**International Journal of Engineering Research and Development**
**e**-ISSN: 2278-067X, **p**-ISSN: 2278-800X, www.ijerd.com
Volume 7, Issue 2 (May 2013), PP. 12-20

# Evaluation of chip breaker using flank wear on EN-8 steel and optimization of machining parameters for maximum tool life and minimum chip length using RSM methodology

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***Abstract :*** *Machining is one of the common and essential part of manufacturing of all most all metal products. In today's era of automatic machines optimization of machining operations is one of the key requirements During turning operation, unbroken chips pose a major hindrance, the continuous chip generated during turning operation deteriorates the work piece precision and causes safety hazards for the operator So, the development of a effective chip breaker is necessary in order to control the size and shape of the chips thereby increasing the tool life and for the atomization of turning operations . In this study, the role of different parameters like feed, speed, depth of cut along with flank wear on chip characteristics have been studied for machining of EN-8 (AISI 1040) steel. The MINITAB software has been used for design and analysis of the experiments conducted. Optimization of the machining parameters has been done using MINITAB software in order to maximize the tool life and minimize the chip length by adopting Response Surface Methodology (RSM).*

***Keywords:*** *EN-8 steel-design of effective chip breaker-RSM-tool life-chip length.*

## I. INTRODUCTION

Machining (**turning**), is one of the most important material removal methods. It uses a single point cutting tool to cut the unwanted portion of material to achieve the desired geometry. Machining process produces chips due to removal of excess material from the metal surface. The geometrical and metallurgical characteristics of these chips are very representative of the performances of the process. Indeed, they bear witness to most of the physical and thermal phenomena occurring during the machining.

Numerous chips are being generated in short time during machining operations which requires effective control of length, moreover thickness of chips and tool life are some of the most important factors for work performance. When the chips are out of control , it may lead to system failure which directly affects productivity and is also very dangerous for the person working on machine.

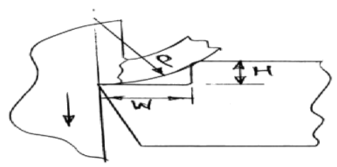
Failure in chip control has a significant effect on surface roughness of work piece, precision of product and also on the life of the tool. So, it is important in order to analysis the performance of the chip breaker. Tool life is the time up to which the tool is functioning satisfactorily.

**Tool life:**

The Taylor's equation for tool life is generally given by the formula: $TV^n=C$, the value of C and n depend upon the type of tool used. Many researchers have been done in the view of developing some equations for tool life including parameters like feed, depth of cut, wear, cutting speed etc. So, besides cutting speed, other parameters also have a significant influence on tool life. So in this project experiments have been done to calculate the tool life at different flank wear values and the observation values of tool life are tabulated .

### I.1 CHIP BREAKER

***Design of a chip breaker***: In, order to control the long and continuous chips produced during the machining process, the chip breaker is used. A chip breaker (in-built) type is designed in this experiment in order to control the long chips produced during machining of EN-8 steel, this chip breaker designed works on the principle of force breaking. The uncut layer is first elastically deformed followed by plastic deformations and separation taking place near the cutting edge of the tool.




**W** = width, **H** = height

**Principle of chip breaking**

**I.2 WORK MATERIAL:**

The composition of EN-8 steel is given below:

| Carbon | Manganese | Silicon | sulphur | phosphorous |
|---|---|---|---|---|
| 0.35% | 0.06-1.00% | 0.05-0.35% | 0.06% | 0.06% |

**II. EXPERIMENTAL PROCEDURE**

The different equipments used in the experimentation are given below:

(a) LATHE machine
(b) Grinding machine
(c) Tool maker's microscope
(d) PDF-Xchange viewer software
(e) MINITAB software

***II.1 Design and selection of chip breaker:***

Before, starting the experiment we have design an effective chip breaker for the appropriate control of chips produced. so, for this purpose by adopting trial and error method different chip breakers are made and tested. So, the following are the different designs proposed and **3rd design** is selected as the best.

| TOOL NO. | WIDTH(mm) | HEIGHT(mm) | ϕs |
|---|---|---|---|
| 1 | 3.0 | 10 | $0.9^0$ |
| 2 | 3.0 | 8 | $1.5^0$ |
| 3 | 2.5 | 6 | $0.6^0$ |

***2.2 The experimental setup for chip breaking:*** ***2.3 grinding machine used for tool design***

***Experimental setup (cutting tool with work piece)***

***Tool grinding machine***

***II.4 Experimental Conditions:***

| Condition | Units | Value |
|---|---|---|
| Cutting speed | m/min | 30,45,50 |
| Depth of cut | mm | 0.2,0.3,0.4 |
| Feed | mm/rev | 0.5,0.75,1.0 |
| Work piece material | | EN-8(AISI 1040) Steel |

***II.5 experiment input chart:***

**Response surface methodology*:*** In statistics, **response surface methodology (RSM)** explores the relationships between several explanatory variables and one or more response variables. There are two types of methodologies (designs) in RSM which can be adopted. They are central **composite design** and **box-behnken** design. For our experiment we have concluded that central composite design is the best involving 4 variable factors and 3 response variables and if experiment is performed under unblocked condition.

The following is the input chart obtained from the MINITAB for the design of the experiments.

| Sl no: | Std order | Run order | Pt type | blocks | Feed (mm/rev) | Depth of cut (mm) | Velocity (m/min) | Wear (mm) |
|---|---|---|---|---|---|---|---|---|
| **1** | 1 | 19 | 1 | 1 | 0.75 | 0.3 | 46.23 | 0.5 |
| **2** | 2 | 6 | 1 | 1 | 1 | 0.4 | 50.26 | 0.5 |
| **3** | 3 | 24 | 1 | 1 | 0.5 | 0.4 | 50.26 | 0.5 |
| **4** | 4 | 23 | -1 | 1 | 1 | 0.2 | 50.26 | 0.5 |
| **5** | 23 | 9 | 1 | 1 | 1 | 0.4 | 30.66 | 0.5 |
| **6** | 5 | 15 | 1 | 1 | 1 | 0.2 | 30.66 | 0.5 |
| **7** | 6 | 5 | 1 | 1 | 0.5 | 0.4 | 30.66 | 0.5 |
| **8** | 7 | 26 | 1 | 1 | 0.5 | 0.2 | 50.26 | 0.5 |
| **9** | 8 | 31 | 1 | 1 | 0.5 | 0.2 | 30.66 | 0.5 |
| **10** | 21 | 17 | -1 | 1 | 0.75 | 0.3 | 46.23 | 1.0 |
| **11** | 19 | 22 | -1 | 1 | 0.75 | 0.3 | 46.23 | 1.0 |
| **12** | 17 | 7 | -1 | 1 | 0.75 | 0.3 | 46.23 | 1.0 |
| **13** | 29 | 1 | 0 | 1 | 0.75 | 0.3 | 46.23 | 1.0 |
| **14** | 31 | 8 | 0 | 1 | 0.75 | 0.3 | 46.23 | 1.0 |
| **15** | 25 | 11 | 0 | 1 | 0.75 | 0.3 | 46.23 | 1.0 |
| **16** | **27** | **12** | **0** | **1** | **0.75** | **0.3** | **46.23** | **1.0** |
| **17** | 30 | 14 | 0 | 1 | 1 | 0.3 | 46.23 | 1.0 |
| **18** | 26 | 21 | 0 | 1 | 0.75 | 0.4 | 46.23 | 1.0 |
| **19** | 28 | 29 | 0 | 1 | 0.75 | 0.3 | 50.26 | 1.0 |
| **20** | 18 | 28 | -1 | 1 | 0.5 | 0.3 | 46.23 | 1.0 |
| **21** | 20 | 16 | -1 | 1 | 0.75 | 0.2 | 46.23 | 1.0 |
| **22** | 22 | 30 | -1 | 1 | 0.75 | 0.3 | 30.66 | 1.0 |
| **23** | 9 | 27 | 1 | 1 | 0.75 | 0.3 | 46.23 | 1.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **24** | 10 | 13 | 1 | 1 | 1 | 0.4 | 50.26 | 1.5 |
| **25** | 11 | 3 | 1 | 1 | 0.5 | 0.4 | 50.26 | 1.5 |
| **26** | 12 | 18 | 1 | 1 | 1 | 0.2 | 50.26 | 1.5 |
| **27** | 24 | 10 | -1 | 1 | 1 | 0.4 | 30.66 | 1.5 |
| **28** | 13 | 25 | 1 | 1 | 0.5 | 0.2 | 50.26 | 1.5 |
| **29** | 14 | 20 | 1 | 1 | 1 | 0.2 | 30.66 | 1.5 |
| **30** | 15 | 2 | 1 | 1 | 0.5 | 0.4 | 30.66 | 1.5 |
| **31** | 16 | 4 | 1 | 1 | 0.5 | 0.2 | 30.66 | 1.5 |

So, the experiments have been conducted by the information obtained from MINTAB, the above chart is obtained using RSM technique. (central composite design)

***II.6 Calculating chip thickness:***

The chip thickness is measured by using the tool maker's microscope just by placing the chip on the work plane of the tool maker's microscope. The least count of the microscope is equal to 0.005mm**.**

***II.7 Calculating chip length:***

The chip length is measured by using the PDF-Xchange Viewer Software just by importing the photographs of the chips and by tracing the objects of the chips in the software the lengths can be determined. The value of the lengths are displaced at the right most bottom.

## III. RESULTS AND DISCUSSIONS:

### III.1 Observation table for chip length and chip thickness:

The chip which are obtained at different input parameters are taken, and their photographs are imported to find lengths and the tool maker's microscope is used for calculating the chip thickness:

| Sl no. | Feed(mm/rev) | d.o.c(mm) | Speed(m/min) | Wear(mm) | L1 | L2 | L3 | L(avg)(mm) | Chip thickness(mm) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.3 | 0.75 | 46.23 | 0.5 | 10.6 | 9.72 | 9.2 | 9.84 | 0.4324 |
| 2 | 0.4 | 1 | 50.26 | 0.5 | 12.31 | 11.98 | 12.4 | 12.213 | 0.943 |
| 3 | 0.4 | 0.5 | 50.26 | 0.5 | 7.1 | 7.5 | 7.43 | 7.343 | 0.577 |
| 4 | 0.2 | 1 | 50.26 | 0.5 | 12.3 | 10.1 | 14.3 | 12.23 | 0.512 |
| 5 | 0.4 | 1 | 30.66 | 0.5 | 11.1 | 14.9 | 13.6 | 13.2 | 0.853 |
| 6 | 0.2 | 1 | 30.66 | 0.5 | 15.7 | 10.4 | 10.9 | 12.33 | 0.48 |
| 7 | 0.4 | 0.5 | 30.66 | 0.5 | 7.9 | 13.2 | 10.1 | 10.4 | 0.5 |
| 8 | 0.2 | 0.5 | 50.26 | 0.5 | 7.0 | 6.8 | 10.2 | 8 | 0.453 |
| 9 | 0.2 | 0.5 | 30.66 | 0.5 | 10.52 | 7.5 | 9.4 | 9.14 | 0.395 |
| 10 | 0.3 | 0.75 | 46.23 | 1 | 8.45 | 7.8 | 12.7 | 9.65 | 0.943 |
| 11 | 0.3 | 0.75 | 46.23 | 1 | 8.3 | 10.3 | 8.4 | 9 | 0.875 |
| 12 | 0.3 | 0.75 | 46.23 | 1 | 8.2 | 10.7 | 6.79 | 8.566 | 0.811 |
| 13 | 0.3 | 0.75 | 46.23 | 1 | 12 | 7.8 | 7.7 | 9.166 | 0.912 |
| 14 | 0.3 | 0.75 | 46.23 | 1 | 7.9 | 10.1 | 8.4 | 8.8 | 0.826 |
| 15 | 0.3 | 0.75 | 46.23 | 1 | 6.4 | 9.0 | 9.8 | 8.425 | 0.9546 |
| 16 | 0.3 | 0.75 | 46.23 | 1 | 8.8 | 8.4 | 12.5 | 9.9 | 0.911 |
| 17 | 0.3 | 1 | 46.23 | 1 | 11.5 | 9.8 | 10.6 | 10.6 | 1.03 |
| 18 | 0.4 | 0.75 | 46.23 | 1 | 9 | 8.66 | 9.2 | 8.956 | 1.088 |
| 19 | 0.3 | 0.75 | 50.26 | 1 | 8.4 | 10.1 | 8.92 | 9.14 | 1.1053 |
| 20 | 0.3 | 0.5 | 46.23 | 1 | 7.2 | 6.6 | 7.8 | 7.2 | 0.8526 |
| 21 | 0.2 | 0.75 | 46.23 | 1 | 9.8 | 8.8 | 11.66 | 10.089 | 0.883 |
| 22 | 0.3 | 0.75 | 30.66 | 1 | 9.1 | 9.8 | 8.50 | 9.135 | 1.101 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 23 | 0.3 | 0.75 | 46.23 | 1.5 | 7.67 | 7.9 | 11.2 | 8.924 | 0.923 |
| 24 | 0.4 | 1 | 50.26 | 1.5 | 10.1 | 7.53 | 8.8 | 8.81 | 1.2643 |
| 25 | 0.4 | 0.5 | 50.26 | 1.5 | 6.5 | 9.4 | 6.7 | 7.53 | 0.9923 |
| 26 | 0.2 | 1 | 50.26 | 1.5 | 8.4 | 6.5 | 10.6 | 8.5 | 0.99 |
| 27 | 0.4 | 1 | 30.66 | 1.5 | 12.5 | 7.9 | 8.0 | 9.466 | 1.253 |
| 28 | 0.2 | 0.5 | 50.26 | 1.5 | 8.9 | 8.8 | 8.4 | 8.71 | 0.933 |
| 29 | 0.2 | 1 | 30.66 | 1.5 | 7.8 | 7.7 | 7.2 | 7.56 | 0.88 |
| 30 | 0.4 | 0.5 | 30.66 | 1.5 | 9.29 | 11.9 | 7.4 | 9.53 | 0.975 |
| 31 | 0.2 | 0.5 | 30.66 | 1.5 | 8.9 | 11.2 | 6.93 | 9.01 | 0.873 |

**III.2 Estimated Regression Coefficients for chip length**
**Response Surface Regression: chip length versus feed, doc, velocity, wear**

| term | Coef | SE Coef | T | P |
|---|---|---|---|---|
| Constant | 9.43105 | 0.2612 | 36.113 | 0.001 |
| feed | 0.97690 | 0.1194 | 8.813 | 0.002 |
| doc | 0.13152 | 0.1194 | 1.102 | 0.287 |
| velocity | -0.40528 | 0.1191 | -3.403 | 0.004 |
| wear | -0.94037 | 0.1194 | -7.877 | 0.000 |
| feed*feed | -0.20057 | 0.3137 | -0.639 | 0.532 |
| doc*doc | 0.42193 | 0.3137 | 1.345 | 0.197 |
| velocity*velocity | -0.30870 | 0.4920 | -0.627 | 0.539 |
| wear*wear | 0.28143 | 0.3197 | 0.897 | 0.383 |
| feed*doc | 0.19538 | 0.1263 | 1.546 | 0.142 |
| feed*velocity | 0.39210 | 0.1240 | 3.163 | 0.006 |
| feed*wear | -0.97088 | 0.1263 | -7.685 | 0.002 |

R-Sq = 93.71% R-Sq(pred) = 76.89% R-Sq(adj) = 88.20%

So, here when the experiment is conducted at 95% confidence levels, 93% has been obtained which gives us the validity of the experiment.

**Analysis of Variance for chip length before modification:**

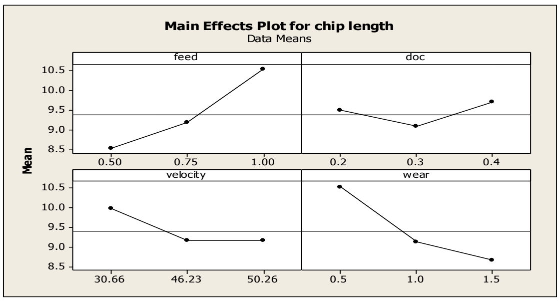
| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| **Regression** | 14 | 60.853 | 60.853 | 4.3466 | 4.02 | 0.000 |
| **Linear** | 4 | 37.719 | 36.209 | 9.0523 | 5.45 | 0.000 |
| **Square** | 4 | 1.152 | 1.152 | 0.2881 | | |
| **Interaction** | 6 | 21.982 | 21.982 | 3.6637 | 4.35 | 0.000 |
| **Residual Error** | 16 | 4.086 | 4.086 | 0.2554 | | |
| **Lack-of-Fit** | 10 | 2.304 | 2.304 | 0.2304 | 0.78 | 0.656 |
| **Pure Error** | 6 | 1.782 | 1.782 | 0.2971 | | |
| **Total** | 30 | 64.939 | | | | |

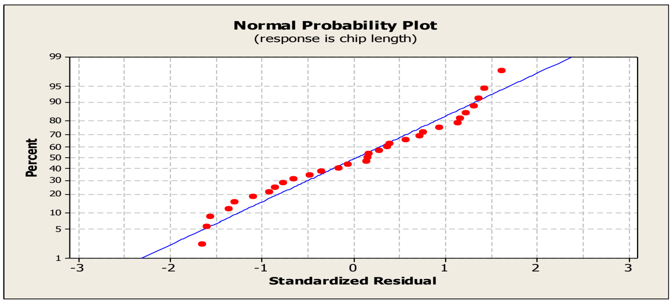
So, the parameters whose p-value is less than 0.05 are taken and again the **co-efficient table** is **modified**.

The predicted equation for chip length after modification is obtained from MINITAB software:

**Chip length**=3.75128+ (5.19933*f)+(18.4344*doc)-(0.0381443*v)+(3.97458*w)+(0.160042*f*v)-(7.767*f*w)-(0.423116*d*v)

**The graphs for chip length are given below:**




**3.3 Estimated co-efficient for chip thickness**:
**Response Surface Regression for chip thickness versus feed, wear, depth of cut, speed.**

| Term | Coef | SE Coef | T | P |
|---|---|---|---|---|
| Constant | 0.818266 | 0.02648 | 30.906 | 0.006 |
| feed | 0.091804 | 0.01210 | 7.585 | 0.002 |
| doc | 0.114005 | 0.01210 | 9.419 | 0.004 |
| velocity | 0.025550 | 0.01208 | 2.116 | 0.050 |
| wear | 0.218896 | 0.01210 | 18.085 | 0.05 |
| feed*feed | -0.013395 | 0.03180 | -0.421 | 0.679 |
| doc*doc | 0.030805 | 0.03180 | 0.969 | 0.347 |
| velocity*velocity | 0.250249 | 0.04988 | 5.017 | 0.03 |
| wear*wear | -0.276995 | 0.03180 | -8.710 | 0.007 |
| feed*doc | 0.066312 | 0.01281 | 5.177 | 0.0052 |
| feed*velocity | 0.001638 | 0.01257 | 0.130 | 0.898 |
| feed*wear | -0.015563 | 0.01281 | -1.215 | 0.242 |
| doc*velocity | -0.004669 | 0.01257 | -0.372 | 0.715 |
| doc*wear | -0.014025 | 0.01281 | -1.095 | 0.290 |
| velocity*wear | -0.001636 | 0.01257 | -0.130 | 0.898 |

R-Sq = 97.45%  R-Sq(pred) = 92.80%  R-Sq(adj) = 95.22%

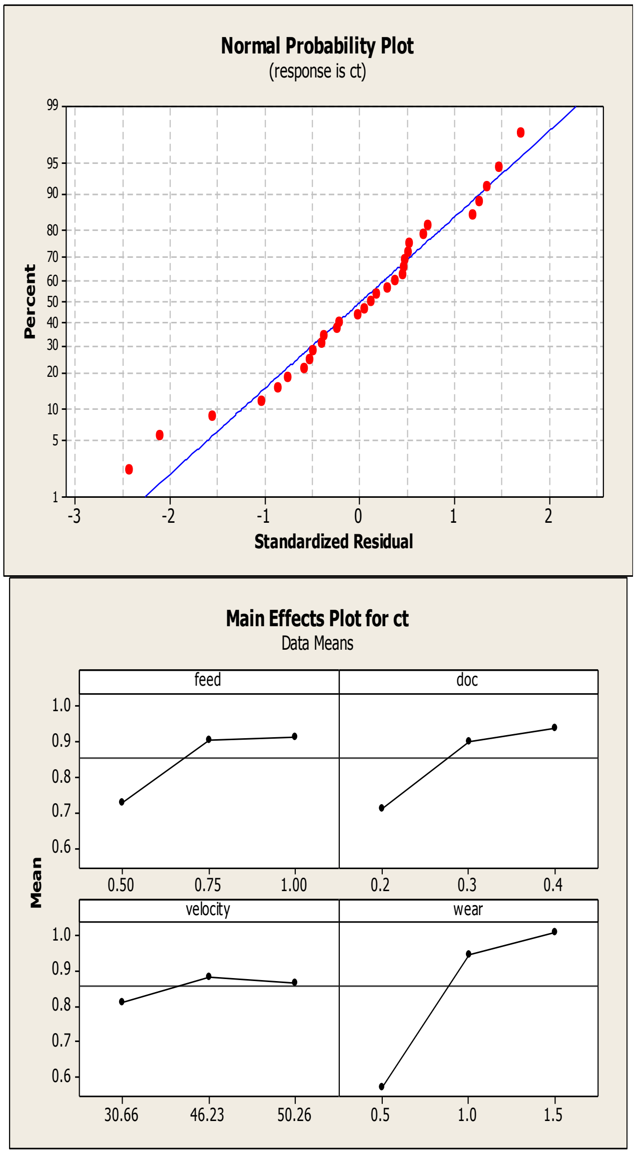
So, here when the experiment is conducted at 95% confidence levels, 93% has been obtained which gives us the validity of the experiment.

**Analysis of Variance for chip thickness before modification:**

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Regression | 14 | 1.60428 | 1.60428 | 0.114591 | 3.66 | 0.045 |
| Linear | 4 | 1.26677 | 1.25412 | 0.313531 | 1.45 | 0.04 |
| Square | 4 | 0.25968 | 0.25968 | 0.064921 | 4.73 | 0.028 |
| Interaction | 6 | 0.07783 | 0.07783 | 0.012972 | 4.94 | 0.07 |
| Residual Error | 16 | 0.04200 | 0.04200 | 0.002625 | | |
| Lack-of-Fit | 10 | 0.02353 | 0.02353 | 0.002353 | 0.76 | 0.663 |
| Pure Error | 6 | 0.01847 | 0.01847 | 0.003078 | | |
| Total | 30 | 1.64628 | | | | |

So, the parameters whose p-value is less than 0.05 are taken and again the **co-efficient table** is **modified.**
The predicted equation for chip thickness after modification is obtained from MINITAB software as:
**Chip thickness**=3.63227-(0.48106*f)-(0.852375*doc)-(0.217756*v)+(2.59453*w)+(0.00272322*v*v)-(1.07848*w*w)+ (2.6250*f*doc)

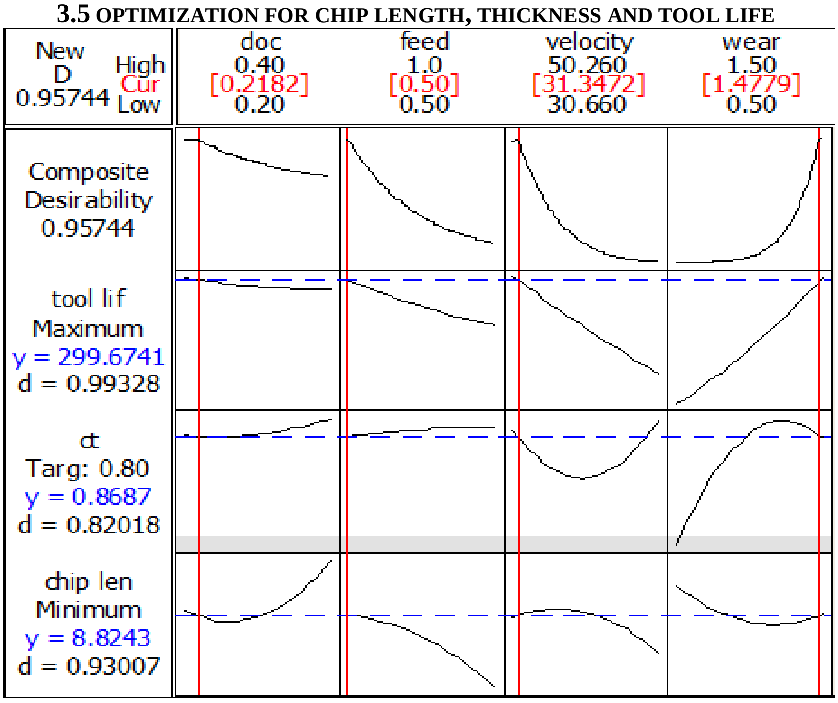
**The graphs for chip thickness is given below:**



### 3.4 OBSERVATION TABLE FOR TOOL LIFE:

| Sl no: | Feed (mm/rev) | Doc(mm) | Speed(m/min) | Wear(mm) | tool life(min) |
|---|---|---|---|---|---|
| 1 | 0.75 | 0.3 | 46.23 | 0.5 | 4.63 |
| 2 | 1 | 0.4 | 50.26 | 0.5 | 2.7923 |
| 3 | 0.5 | 0.4 | 50.26 | 0.5 | 4.778 |
| 4 | 1 | 0.2 | 50.26 | 0.5 | 3.0982 |
| 5 | 1 | 0.4 | 30.66 | 0.5 | 11.5632 |
| 6 | 1 | 0.2 | 30.66 | 0.5 | 12.83 |
| 7 | 0.5 | 0.4 | 30.66 | 0.5 | 19.787 |
| 8 | 0.5 | 0.2 | 50.26 | 0.5 | 5.6301 |
| 9 | 0.5 | 0.2 | 30.66 | 0.5 | 21.955 |
| 10 | 0.75 | 0.3 | 46.23 | 1 | 26.2058 |
| 11 | 0.75 | 0.3 | 46.23 | 1 | 26.2058 |
| 12 | 0.75 | 0.3 | 46.23 | 1 | 26.2058 |
| 13 | 0.75 | 0.3 | 46.23 | 1 | 26.2058 |
| 14 | 0.75 | 0.3 | 46.23 | 1 | 26.2058 |
| 15 | 0.75 | 0.3 | 46.23 | 1 | 26.2058 |
| 16 | 0.75 | 0.3 | 46.23 | 1 | 26.2058 |
| 17 | 1 | 0.3 | 46.23 | 1 | 20.9686 |
| 18 | 0.75 | 0.4 | 46.23 | 1 | 25.099 |
| 19 | 0.75 | 0.3 | 50.26 | 1 | 20.611 |
| 20 | 0.5 | 0.3 | 46.23 | 1 | 35.881 |
| 21 | 0.75 | 0.2 | 46.23 | 1 | 27.849 |
| 22 | 0.75 | 0.3 | 30.66 | 1 | 85.357 |
| 23 | 0.75 | 0.3 | 46.23 | 1.5 | 72.2147 |
| 24 | 1 | 0.4 | 50.26 | 1.5 | 43.5277 |
| 25 | 0.5 | 0.4 | 50.26 | 1.5 | 74.4842 |
| 26 | 1 | 0.2 | 50.26 | 1.5 | 82.6454 |
| 27 | 1 | 0.4 | 30.66 | 1.5 | 180.2607 |
| 28 | 0.5 | 0.2 | 50.26 | 1.5 | 82.6454 |
| 29 | 1 | 0.2 | 30.66 | 1.5 | 200.0118 |
| 30 | 0.5 | 0.4 | 30.66 | 1.5 | 308.4604 |
| 31 | 0.5 | 0.2 | 30.66 | 1.5 | 342.2583 |

### 3.5 OPTIMIZATION FOR CHIP LENGTH, THICKNESS AND TOOL LIFE



The values in (red color) the above plot show the optimum conditions for machining. So, from the optimization plot the optimum machining parameters for maximum chip length and maximum tool life are obtained as **chip length=8.8243mm**, **tool life =299.6741min**, **chip thickness =0.8687 mm** at

***Depth of cut =0.2182 mm, feed =0.50mm/rev, velocity=31.3472m/min, wear=1.4779mm***

**4.CONCLUSIONS:**

(a) In this experimental study , the effect of different parameters like feed, depth of cut, cutting speed and flank wear on the chip length and chip thickness is studied. Main aim of the study was to analyze the effect of flank wear on response parameters.

(b) By analyzing the result , we can conclude that besides different parameters like feed , depth of cut, cutting speed , the flank wear contributes a lot in order to control the chip lengths and there by increasing the tool life.

(c) Besides the cutting speed , flank wear is also an important factor which contributes for the increase in tool life .

By considering the optimal values of parameters from optimal graph, we can a perfect machining conditions for maximum tool life and minimum chip length for an optimal value of chip thickness.

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