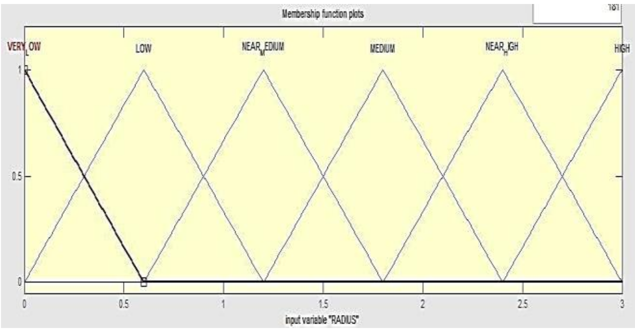


(d)

Fig.. 2. (a) Membership function for chip breaker depth; (b) Membership function for land; (c) Membership function for breadth;

(d) Membership function for radius of chip breaker

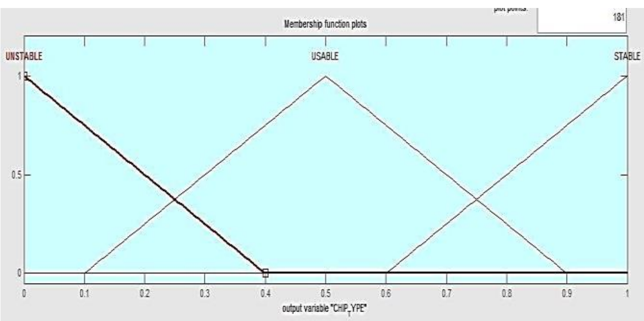


Fig. 3. Chip breakability for chip breaker

4.2 Fuzzy rules

The relationships between input parameters which are Chip breaker depth, land, Breadth and radius with the response i.e. chip breakability were referred to construct the rules between them. Experimental data results were simulated in the MATLAB software on the basis of Mamdani fuzzy logic.

(i) Set of rules for finishing operations:

1. If (DEPTH is medium) and (LAND is very_low) and (BREADTH is low) and (RADIUS is low) then (CHIP_TYPE is STABLE) (1)
2. If (DEPTH is low) and (LAND is low) and (BREADTH is very_low) and (RADIUS is medium) then (CHIP_TYPE is STABLE) (1)
3. If (DEPTH is low) and (LAND is very_low) and (BREADTH is very_low) and (RADIUS is high) then (CHIP_TYPE is STABLE) (1)
4. If (DEPTH is medium) and (LAND is near_medium) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is USABLE) (1)
5. If (DEPTH is high) and (LAND is very_low) and (BREADTH is near_medium) and (RADIUS is medium) then (CHIP_TYPE is USABLE) (1)
6. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is UNSTABLE) (1)
7. If (DEPTH is near_medium) and (LAND is near_high) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is UNSTABLE) (1)
8. If (DEPTH is medium) and (LAND is medium) and (BREADTH is low) and (RADIUS is near_medium) then (CHIP_TYPE is USABLE) (1)
9. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is USABLE) (1)
10. If (DEPTH is near_medium) and (LAND is near_medium) and (BREADTH is high) and (RADIUS is near_high) then (CHIP_TYPE is USABLE) (1)
11. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is USABLE) (1)
12. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is very_low) then (CHIP_TYPE is UNSTABLE) (1)
13. If (DEPTH is low) and (LAND is high) and (BREADTH is near_high) and (RADIUS is very_low) then (CHIP_TYPE is UNSTABLE) (1)

(ii) Set of rules for light roughing operations:

1. If (DEPTH is medium) and (LAND is very_low) and (BREADTH is low) and (RADIUS is low) then (CHIP_TYPE is STABLE) (1)
2. If (DEPTH is low) and (LAND is low) and (BREADTH is very_low) and (RADIUS is medium) then (CHIP_TYPE is STABLE) (1)
3. If (DEPTH is low) and (LAND is very_low) and (BREADTH is very_low) and (RADIUS is high) then (CHIP_TYPE is STABLE) (1)
4. If (DEPTH is medium) and (LAND is near_medium) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is USABLE) (1)
5. If (DEPTH is high) and (LAND is very_low) and (BREADTH is near_medium) and (RADIUS is medium) then (CHIP_TYPE is STABLE) (1)
6. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is UNSTABLE) (1)
7. If (DEPTH is near_medium) and (LAND is near_high) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is UNSTABLE) (1)
8. If (DEPTH is medium) and (LAND is medium) and (BREADTH is low) and (RADIUS is near_medium) then (CHIP_TYPE is STABLE) (1)
9. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is USABLE) (1)
10. If (DEPTH is near_medium) and (LAND is near_medium) and (BREADTH is high) and (RADIUS is near_high) then (CHIP_TYPE is USABLE) (1)
11. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is USABLE) (1)
12. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is very_low) then (CHIP_TYPE is UNSTABLE) (1)
13. If (DEPTH is low) and (LAND is high) and (BREADTH is near_high) and (RADIUS is very_low) then (CHIP_TYPE is UNSTABLE) (1)

(iii) Set of rules for heavy roughing operations:

1. If (DEPTH is medium) and (LAND is very_low) and (BREADTH is low) and (RADIUS is low) then (CHIP_TYPE is usable) (1)
2. If (DEPTH is low) and (LAND is low) and (BREADTH is very_low) and (RADIUS is medium) then (CHIP_TYPE is usable) (1)
3. If (DEPTH is low) and (LAND is very_low) and (BREADTH is very_low) and (RADIUS is high) then (CHIP_TYPE is usable) (1)
4. If (DEPTH is medium) and (LAND is near_medium) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is usable) (1)
5. If (DEPTH is high) and (LAND is very_low) and (BREADTH is near_medium) and (RADIUS is medium) then (CHIP_TYPE is unstable) (1)
6. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is stable) (1)
7. If (DEPTH is near_medium) and (LAND is near_high) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is stable) (1)
8. If (DEPTH is medium) and (LAND is medium) and (BREADTH is low) and (RADIUS is near_medium) then (CHIP_TYPE is stable) (1)
9. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is stable) (1)
10. If (DEPTH is near_medium) and (LAND is near_medium) and (BREADTH is high) and (RADIUS is near_high) then (CHIP_TYPE is stable) (1)
11. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is stable) (1)
12. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is very_low) then (CHIP_TYPE is stable) (1)
13. If (DEPTH is low) and (LAND is high) and (BREADTH is near_high) and (RADIUS is very_low) then (CHIP_TYPE is stable) (1)

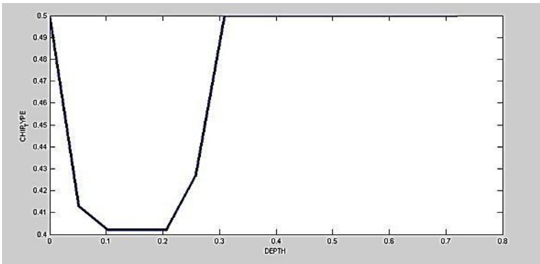
(iv) Set of rules for roughing operations

1. If (DEPTH is medium) and (LAND is very_low) and (BREADTH is low) and (RADIUS is low) then (CHIP_TYPE is UNSTABLE) (1)
2. If (DEPTH is low) and (LAND is low) and (BREADTH is very_low) and (RADIUS is medium) then (CHIP_TYPE is UNSTABLE) (1)
3. If (DEPTH is low) and (LAND is very_low) and (BREADTH is very_low) and (RADIUS is high) then (CHIP_TYPE is UNSTABLE) (1)
4. If (DEPTH is medium) and (LAND is near_medium) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is UNSTABLE) (1)
5. If (DEPTH is high) and (LAND is very_low) and (BREADTH is near_medium) and (RADIUS is medium) then (CHIP_TYPE is UNSTABLE) (1)
6. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is USABLE) (1)
7. If (DEPTH is near_medium) and (LAND is near_high) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is USABLE) (1)
8. If (DEPTH is medium) and (LAND is medium) and (BREADTH is low) and (RADIUS is near_medium) then (CHIP_TYPE is USABLE) (1)
9. If (DEPTH is near_medium) and (LAND is medium) and (BREADTH is near_medium) and (RADIUS is near_medium) then (CHIP_TYPE is USABLE) (1)
10. If (DEPTH is near_medium) and (LAND is near_medium) and (BREADTH is high) and (RADIUS is near_high) then (CHIP_TYPE is USABLE) (1)
11. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is low) then (CHIP_TYPE is USABLE) (1)
12. If (DEPTH is near_medium) and (LAND is high) and (BREADTH is medium) and (RADIUS is very_low) then (CHIP_TYPE is STABLE) (1)
13. If (DEPTH is low) and (LAND is high) and (BREADTH is near_high) and (RADIUS is very_low) then (CHIP_TYPE is STABLE) (1)

V. DEFUZZIFICATION AND RESULTS

Defuzzification is the conversion of the fuzzy quantity to precise value, just as fuzzyfication is the conversion of precise value to a fuzzy quantity. The selection of the model is important as it gives the accuracy of the model. In this model centroid of area (COA) Defuzzification method is used as it provide highly accurate prediction and analysis (Saurin seth et al., 2014)

5.1 The results shown for various operations are:
5.1.1 Finishing operation



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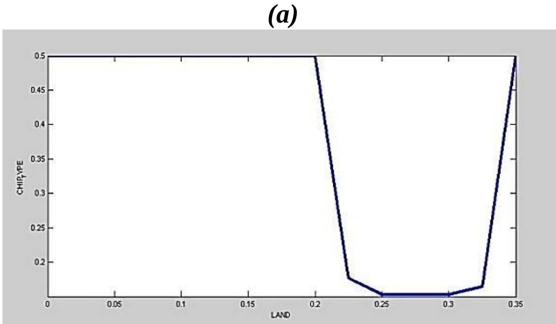

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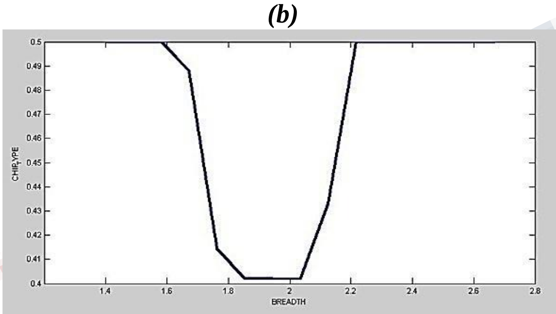

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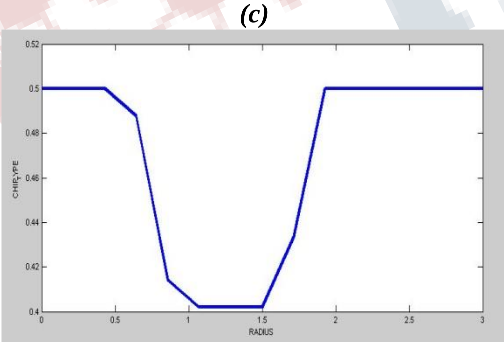
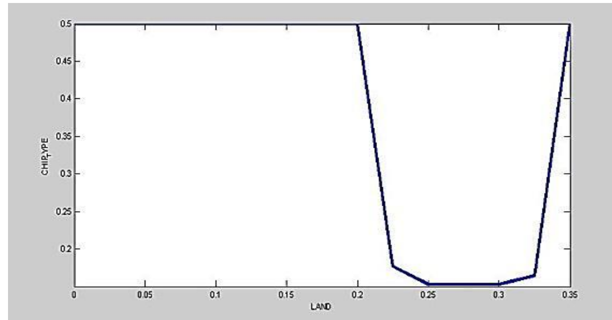


(d)

Fig. 4. Fuzzy results (a) Chip breaker depth v/s chip breakability; (b) Chip breaker land v/s chip breakability; (c) Chip breaker breadth v/s chip breakability; (d) Chip breaker radius v/s chip breakability

5.1.2 Light roughing



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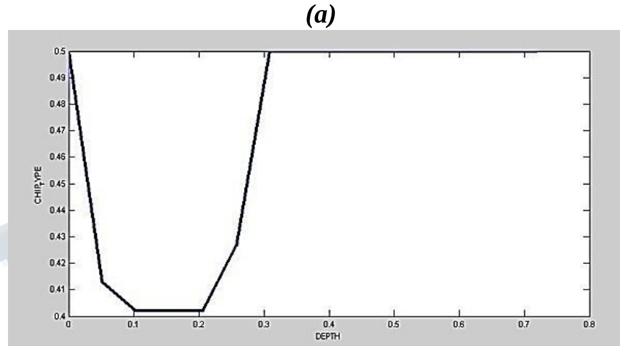

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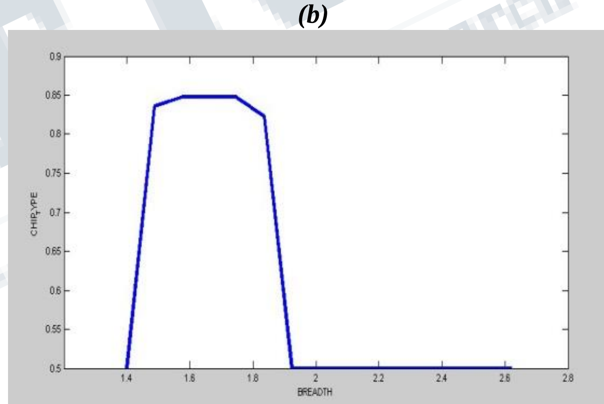

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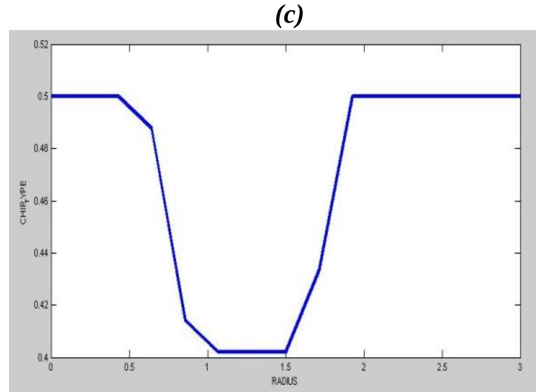

(d)

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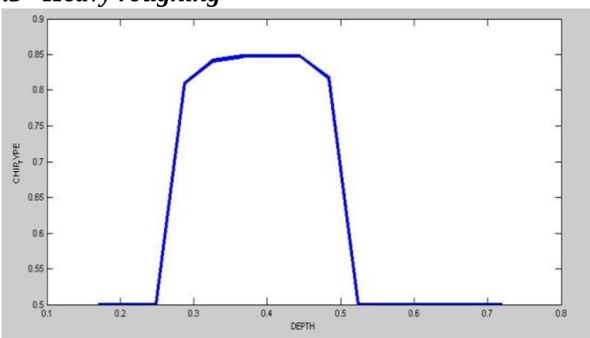
ISSN (Online) 2394-6849
International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 5, Issue 2, February 2018

Fig. 5. Fuzzy results (a) Chip breaker land v/s chip breakability; (b) Chip breaker depth v/s chip breakability; (c) Chip breaker breadth v/s chip breakability; (d) Chip breaker radius v/s chip breakability

5.1.3 Heavy roughing



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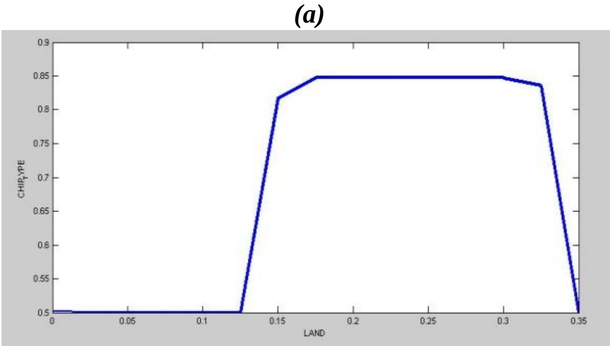

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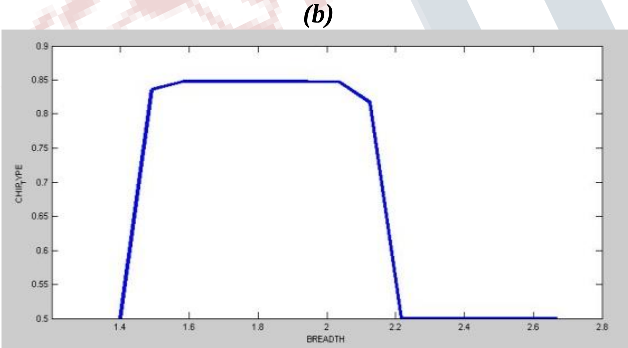

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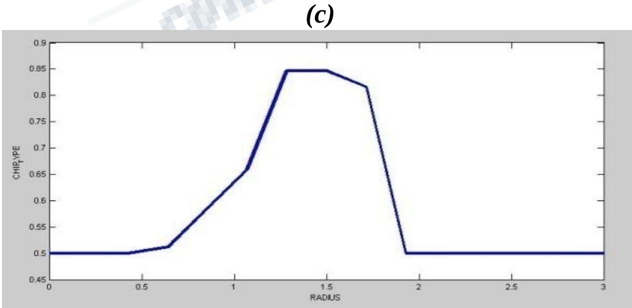

(d)

Fig. 6, Fuzzy results (a) Chip breaker depth v/s chip breakability; (b) Chip breaker land v/s chip breakability; (c) Chip breaker breadth v/s chip breakability; (d) Chip breaker radius v/s chip breakability.

5.1.4 Roughing

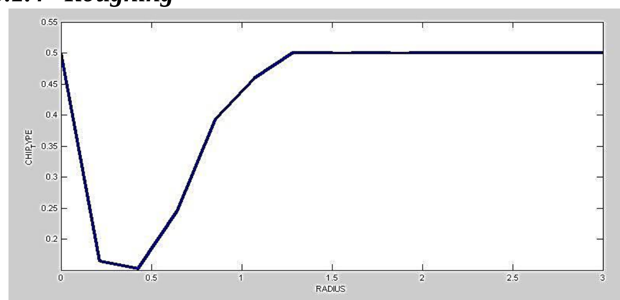

Fig.7. Fuzzy results for Chip breaker radius v/s chip breakability

5.2Investigating the Fuzzy model accuracy

After constructing the fuzzy rules, the proposed fuzzy model is used to predict the geometry for grooved chip breaker for different operations which can be seen in a rule viewer as shown in Fig. 8 for a randomly chosen geometry at S.No 13 for

Roughing operations as mentioned in Table 2. Similarly for different operations we can predict the values of chip breakability and compare with experimental result as mentioned in Table 2.

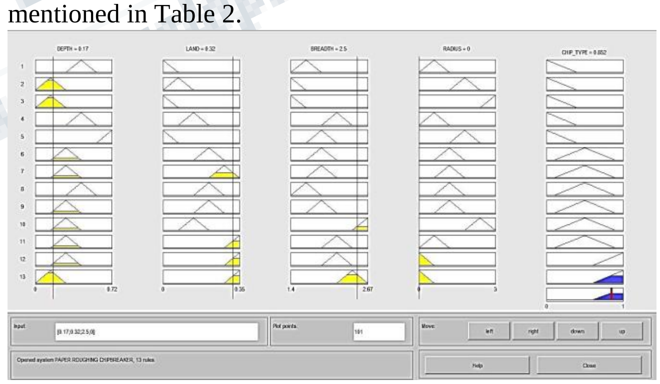

Fig. 8 Rule viewer Dialog box for Predicted Chip breakability value as a Stable chip formed

5.3 Comparison

Based on the results obtained from fuzzy logic to predict the grooved chip breaker geometry for various operation is compared with the actual experimental results conducted, which is found to be validating with an accuracy of an aggregate 81%. A comparison chart is shown for various operations conducted in Fig. 9.

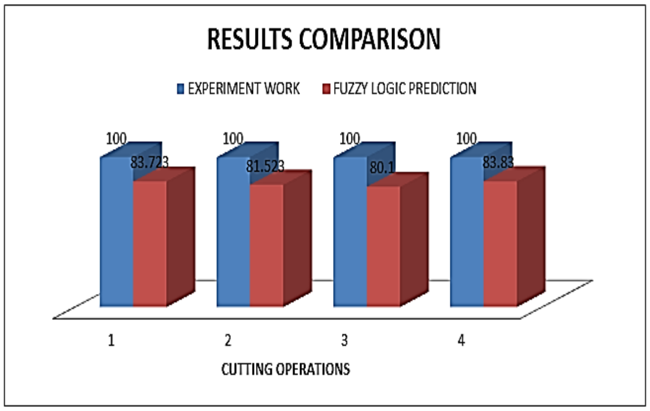

Fig.9. A comparison chart is shown for various operations conducted

1. FINISHING
2. LIGHT ROUGHING
3. MEDIUM ROUGHING
4. ROUGHING

VI. CONCLUSION

1. For finishing operation high range depth, low range land and extreme ranges for breadth and radius is desired for yielding good chip breakability.

2. Similarly for Light roughing operation breadth range from 1.4 mm - 1.9 mm is beneficial for yielding good chip breakability, rest parameters is same as for finishing operation.

3. For Heavy roughing operation depth ranging from 0.25mm - 0.53 mm is preferred, for land high range and breadth as well as radius medium range is preferred for high chip breakability.

4. For Roughing operation only parameter i.e. radius affects the chip breakability factor. In general high range i.e. 1mm – 3mm yields good result.

5. Regarding designing the geometries of the grooved tool breaker for the different cutting operations, fuzzy logic is easy method with an accuracy of aggregate 81% which is more reliable and convenient approach to deal with the problems of manufacturing sector.

6. In future this method will provide more flexibility in production of general grooved tool breaker commercially with optimize geometries for the number of combinations of work piece materials to yield high chip breakability in manufacturing industries.

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