EVALUATION OF CHIP BREAKER USING FLANK WEAR

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR DEGREE OF

Bachelor of Technology
in
Mechanical Engineering

By

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Department of Mechanical Engineering
National Institute of Technology
Rourkela

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Under the Guidance of
Prof. C.K. Biswas

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2010

National Institute of Technology
ROURKELA

CERTIFICATE

This is to certify that the thesis entitled, "**EVALUATION OF CHIP BREAKER WITH FLANK WEAR"** submitted by **Sri Sumit Goyal** in partial fulfillment of the requirements for the award of Bachelor of Technology in **Mechanical Engineering** at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

Date:

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ABSTRACT

Machining is a common and essential part of manufacturing of almost all metal products, and also or other materials like wood and plastic. In the 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 during machining and hence appropriate control of the chip shape becomes a very important task for maintaining reliable machining process. The continuous chip generated during turning operation deteriorates the workpiece precision and causes safety hazards for the operator. In particular, effective chip control is necessary for a CNC machine or automatic production system because any failure in chip control can cause the lowering in productivity and the worsening in operation due to frequent stop. Chip control in turning is difficult in the case of mild steel because chips are continuous. Thus the development of a chip breaker for mild steel is an important subject for the automation of turning operations. In this study, the role of different parameters like speed, feed and depth of cut, tool flank wear and chip breaker height and width are studied. In this study chip characteristics were tested for changing tool flank wear values. Response surface methodology was used to analyze the relationship between several explanatory variables and two predecided response variables. The chips obtained were found to have greater thickness at low feed and depth of cut, and gradually decreased as feed and depth of cut increases. The analysis lead to the conclusion that cutting speed and depth of cut are the most significant factors along with their higher order terms and interactions between variables.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

Conventional **machining**, one of the most important material removal methods, is a collection of material-working processes in which power-driven machine tools, such as lathes, milling machines, and drill presses, are used with a sharp cutting tool to mechanically cut the 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.

Maximization in productivity is required in present day manufacturing methods. Introduction of Computer Integrated Manufacturing (CIM) system and Flexible Manufacturing System (FMS) have led to maximization in productivity. Keeping in eye the present demanding situation, the quality of cutting tools has been improved continuously for better and more efficient cutting techniques.

Numerous chips are being generated in short time during machining operarions which requires effective control of lenth and thickness of chips which is one 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.

The chip shape generated in cutting processing is closely related to product productivity. If an incorrect chip shape is generated, the production is highly inefficient in terms of time and money because of safety hazards to the operator, damage of production tools and work piece surface, not to mention the loss in productivity due to the frequent stopping of the production machine.

Failure in chip control has a significant effect on surface roughness of the workpiece, precision of product, and wear of tool, etc. However, chip breaker performance testing requires significant time and efforts as eveloping new cutting inserts necessitates forming, sintering, grinding, and coating processes, extends developing time and involves expensive research.

Tool wear describes the gradual failure of tool because of regular operation. It is a term often associated with tipped tools, tool bits, or drill bits that are used with machine tools. Flank wear is a type of wear in which the portion of the tool in contact with the finished part erodes. This type of wear can be described using tool life expectancy equation. In this study we have varied tool flank wear with other parameters like feed, depth of cut and speed to observe its effects on chip shapes.

Chip control is highly essential to ensure reliable operation in automated as well as traditional or manual control machining systems. Effective chip control includes predictability of chip form/chip breakability for a given set of input machining conditions. However because of complexity of chip formation mechanism under different combinations of machining conditions studying the effect of individual parameter and their mutual interactions, it is difficult to predict the chip formation process and chip geometries in advance.

1.1 CHIP BREAKER

Chip breaker is defined as the modifications of the face to control or break the chip, consisting of either an integral groove or integral or attached obstruction. The controlling and breaking of chip can be accomplished by chip breakers by improving chip breakability which results in efficient chip control and improved productivity. It also decreases cutting resistance which also leads to a greater tool life, and gives a better surface finish to the work-piece. A chip breaker is usually used for improving chip breakability by decreasing the chip radius. The chip breaker pattern affects chip breakability.

The principle of chip breaker is that fracture is generated by the force and moment acting on chip surface. A chip breaker acts by controlling the radius of the chip and directing the chip in such a way that it breaks into a shorter length, in addition to an appropriate chip breaker design, it is necessary to have the correct tool geometry so that the chip will follow the proper path across the tool face.

1.2 CHIP BREAKING IN SINGLE POINT CUTTING TOOL

In the machining process the tool is oriented in such a manner that the excess material is removed from the parent work-piece in the form of chips. When a cutting tool removes a layer from the work piece, the uncut layer is first elastically deformed followed by plastic deformations separation taking place near the cutting edge of the tool, however it is difficult to postulate that deformation is concentrated at one point or one line. Chip is formed by a process of deformation when subjected by a force impressed by the cutting tool on the work material.

Generation of narrow and long chips during the machining by a single point cutting tool lead to problems such as difficulty in chip handling, surface damage of products, tangling together and safety hazards for the operator. Therefore, it is necessary to cut chips to the appropriate size.

Chip breaking is done in two ways

- self breaking :- This is accomplished by without using a separate chip breaker either as an attachment or an additional geometric modification of the tool.
- Forced chip breaking :- If the hot continuous chip does not become enough curl or work hardened it may not break, in this case the running chip is forced to bend or closely curl so that it breaks into pieces.

Various factors that affect the chip formation analysis for continuous chips can be depth of cut to feed ratio, number of active or passive cutting edges, length of cutting edge to width of cut ratio, cutting speed, inclination angle (ʎ), rake angle, depth of cut to diameter ratio (for turning and similar cases), action of cutting fluids etc. Analysis of these factors lead to better designs of chip breaker.

Chip breaking is usually caused by curling of the removed metal and than striking against work-piece or tool. Different Patterns and sizes of broken chips are obtained 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.

Externally applied forces increases the fracture strain of the chip and decreases the radius of the chip, so for determination of chip pattern these forces should be kept at optimum levels. Even though much research has been done and still being done on to predict the chip behavior and to achieve maximum chip control but it is still difficult to break chips in the finishing of mild steel.

1.3 CLASSIFICATION OF CHIP PATTERN

Chips are classified either on the basis of mechanism of chip formation or the inal shape of the chip. Chip pattern has been classified by CIRP and INFOS, but each classification is very similar. Chip pattern classified by INFOS is illustrated in fig. 1

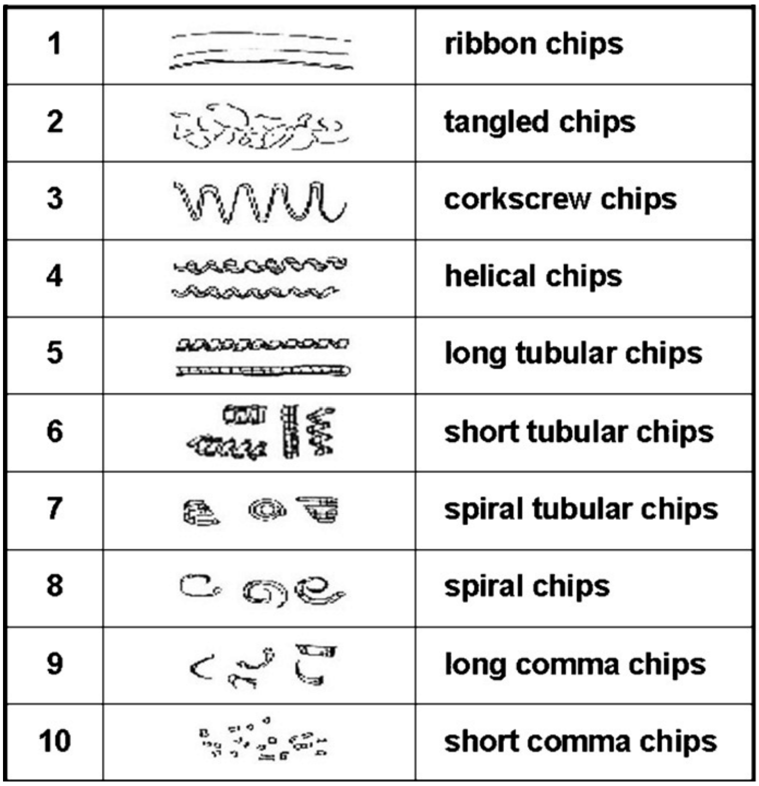


Fig.1 Classification of chip pattern (INFOS)

1.4 TOOL WEAR

Tool wear describes the gradual failure of cutting tools due to regular operation. It is a term often associated with tipped tools, tool bits, or drill bits that are used with machine tools.

Types of wear include:

- **flank wear** in which the portion of the tool in contact with the finished part erodes. Can be described using the Tool Life Expectancy equation.

- **crater wear** in which contact with chips erodes the rake face. This is somewhat normal for tool wear, and does not seriously degrade the use of a tool until it becomes serious enough to cause a cutting edge failure.

- **built-up edge** in which material being machined builds up on the cutting edge. Some materials (notably aluminum and copper) have a tendency to anneal themselves to the cutting edge of a tool. It occurs most frequently on softer metals, with a lower melting point. It can be prevented by increasing cutting speeds and using lubricant. When drilling it can be noticed as alternating dark and shiny rings.

- **glazing** occurs on grinding wheels, and occurs when the exposed abrasive becomes dulled. It is noticeable as a sheen while the wheel is in motion.

- **edge wear**, in drills, refers to wear to the outer edge of a drill bit around the cutting face caused by excessive cutting speed. It extends down the drill flutes, and requires a large volume of material to be removed from the drill bit before it can be corrected.

The useful life of tool is limited by tool wear. Wear can be described as the total loss of weight or mass of the sliding pairs accompanying friction.

CHAPTER 2

BRIEF INTRODUCTION OF THE PROJECT

2.1 NEED AND PURPOSE OF CHIP BREAKING

Continuous machining operations like turning of ductile metals, produce continuous chips of different shapes which leads to their handling and disposal problems and are not safe for working. The problems become acute when ductile but strong metals like steels are machined at high cutting velocity for high MRR by flat rake face type carbide or ceramic inserts.

The sharp edged hot continuous chip that comes out at very high speeds becomes dangerous to the operator and the other people working In the vicinity. Very small sized chips pose serious problems for the safety of the workman working on the machine. These chips comes out of the machine in uncontrolled directions that makes it difficult to handle and dispose. When chips breaking is not proper long continuous chips may cause entangling with the rotating job. That may impair the surface finish of the product.

Therefore to get the proper surface finish and highly efficient machining operation it is essentially needed to break continuous chips into small regular pieces for

- Safety of the working people
- Prevention of damage of the product
- Easy collection and disposal of chips.
- Improving machinability by reducing the chip-tool contact area cutting forces and crater wear of the cutting tool.

Therefore this study tends to solve the problems of uncontrolled chip formation and construct the basis of improved factory automation by using chip breakers of the attached obstruction type, which represents a relatively new concept in chip breaking.

In this projest work, parameters like cutting speed, feed, depth of cut, height and width of chip breaker and along with that one other parameter tool flank wear will be taken as input parameter and their effect on the chip breakability will be studied, so that better control of chip can be done.

CHAPTER 3

LITERATURE REVIEW

3. LITERATURE REVIEW

3.1 EXPERIMENTAL STUDIES ON CHIP BREAKER

J.D.Kim et.al. [1], has presented experimental research dealing with the modeling of chip formation process using different insert geometries and leas to important characteristic parameters in chip control. The study is focused on chip breaker design by analyzing characteristics like cutting speed, feed and depth of cut for experimental cutting of mild steel with chip breaker. It emphasizes on that attached type chip breaker is better than a grooved one. In this work a designed chip breaker with three chip breakers attached –two side curl chip breakers and one up curl chip breaker is used for fine and rough breaking. The chip breaker is similar to conventional attached to the chip breaker except its shape is an arc.

The experiment chip breaking conditions in to three regions – uncontrolled, transient and control. The experimental research establishes that for finish turning operation with that of curl less than 1 mm designed chip breaker is much more effective than conventional chip breaker. At cutting speeds less than 150 m/min the chip breaking conditions are better than at high cutting speeds. Major factor of chip breaking is the chip flow direction in the designed chip breaker. Increasing the cutting speed changes the chip type from side curl to up curl.

R.M.D. Mesquita et.al [2], devised a method for the prediction of cutting forces to predict the cutting forces for a wide range of cutting conditions. considering the indentation and ploughing effect and pressure of a parallel groove type chip breaker. The technique is based on the measurement of chip breaker geometry and the effective side rake angle. Tests are done on martensitic stainless steel using coated carbide tools. Two types of tests are discussed in the paper, one to access the indentation or ploughing effect and other to establish the mean dynamic stress, mean friction angle and machinability constant and to check the fisibility of the model.

Hong-Gyoo Kim et.al [3], used the neural network analysis to analyze the performance of a commercial chip breaker. Form parameters such as depth of cut, land breadth depth of cut and radius are provided as input to the neural network. The experimental work established the fact that as the chip breaker depth increases, and the width decreases, performance of chip breaking was excellent at the finishing area. However, the chip breakability was excellent at the roughing area as the depth decreased and the width increased.

N.S.Das et.al [4] developed a field model for orthogonal cutting with step type chip breaker with adhesion friction at chip tool interface using kudo's basic slip line field. An alternate method is suggested for estimation of breaking strain in the chip. The analysis showed that the breaking strain in the chip is the most important factor on which chip breaking depends and a method was suggested for determining chip breaker distance for any given feed and chip breaker height for effective chip breaking. It also showcased that the chip breaking criterion is based neither on specific cutting energy nor on material damage which can be taken as adequate criterion for chip breaking.

K.P.Maity et.al. [5] presented a theoretical analysis of metal machining with an orthogonal cutting tool using the slip line field analysis given by Dewhurst assuming constant friction. The height of chip breaker is kept at four times the that of uncut chip thickness while its position with respect to principal cutting edge is varied. The paper shows that the position of chip breakers vary within a range for under breaking and over breaking conditions for a particular feed. The optimum position for the chip breaker is around 13-14 times the uncut chip thickness. With the step heights used in the experiment it was seen that there is no chip breaking effect when the chip breaker position is more than 28.5 times the uncut chip thickness.

J.P. Choi et al [6] proposed a systematic chip breaking prediction method using a 3d cutting model with the equivalent parameter concept. A new type insert with medium type insert for medium finish operations with variable parameters was designed by modifying the commercial one. The chip strain ratio is used as a chip breaking criteria. In this paper the effect of each parameter on chip breakage are examined to simulation, a new insert with variable parameters along the main cutting edge is designed and simulated.

Shi, T. et al [7] developed a slip line field model for orthogonal cutting with chip breake and flank wear. The model predicts a linear relationship between flank wear and cutting force components. The results also show that non-zero strains occur at and below the machined surface when machining with a worn tool. Severity and depth of deformation below the machined surface increases with increasing flank wear. Forces acting on the chip breaker surface are found to be small and suggest that chip control for automated machining may be feasible with other means.

3.2 Principles of chip-breaking

The principles and methods of chip breaking are generally classified as follows:

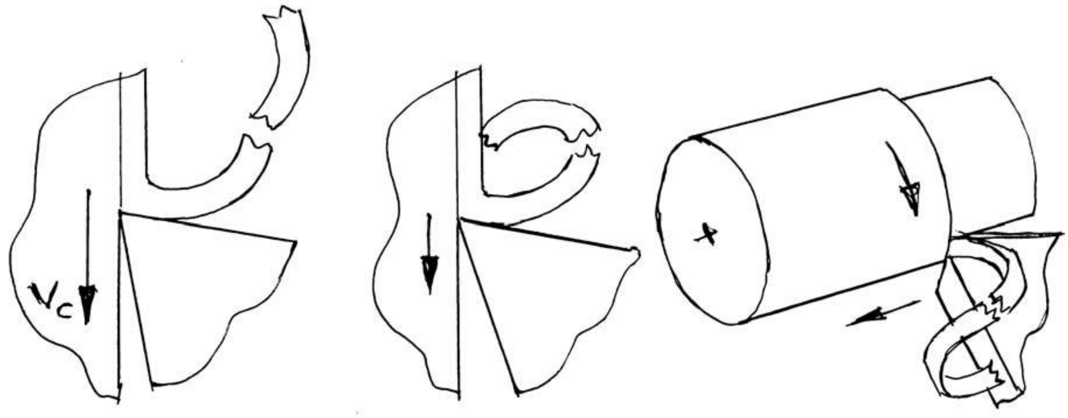
- **Self breaking**: This is accomplished without using a separate chip-breaker either as an attachment or an additional geometrical modification of the tool.
- **Forced chip breaking** by additional tool geometrical features or devices

(a) Self breaking of chips

Ductile chips usually become curled or tend to curl (like clock spring) even in machining by tools with flat rake surface due to unequal speed of flow of the chip at its free and generated (rubbed) surfaces and unequal temperature and cooling rate at those two surfaces. With the increase in cutting velocity and rake angle (positive) the radius of curvature increases, which is more dangerous. In case of oblique cutting due to presence of inclination angle, restricted cutting effect etc. the curled chips deviate laterally resulting helical coiling of the chips.

The curled chips may self break:

- By natural fracturing of the strain hardened outgoing chip after sufficient cooling and spring back as indicated in Fig.3.1 (a). This kind of chip breaking is generally observed under the condition close to that which favors formation of jointed or segmented chips.
- By striking against the cutting surface of the job, as shown in Fig. 3.1 (b), mostly under pure orthogonal cutting.
- By striking against the tool flank after each half to full turn as indicated in Fig 3.1(c).



(a) Natural (b) striking on job (c) striking at tool flank

Fig. 3.1 Principles of self breaking of chips.

(b) Forced chip-breaking

The hot continuous chip becomes hard and brittle at a distance from its origin due to work hardening and cooling. If the running chip does not become enough curled and work hardened, it may not break. In that case the running chip is forced to bend or closely curl so that it breaks into pieces at regular intervals. Such broken chips are of regular size and shape depending upon the configuration of the chip breaker.

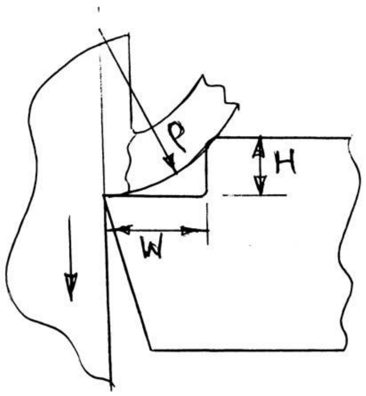
Chip breakers are basically of two types:

• In-built type

• Clamped or attachment type

In-built breakers are in the form of step or groove at the rake surface near the cutting edges of the tools. Such chip breakers are provided either

- After their manufacture – in case of HSS tools like drills, milling cutters, broaches etc and brazed type carbide inserts.
- During their manufacture by powder metallurgical process – e.g., throw away type inserts of carbides, ceramics and cermets.



W = width, **H** = height, **β** = shear angle

Fig. 3.2 Principle of forced chip breaking.

The unique characteristics of in-built chip breakers are:

- The outer end of the step or groove acts as the heel that forcibly bends and fractures the running chip
- Simple in configuration, easy manufacture and inexpensive
- The geometry of the chip-breaking features are fixed once made (i.e., cannot be controlled)
- Effective only for fixed range of speed and feed for any given tool-work combination.

Some commonly used step type chip breakers:

a. Parallel step
b. Angular step; positive and negative type
c. Parallel step with nose radius – for heavy cuts

Groove type in-built chip breaker may be of

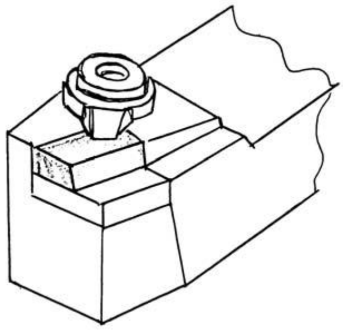
- Circular groove
- Tilted V groove

(c) Clamped type chip-breaker

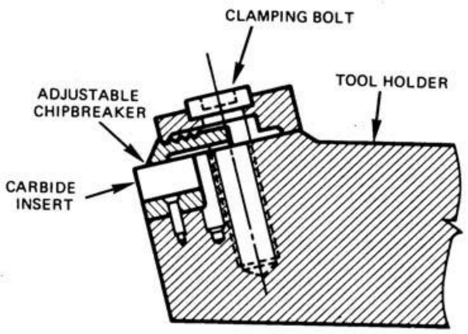
Clamped type chip breakers work basically in the principle of stepped type chip-breaker but have the provision of varying the width of the step and / or the angle of the heel.

Fig. 3.3 schematically shows three such chip breakers of common use:

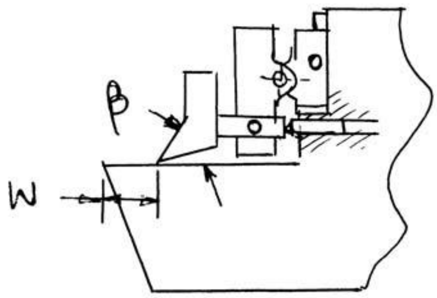
a. With fixed distance and angle of the additional strip – effective only for a limited domain of parametric combination
b. With variable width (W) only – little versatile
c. With variable width (W), height (H) and angle (β) – quite versatile but less rugged and more expensive.



(a) Fixed geometry



(b) variable width



(c) Variable width and angle

Fig. 3.3 Clamped type chip breakers

CHAPTER 4

EXPERIMENTAL WORK

In this section the procedure adopted for the experiment is explained. Like the tools for the experiment were selected among the five number of tools by checking the various geometrical parameters of the different tools like rake angles and end relief angles using tool maker's microscope. Selected tools are prepared for experimenting by attaching chip breaker. The experiment was carried out on a heavy duty HMT lathe machine and measurements on the samples were done using tool maker's microscope.

4.1 PROCEDURE:

Before starting the experiment, tool to be used in the experiment was selected by making different measurements on three different cutting tools using the tool maker's microscope. Different parameters measured for five tools are given in table 1.

Table.1 Measured parameters for differant tools

TOOL NO.	ϕp	ϕs	γ_x	γ_y	W(mm)	H(mm)
I	89.78˚	0.22˚	13.41˚	1.267˚	4.35	.52
II	88.38˚	1.62˚	10.760˚	2.938˚	2.5	.22
III	89.86˚	0.14˚	14.811˚	0.543˚	2.5	.67

Tool III was finally selected for the experiment. Tool wear was initially taken as 0 and it was changed by filing using a flat file. The experiment was carried out b varying different parameters like speed, feed, depth of cut, cutting speed and tool flank wear as per the table.2. Cutting experiments were carried out on a heavy duty HMT lathe as shown in figure 4.1. The tool was fitted in the tool post as shown in fig. 4.2.

Each experiment was performed with continuous straight turning with coolant on. The experimental conditions were determined by using the response surface methodology. Table.3 shows the different steps of values of various parameters used in the experiment.

Fig .4.1 Heavy duty HMT lathe machine

Fig 4.2 Experimental set up (cutting tool with workpiece)

Table 2: Experimental conditions

Condition	Units	Value
Cutting speed	m/min	40, 50, 60
Depth of cut	mm	0.1, 0.3, 0.5
Feed	mm/rev	0.1, 0.3, 0.5
Cutting condition		Flood cooling
Tool		Relief angle 5° Rake angle 5° Side rake angle 0°
Tool material		HSS
Workpiece material		Mild steel

Table.3: Experiment Input Chart

S.No.	Std Order	RunOrder	PtType	Blocks	F (mm/rev)	V (m/min)	D (mm)	Wear (mm)
1	1	19	1	1	0.1	27	0.1	0
2	2	6	1	1	0.3	27	0.1	0
3	3	24	1	1	0.1	45	0.1	0
4	4	23	1	1	0.3	45	0.1	0
5	23	9	-1	1	0.2	35	0.2	0
6	5	15	1	1	0.1	27	0.3	0
7	6	5	1	1	0.3	27	0.3	0
8	7	26	1	1	0.1	45	0.3	0
9	8	31	1	1	0.3	45	0.3	0
10	21	17	-1	1	0.2	35	0.1	0.5
11	19	22	-1	1	0.2	27	0.2	0.5
12	17	7	-1	1	0.1	35	0.2	0.5
13	29	1	0	1	0.2	35	0.2	0.5
14	31	8	0	1	0.2	35	0.2	0.5
15	25	11	0	1	0.2	35	0.2	0.5
16	27	12	0	1	0.2	35	0.2	0.5
17	30	14	0	1	0.2	35	0.2	0.5
18	26	21	0	1	0.2	35	0.2	0.5
19	28	29	0	1	0.2	35	0.2	0.5
20	18	28	-1	1	0.3	35	0.2	0.5
21	20	16	-1	1	0.2	45	0.2	0.5
22	22	30	-1	1	0.2	35	0.3	0.5
23	9	27	1	1	0.1	27	0.1	1
24	10	13	1	1	0.3	27	0.1	1
25	11	3	1	1	0.1	45	0.1	1
26	12	18	1	1	0.3	45	0.1	1
27	24	10	-1	1	0.2	35	0.2	1
28	13	25	1	1	0.1	27	0.3	1
29	14	20	1	1	0.3	27	0.3	1
30	15	2	1	1	0.1	45	0.3	1
31	16	4	1	1	0.3	45	0.3	1

CHAPTER 5

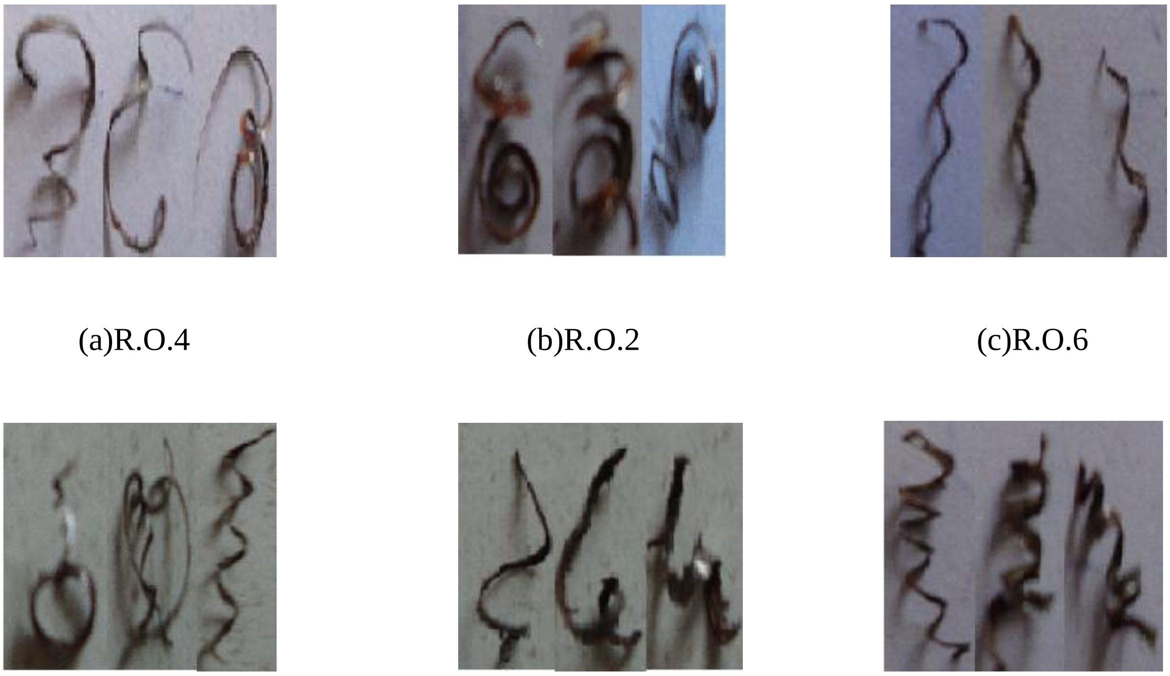
RESULTS AND DISCUSSIONS

Table 4 shows the observation table for the experimental work on the lathe machine. In the table first column contains the run order value. Onsecutive column show value of feed, cutting speed, depth of cut, flank wear, measured L values and measured chip thickness.

Table 4 : Observation table

Run Order	f (mm)	V (m/min)	d (mm)	Wear (mm)	L1 (mm)	L2 (mm)	L3 (mm)	L(avg) (mm)	ChipThickness (mm)
19	0.1	27	0.1	0	4.98	4.09	4.94	4.67	0.308
6	0.3	27	0.1	0	18	12.05	11.4	13.81	0.305
24	0.1	45	0.1	0	17.73	37.47	38.93	31.37	0.124
23	0.3	45	0.1	0	23.91	23.68	24.33	23.97	0.201
9	0.2	35	0.2	0	6.99	6.09	7.73	6.93	0.241
15	0.1	27	0.3	0	6.55	7.27	10	7.904	0.287
5	0.3	27	0.3	0	11.97	6.89	8.22	9.02	0.455
26	0.1	45	0.3	0	9.2	12.07	9.49	10.253	0.182
31	0.3	45	0.3	0	19.2	15.83	14.19	16.4	0.304
17	0.2	35	0.1	0.5	42.19	13.6	13.26	23.01	0.262
22	0.2	27	0.2	0.5	16.47	28.09	18.27	20.94	0.164
7	0.1	35	0.2	0.5	13.8	16.74	19.63	16.72	0.23
1	0.2	35	0.2	0.5	9.15	10.6	7.04	8.93	0.287
8	0.2	35	0.2	0.5	12.21	33.58	20.1	21.96	0.222
11	0.2	35	0.2	0.5	10.89	10.8	12.8	11.49	0.221
12	0.2	35	0.2	0.5	10.27	14.07	11.05	11.79	0.288
14	0.2	35	0.2	0.5	20.37	19.36	18.36	19.36	0.255
21	0.2	35	0.2	0.5	20.37	19.36	18.36	19.36	0.255
29	0.2	35	0.2	0.5	20.37	19.36	18.36	19.36	0.255
28	0.3	35	0.2	0.5	32.4	19.65	25.55	25.86	0.398
16	0.2	45	0.2	0.5	45.45	33.28	39.24	39.32	0.207
30	0.2	35	0.3	0.5	45.39	50.24	26.64	40.75	0.268
27	0.1	27	0.1	1	12.66	7.12	6.94	8.9	0.313
13	0.3	27	0.1	1	25.65	21.62	18.02	21.76	0.367
3	0.1	45	0.1	1	25.65	21.62	18.02	21.76	0.367
18	0.3	45	0.1	1	16.47	15.65	20.86	17.66	0.276
10	0.2	35	0.2	1	17.15	15.97	8.89	13.73	0.313
25	0.1	27	0.3	1	16.87	15.09	17.29	16.41	0.298
20	0.3	27	0.3	1	28.41	21.09	11.58	20.36	0.299
2	0.1	45	0.3	1	24.1	27.8	30.04	27.31	0.198
4	0.3	45	0.3	1	30.85	28.73	28.62	29.4	0.385

Figure 5.1(a) to 5.1 (e) show photographs of some chip samples obtained for different input parameters from run orders 4, 2, 6, 8, 10 and 3 respectively. Measurements of chip length are done by using these photographs with the help of pdf-xchangeviewer software. Chip thickness is measured with the help of tool maker's microscope.



(a)R.O.4 (b)R.O.2 (c)R.O.6

(d)R.O.8 (e)R.O.10 (f)R.O.3

Figure 5.1 : Photographs of chip samples obtained from different run orders

5.1 RESPONSE SURFACE METHODOLOGY FOR L(avg)

RESPONSE SURFACE REGRESSION : L(avg) versus f, V, d, Wear

The experimental results were analyzed by RSM using Minitab software. RSM explores the relationship between several explanatory variables and one or more response variables. The main idea of RSM is to use a set of designed experiments to obtain an optimal response. Using this method, various tables were analyzed to see the relationship of different variables and their significance.

From table.5 regression coefficient of L(avg) vs f, d , v and wear are analysed. This table shows that V, wear*wear, V*V and d*wear have a significant effect on the value of average chip length whereas wear also have a little effect on L(avg). In this regression R-square value is 72.4% which shows fairly feasible experimental results. The analysis was done using uncoded units.

Table.5 Estimated Regression Coefficients for L(avg)

Term	Coef	SE Coef	T	P
Constant	116.189	52.760	2.202	0.043
F	40.079	155.731	0.257	0.800
V	-7.245	3.219	-2.251	0.039
D	46.625	155.731	0.299	0.768
Wear	39.388	19.955	1.974	0.066
f*f	119.461	352.382	0.339	0.739
V*V	0.118	0.044	2.685	0.016
d*d	-121.539	352.382	-0.345	0.735
Wear*Wear	-39.062	14.095	-2.771	0.014
f*V	-1.998	1.576	-1.268	0.223
f*d	-20.606	141.917	-0.145	0.886
f*Wear	14.871	28.383	0.524	0.608
V*d	-0.723	1.576	-0.459	0.652
V*Wear	-0.335	0.315	-1.064	0.303
d*Wear	69.679	28.383	2.455	0.026

S = 5.677 R-Sq = 72.4% R-Sq(adj) = 48.3%

Table.6 shows variance analysis for L(avg). From this chart we can infer that L(avg) depends mainly upon square terms in the equation. Effect of linear and interaction terms are negligible for determination of L(avg). Lack-of-fit value is low that indicates the validity of the experimental setup.

Table.6 variance analysis for L(avg) before modification

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	1354.5	1354.5	96.75	3.00	0.019
Linear	4	679.5	246.3	61.58	1.91	0.158
Square	4	376.2	376.2	94.06	2.92	0.055
Interaction	6	298.8	298.8	49.80	1.55	0.227
Residual Error	16	515.6	515.6	32.22		
Lack-of-Fit	10	328.5	328.5	32.85	1.05	0.497
Pure Error	6	187.1	187.1	31.19		
Total	30	1870.1				

RESPONSE SURFACE REGRESSION: L(avg) versus V, d, Wear

Analysis is again done by using response surface method by removing terms with negligible effect on the value of average chip length. Table.7 shows the regression coefficient values for L(avg). This shows that length of chip depends upon speed of cutting V, depth of cut d, wear, V*V, Wear*Wear and d*Wear. There respective coefficients are given in the the table.

Table.7 Estimated Regression Coefficients for L(avg) after modification

Term	Coef	SE Coef	T	P
Constant	144.897	44.9419	3.224	0.004
V	-7.949	2.6122	-3.043	0.006
d	-32.063	18.4791	-1.735	0.096
Wear	30.368	12.9893	2.338	0.028
V*V	0.118	0.0361	3.273	0.003
Wear*Wear	-39.097	11.5486	-3.385	0.002
d*Wear	69.679	26.8910	2.591	0.016

S = 5.378 R-Sq = 62.9% R-Sq(adj) = 53.6%

R-square value is 62.9% which indicate fairly feasible analysis. Table.8 shows the variance analysis of average chip length after . Lack-of-fit value is in the acceptable range.

Table.8 Analysis of Variance for L(avg) after modification

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	6	1175.9	1175.9	195.98	6.78	0.000
Linear	3	611.3	401.2	133.74	4.62	0.011
Square	2	370.4	370.4	185.21	6.40	0.006
Interaction	1	194.2	194.2	194.21	6.71	0.016
Residual Error	24	694.2	694.2	28.93		
Lack-of-Fit	8	238.1	238.1	29.77	1.04	0.445
Pure Error	16	456.1	456.1	28.50		
Total	30	1870.1				

Figure 5.2 shows normal probability plot of the residuals for the average chip length. The graph shows that almost all the experimental values follow a normal distribution pattern i.e. all the point lie on the diagonal line. Only a few points in the end on the curve are slightly distracted from the pattern. The curve shows that experimental values follow a normal probability distribution which indicates the validity of the setup.

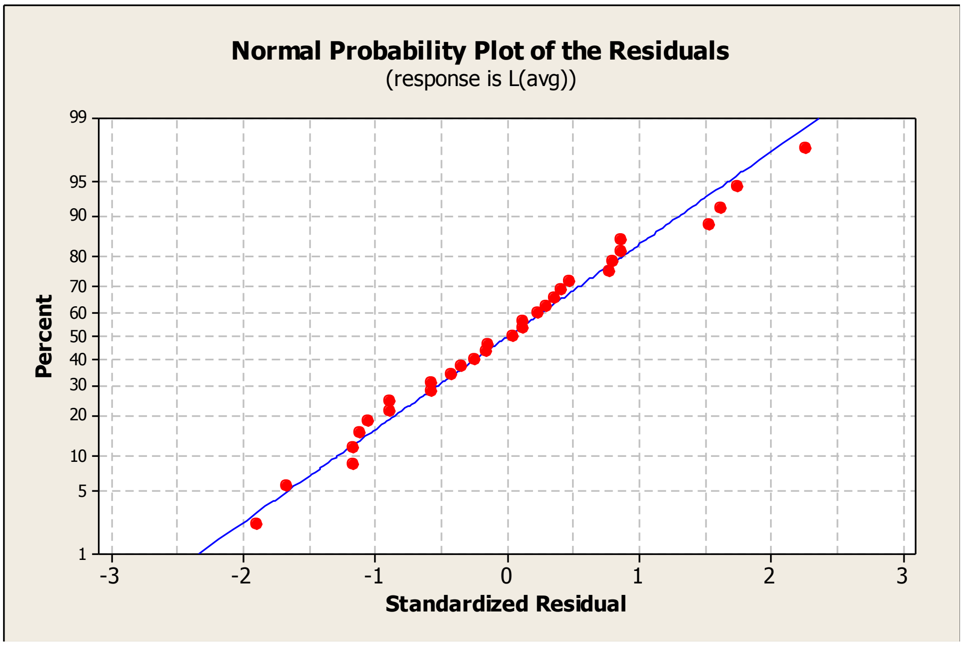


Figure 5.2 normal probability curve of the residuals for chip length

Figure 5.3 shows the graphical representation of the normal versus the fitted values. This plot shows that all the point are almost uniformly distributed above and below the median line which validates the experiment.

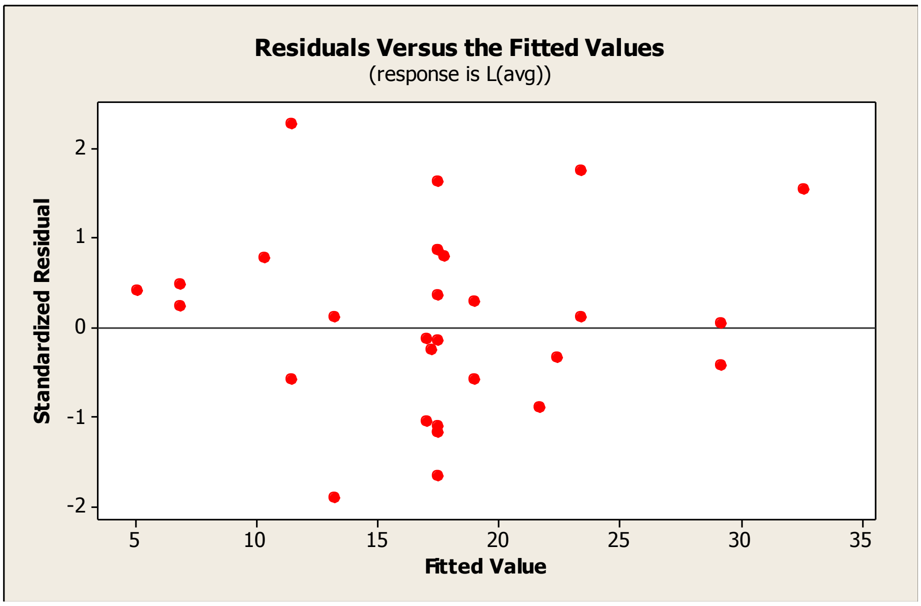


Figure.5.3 Residual Versus the fitted values

Figure 5.4 shows the histogram of the residuals. The residual versus frequency curve is almost according to the Gaussian distribution.

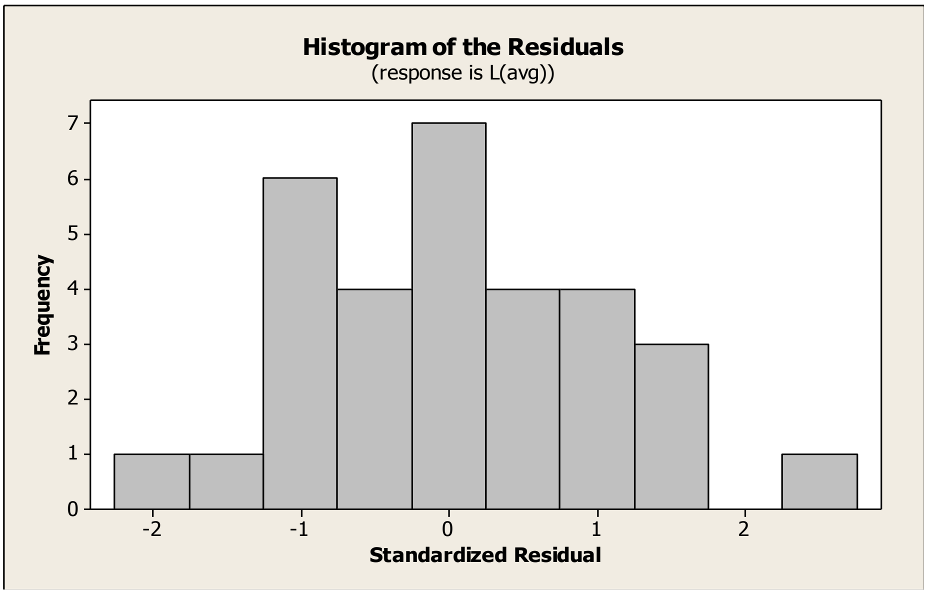


Figure.5.4 Histogram of the residuals

Figure 5.5 is the residual versus the order of the data plot. The curve does not follow any symmetric pattern with the run order value. It shows almost randon beahaviour of residuals with the increasing run order which indicates that the model is a good fit one.

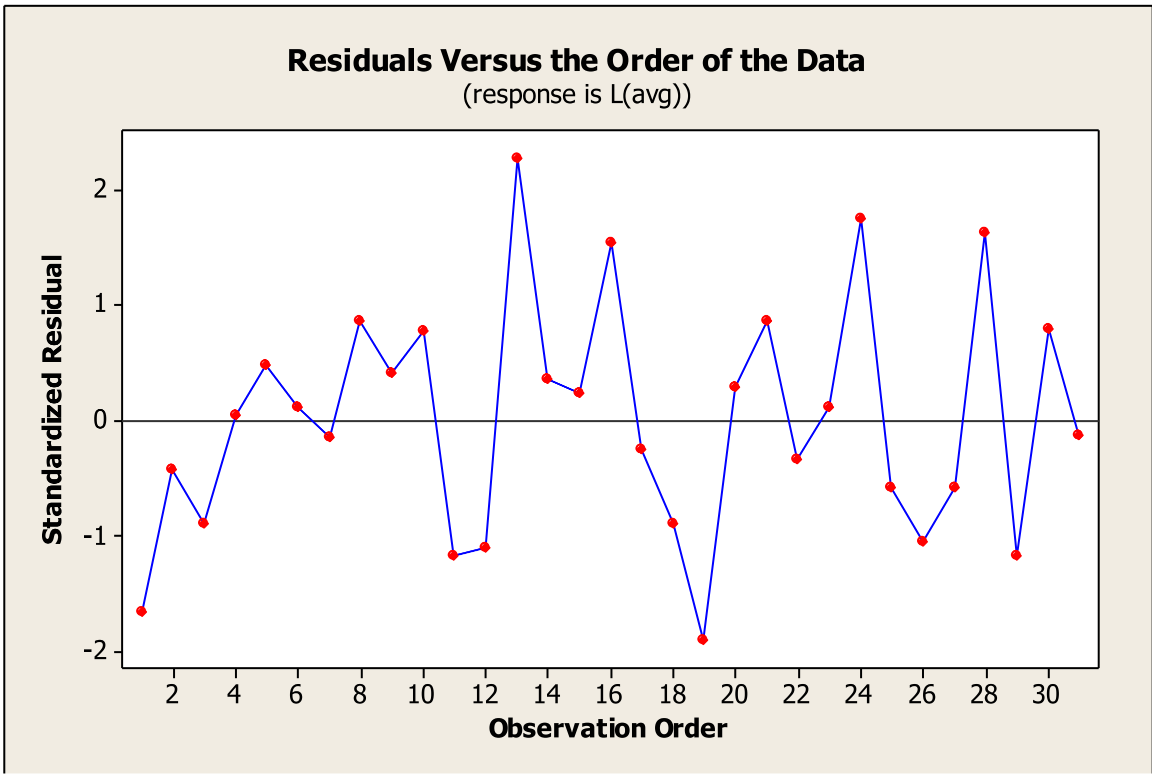


Figure 5.5 Residual versus the order of the data

Main effect of L(avg) plot is shown in figure 5.6. The plot of L(avg) with feed and depth of cut shows little variation of L(avg) with the changing values of these parameters. This pattern explains the negligible effect of f and d in the determination of L(avg) and hence these parameters are neglected for truncated results. There is a significant change in the average value of chip length with the change in values of cutting speed V, as the value of L changes by approximately 11 mm (13-24 mm) with the change in value of speed from 27 to 45 m/min.

L(avg) is also influenced by change in wear value. It's value changes from 13mm to 20 mm by changing flank wear value from 0 to 1mm. Change in the L(avg) value is large for wear values from 0 to .5 mm, from .5 to 1 mm change in flank wear value it's value changes slightly.

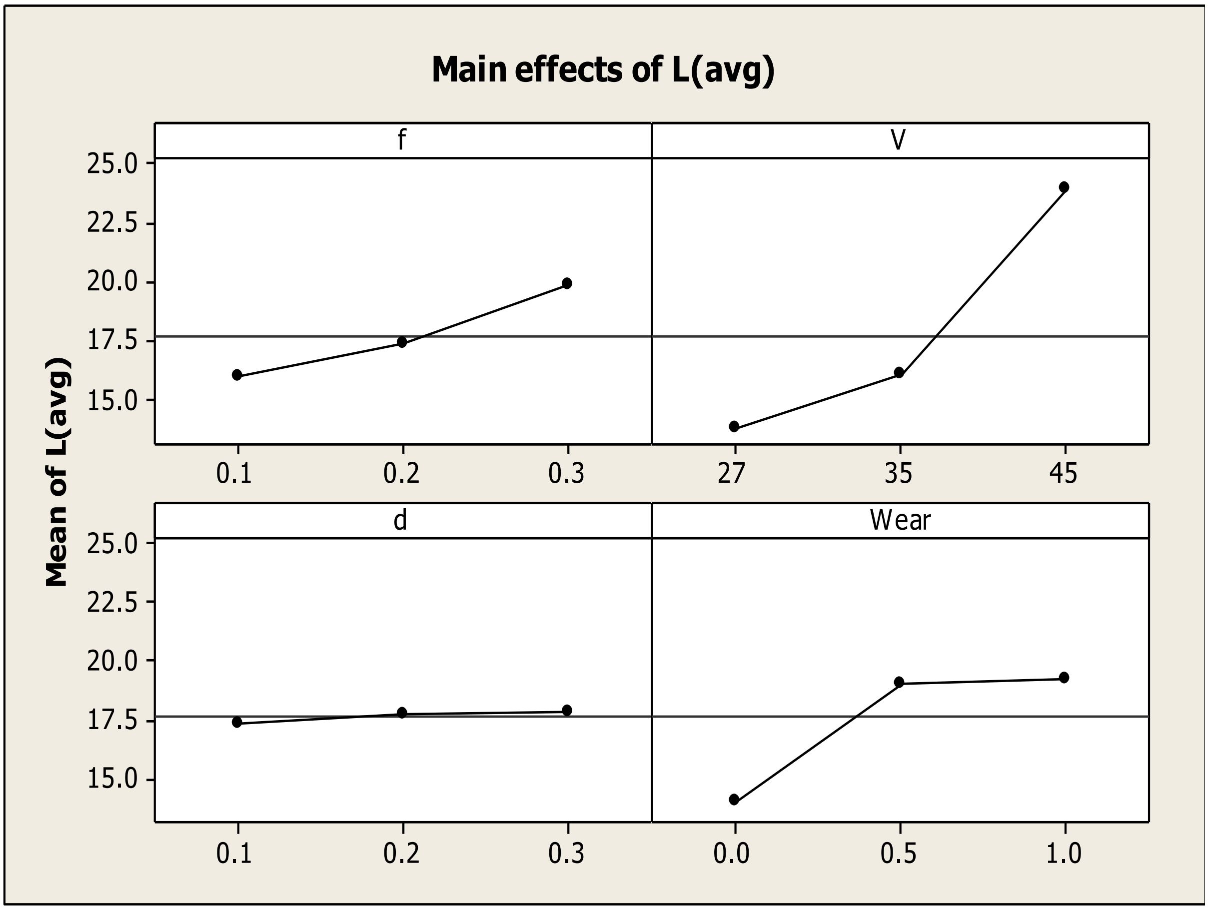


Figure.5.6 Main effects of L(avg)

Figure 5.7 shows interaction plot for L(avg). From this plot it can be inferred that there is significant interaction between the parameters depth of cut and flank wear. It is also evident from the regression analysis. There are also some other interactions shown in the figure between V & d and f & d curves.

Developed equation for the Average chip length is:-

L(avg) = 144.897 – 7.949*V – 32.063*d + 30.368*Wear + .118*V*V – 39.097*wear*wear + 69.679*d*wear

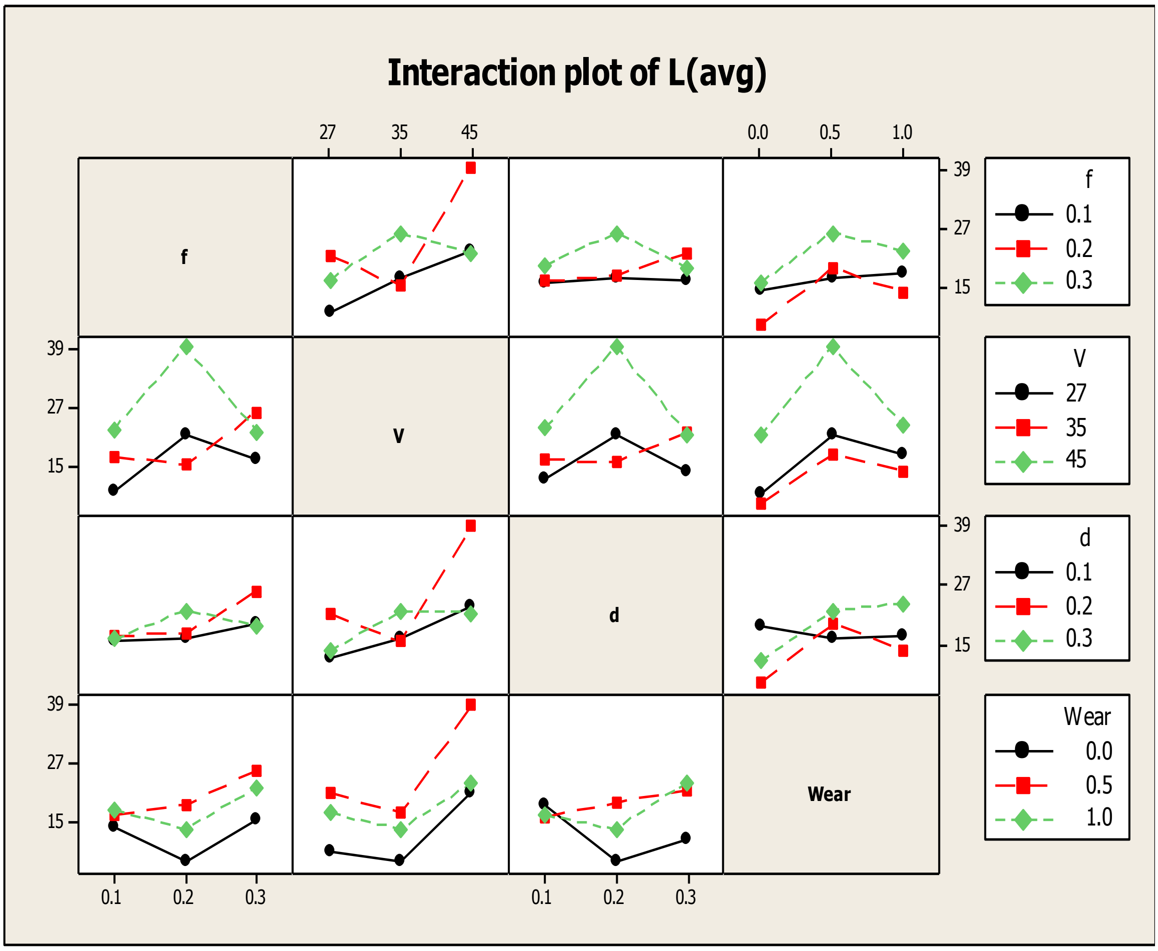


Figure.5.7 Interaction plot of L(avg)

5.2 Response Surface Methodology for chip thickness

Response Surface Regression: Chip Thickness versus f, V, d, Wear

Similar to that for average chip length, response surface analysis was performed on the other output parameter chip thickness. Table.9 shows regression plot for the coefficients to the different terms in the equation for determination of chip thickness before the modifications. In this table coefficients for differant parameters, square of parameters and interaction of parameters are given. Feed has a very significant effect on the response value. Term for which P value is more than 0.05 are considered to have negligible effect on the value of the response. Here we neglect such terms to get the truncated solution. R-square value is 80.5%. and all the analysis were done using non coded units.

Table.9 Regression coefficients for the chip thickness before modification

Term	Coef	SE Coef.	T	P
Constant	-0.11752	0.39695	-0.296	0.771
f	-2.85474	1.17166	-2.436	0.027
V	0.04412	0.02422	1.822	0.087
d	-1.03042	1.17166	-0.879	0.392
Wear	-0.15205	0.15014	-1.013	0.326
f*f	6.33253	2.65119	2.389	0.030
V*V	-0.00077	0.00033	-2.307	0.035
d*d	1.43253	2.65119	0.540	0.596
Wear*Wear	0.10530	0.10605	0.993	0.336
f*V	0.01088	0.01186	0.918	0.372
f*d	2.18750	1.06773	2.049	0.057
f*Wear	-0.15250	0.21355	-0.714	0.485
V*d	0.01029	0.01186	0.868	0.398
V*Wear	0.00552	0.00237	2.328	0.033
d*Wear	-0.42750	0.21355	-2.002	0.063

S = 0.04271 R-Sq = 80.5% R-Sq(adj) = 63.4%.

Analysis of variance for chip thickness is shown in table.10. It shows that square terms has the maximum effect on the chip thickness value. Linear and interaction terms also have slight effect on the response value. Lack-of-fit value is low at .153 which infers that the model is fit.

Table.10 Variance analysis of chip thickness before modification.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	14	0.120532	0.120532	0.008609	4.72	0.002
Linear	4	0.064393	0.020499	0.005125	2.81	0.061
Square	4	0.027450	0.027450	0.006862	3.76	0.024
Interaction	6	0.028690	0.028690	0.004782	2.62	0.058
Residual Error	16	0.029185	0.029185	0.001824		
Lack-of-Fit	10	0.023263	0.023263	0.002326	2.36	0.153
Pure Error	6	0.005923	0.005923	0.000987		
Total	30	0.149717				

RESPONSE SURFACE REGRESSION: Chip thickness versus f, V, Wear

After removing the terms that have negligible effect on the response value, truncated model solution is obtained. Regression coefficient table.11 is as shown below. This indicate that feed and speed of cutting have affects the valur of chip thickness mostly.

Flank wear have negligible effect on chip thickness as a linear term but it's interaction with speed of cutting has minor contribution to the chip thickness value. Variance analysis of chip thickness is given in table.12. It shows that linear and square terms have major contribution in the value of chip thickness but interaction terms also effect it slightly. Lack-of-fit value is low at .354.

Table.11 Estimated regression coefficients for chip thickness

Term	Coef	SE Coef	T	P
Constant	0.57567	0.09701	5.934	0.000
f	-1.50174	0.73067	-2.055	0.050
V	-0.00683	0.00189	-3.621	0.001
Wear	-0.2774	0.10130	-1.607	0.121
f*f	4.82934	1.80327	2.678	0.013
V*Wear	0.00552	0.00275	2.009	0.055

Table.12 Variance analysis for chip thickness after modification

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	0.088524	0.088524	0.017705	7.23	0.000
Linear	3	0.061085	0.045251	0.015084	6.16	0.003
Square	1	0.017556	0.017556	0.017556	7.17	0.013
Interaction	1	0.009883	0.009883	0.009883	4.04	0.055
Residual Error	25	0.061193	0.061193	0.002448		
Lack-of-Fit	9	0.024775	0.024775	0.002753	1.21	0.354
Pure Error	16	0.036418	0.036418	0.002276		
Total	30	0.149717				

Figure 5.8- 5.11 show four residual plots for the response chip thickness. In figure 5.8 residual values are completely random with respect to the run order which is good for the feasibility of the model.

Figure.5.9 shows the histogram of the residuals. The plot is similar to shape of a Gaussian distribution but there are some unusual observations in between which cause deviation from the ideal shape. In plot of residual versus the fitted values (figure.5.10) points are scattered around the middle line with equal density at above and below the midian line. Normal probability plot has points more or less nearby the mean line. The plot indicates a fairly fit model for chip thickness estimation.

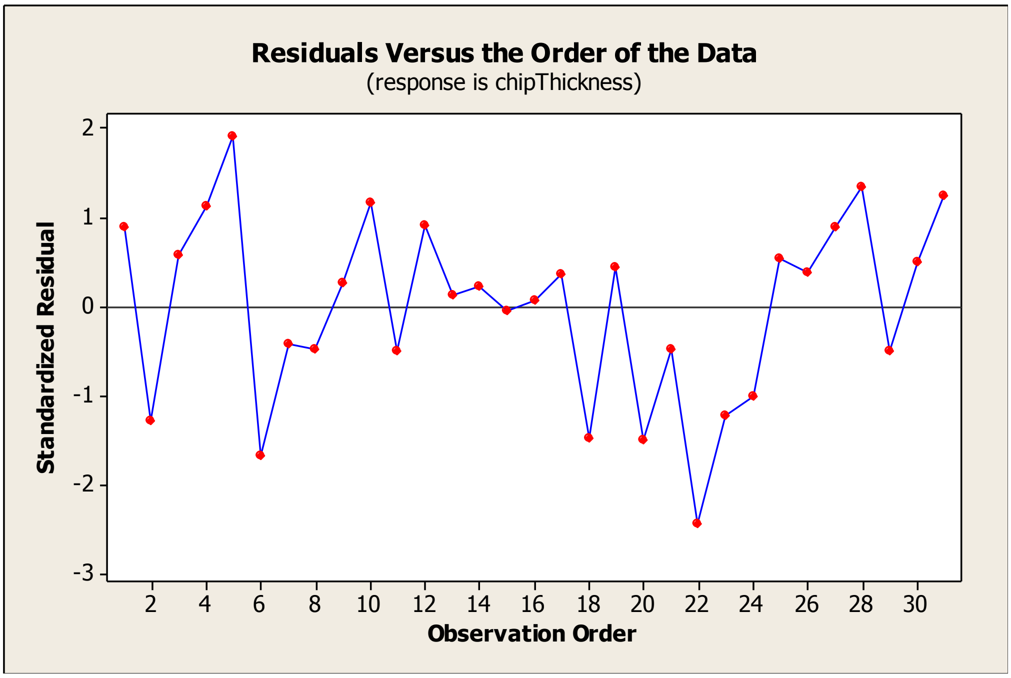


Figure.5.8 Residual versus the order of the data plot for chip thickness

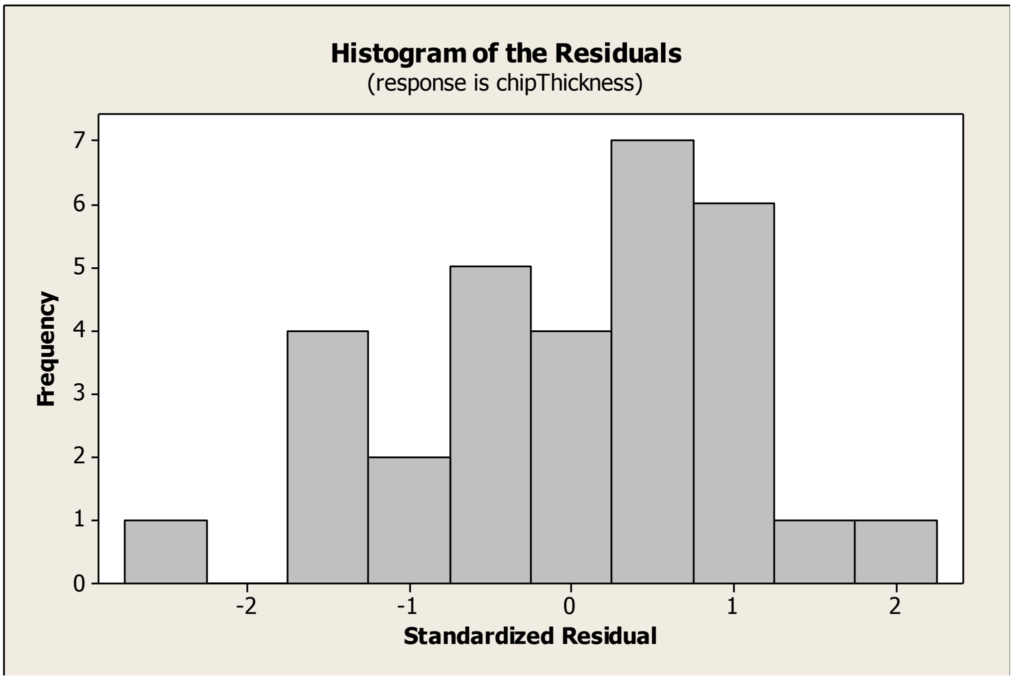


Figure.5.9 Residual histogram for chip thickness

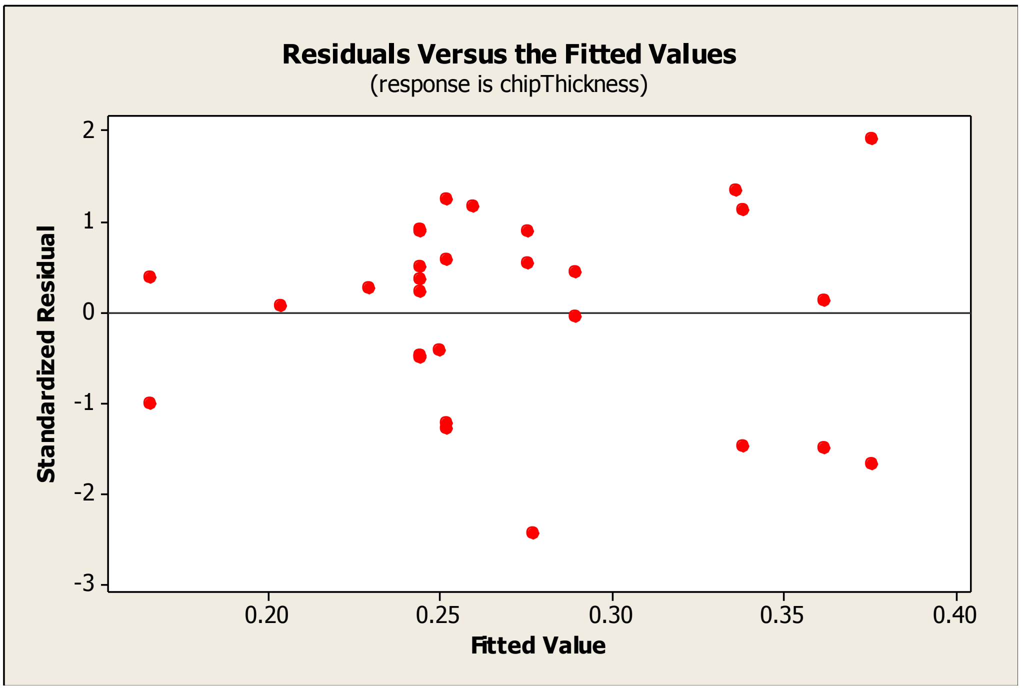


Figure.5.10 Residual versus fitted value plot for chip thickness

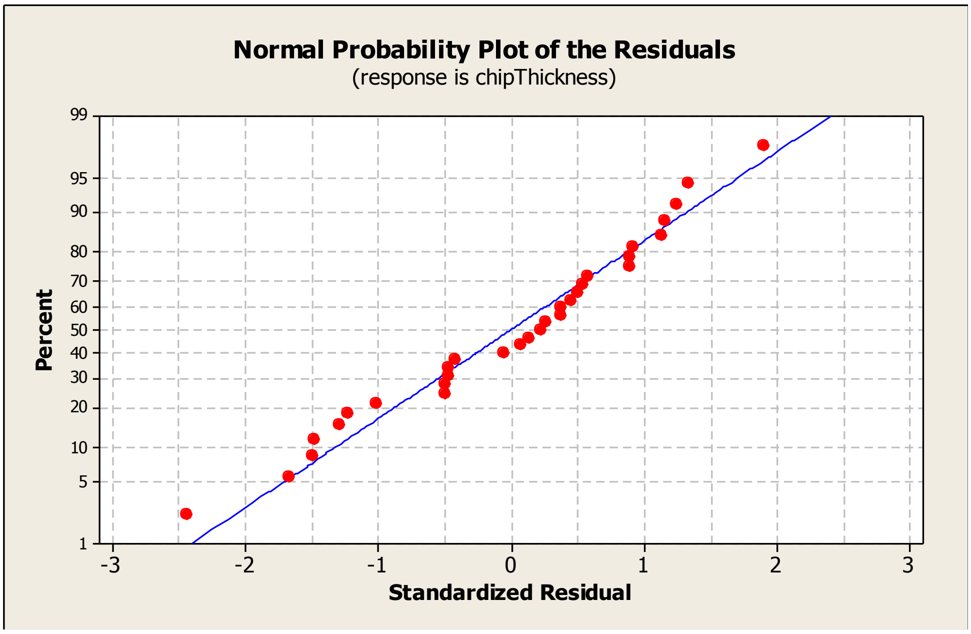


Figure.5.11 Normal probability curve of the residuals for chip thickness

Interaction curves of chip thickness analysis are given in figure.5.12. V and wear has good interaction so their interaction term is there in the equation of the response. Other interactions are there for f &V or V & d. V has the maximum effect on the chip thickness values so it is also having interation with other parameters.

Figure 5.13 is the main effects plot for chip thickness. It is clear by observing the four effect plots that V and f are responsible for change in the value of chip thickness. In both the plots chip thickness value is varying by almost .1 mm because of change in values of V and f from 27 to 45 and .1 to .3 respectively

Tool flank wear does not have any significant effect on the thickness of the chip. Even though its interaction with V changes the value of chip thickness. Response value changes from .27 to approx. 3 because change in flank wear from 0 to 0.1.

Developed equation for chip thickness = .57567 – 1.50174*f - 00683*V + 4.82934*V*V + 0.00552*V*wear

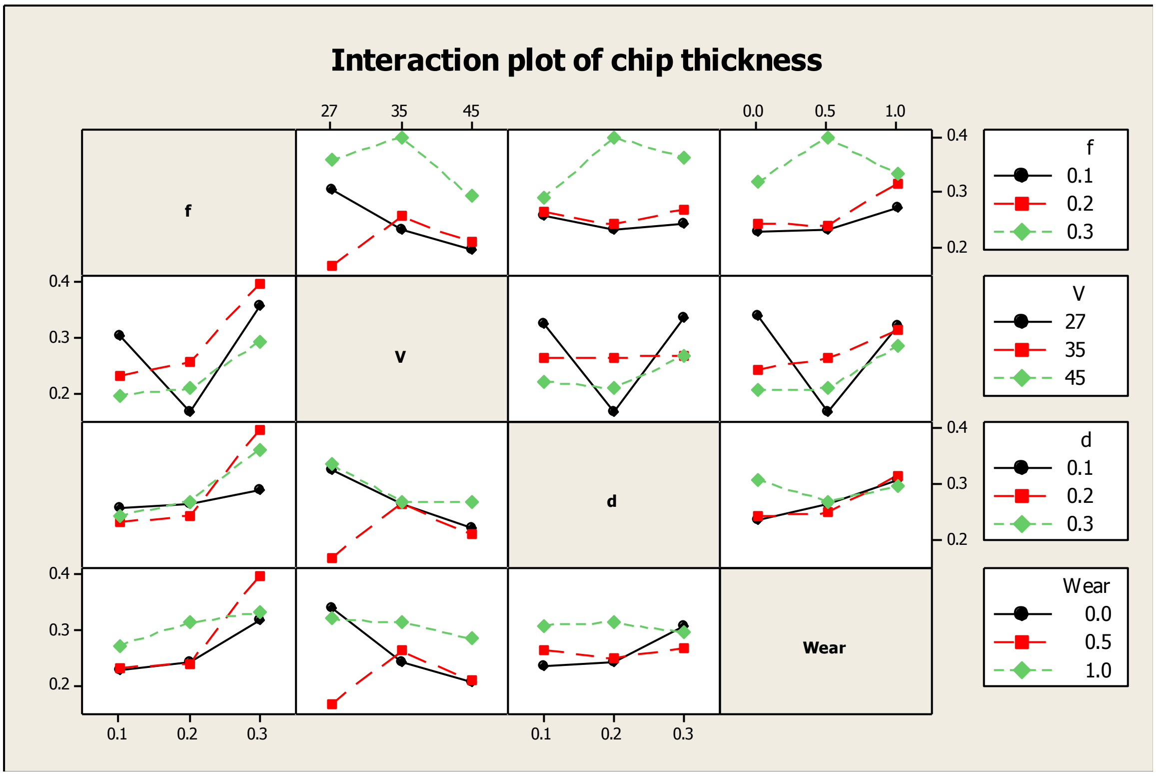


Figure.5.12 Interaction plot of chip thickness

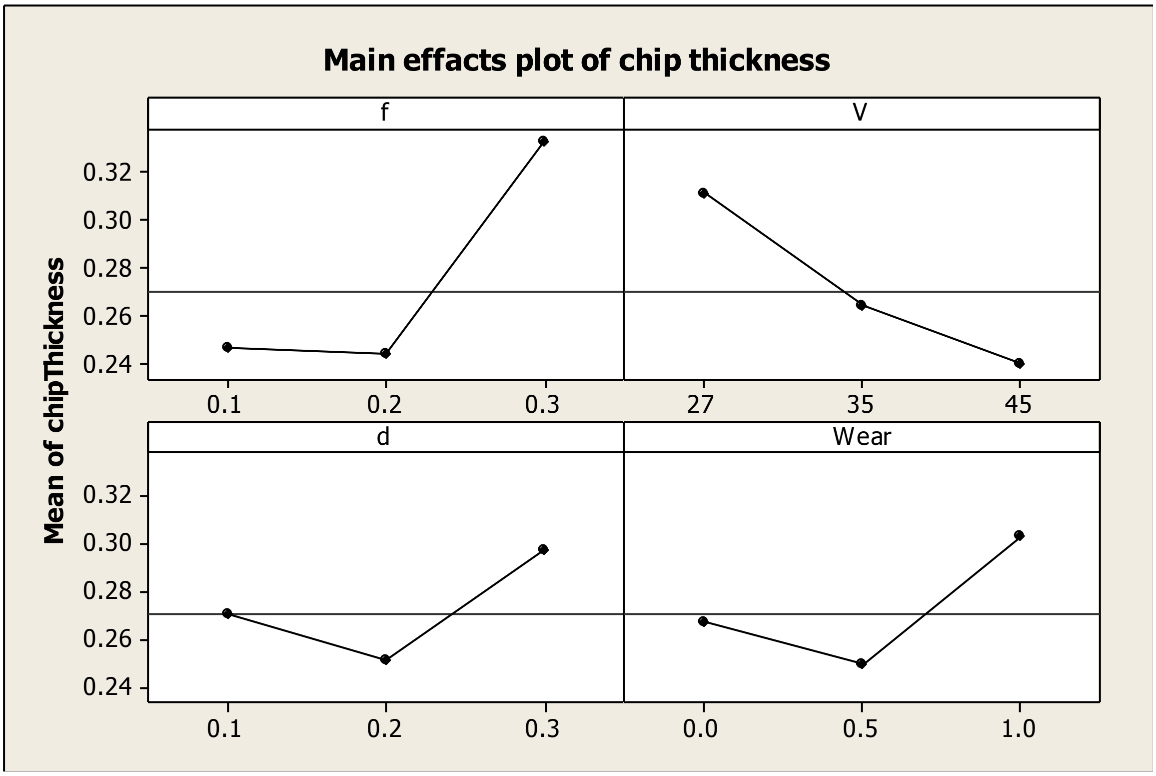


Figure.5.13 Main effacts plot of chip thickness

CONCLUSION

In the experimental study the effect of parameters like feed, depth of cut, cutting speed and tool flank wear on the length of chip and the chip thickness is studies. Main aim of the study was to analyze the effect of tool flank wear on the response parameters.

By analyzing the result it was found that chip thickness increases with increasing feed and decreasing cutting velocity. Thickness of chip first decreases and than increases with the increase in both tool flank wear and depth of cut.

For average chip length speed of cutting is the most important factor which effects its value. But at the same time tool wear also contributes significantly to its value. Length of chip value is observed to increase first with increase in flank wear and than becomes almost constant.

Thus we can conclude that tool flank wear along with other parameters is an important parameters to control chip length.

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