EXPERIMENTAL INVESTIGATION OF HOT MACHINING PROSSES OF HIGH MANGANESE STEEL USING SNMG-CARBIDE INSERTS BY DESIGN OF EXPERIMENTS USING TAGUCHI METHOD

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

Bachelor of Technology
In
Mechanical Engineering

By
J. Goudhaman

Department of Mechanical Engineering
National Institute of Technology
Rourkela
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Under the guidance of:
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CERTIFICATE

This is to certify that the thesis entitled **“Experimental investigation of Hot Machining process of high Manganese steel using SNMG carbide inserts by Design of experiments using Taguchi method’’** submitted by Sri **J. Goudhaman, Roll No: 10303004** in the partial fulfillment of the requirement for the award of **Bachelor of Technology** in **Mechanical Engineering**, National Institute of Technology, Rourkela, is being carried out under my supervision.

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:

Prof. K. P. Maity
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Acknowledgment

I avail this opportunity to extend my hearty indebtedness to my guide **Prof. K. P. Maity**, Professor Mechanical Engineering Department, for his valuable guidance, constant encouragement and kind help at different stages for the execution of this dissertation work.

I also express my sincere gratitude to **Dr. B. K. Nanda**, Head of the Department, Mechanical Engineering, for providing valuable departmental facilities. I also express my gratitude to all the faculty and staff members of Mechanical Engineering Department and the central workshop for extending their help in completing this project.

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ABSTRACT

In the modern world, there is a need of materials with very high hardness and shear strength in order to satisfy industrial requirements. So many materials which satisfy the properties are manufactured. Machining of such materials with conventional method of machining was proved to be very costly as these materials greatly affect the tool life. So to decrease tool wear, power consumed and increase surface finish Hot Machining can be used. Here the temperature of the work piece is raised to several hundred or even thousand degree Celsius above ambient, so as to reduce the shear strength of the material. Various heating method has been attempted, for example, bulk heating using furnace, area heating using torch flame, plasma arc heating, induction heating and electric current resistance heating at tool-work interface. From the past experiments it was found the power consumed during turning operations is primarily due to shearing of the material and plastic deformation of the metal removed. Since both the shear strength and hardness values of engineering materials decrease with temperature, it was thus postulated that an increase in work piece temperature would reduce the amount of power consumed for machining and eventually increase tool life.

The experiment is conducted in an auto feed lathe. The temperature is controlled by a thermocouple and automated flame heating system. The statistical analysis is done by Taguchi method. Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. The primary goal is to find factor settings that minimize response variation, while adjusting (or keeping) the process on target. A process designed with this goal will produce more consistent output. A product designed with this goal will deliver more consistent performance regardless of the environment in which it is used.Taguchi method advocates the use of orthogonal array designs to assign the factors chosen for the experiment. The most commonly used orthogonal array designs are L8, L16, L9 (i.e. eight experimental trials), L16 and L18. The power of the Taguchi method is that it integrates statistical methods into the engineering process.

The significance of the control factors are found in the following order. Cutting speed - 150 rev/min, Depth of Cut - 0.5 mm, Temperature - 600 degree, Feed - 0.05 mm/rev From statistical design of experiments by Taguchi method (MINITAB software) and Hot Machining we find that the power required is decreased and the tool life is increased by 14.8 %.

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CHAPTER I

INTRODUCTION:

With advancement in science and technology, there is a need of materials with very high hardness and shear strength in the market. So many materials which satisfy the properties are manufactured. Machining of such materials with conventional method of machining was proved to be very costly as these materials greatly affect the tool life. So to increase tool life, to decrease the power consumption and for improving the machinability an innovative process Hot Machining came into existence. Here the temperature of the work piece is raised to several hundred or even thousand degree Celsius above ambient, so as to reduce the shear strength of the material. Various heating method has been attempted, for example, bulk heating using furnace, area heating using torch flame, plasma arc heating, induction heating and electric current resistance heating at tool-work interface.

From the past experiments it was found the power consumed during turning operations is primarily due to shearing of the material and plastic deformation of the metal removed. Since both the shear strength and hardness values of engineering materials decrease with temperature, it was thus postulated that an increase in work piece temperature would reduce the amount of power consumed for machining and eventually increase tool life. In figure 1.1 and figure 1.2 the variation of Spindle power with Depth of cut is shown [1] for different materials. In figure 1.3 the variation of decrease in hardness of material with increase in temperature is given [1].

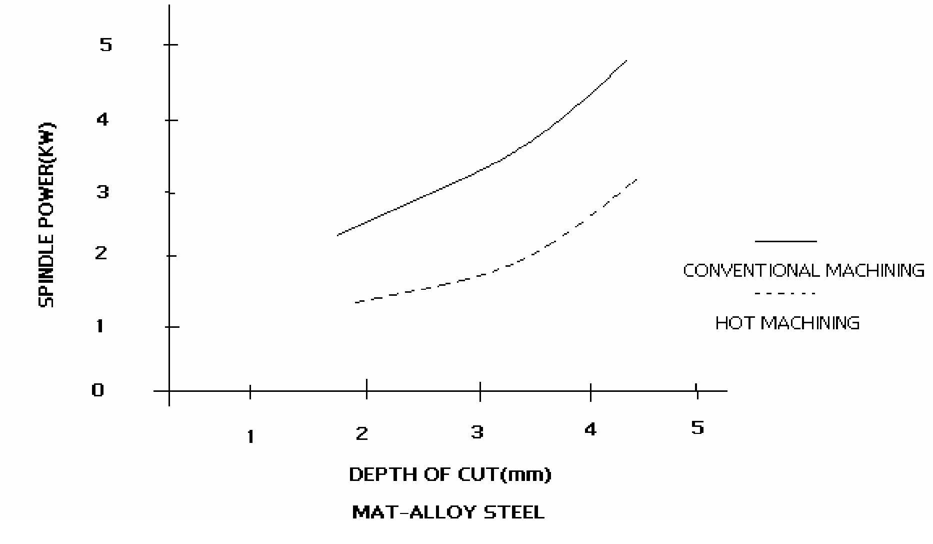


Figure 1.1: Spindle Power Vs Depth of cut

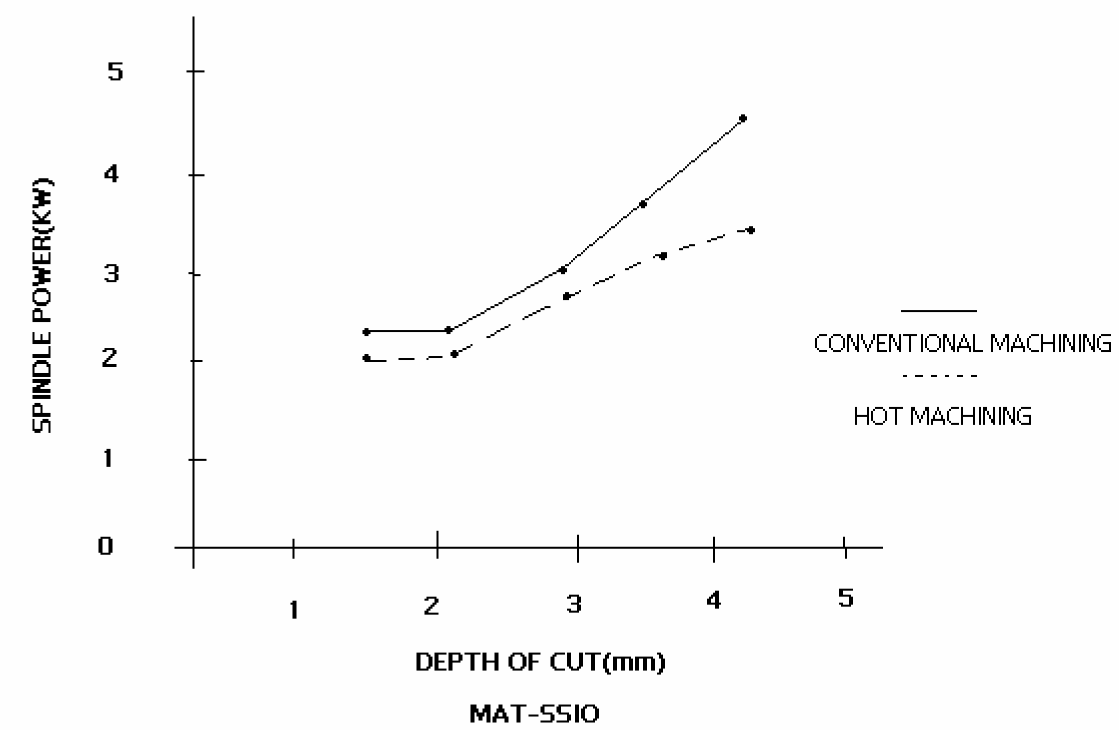


Figure 1.2: Hardness Vs Depth of Cut

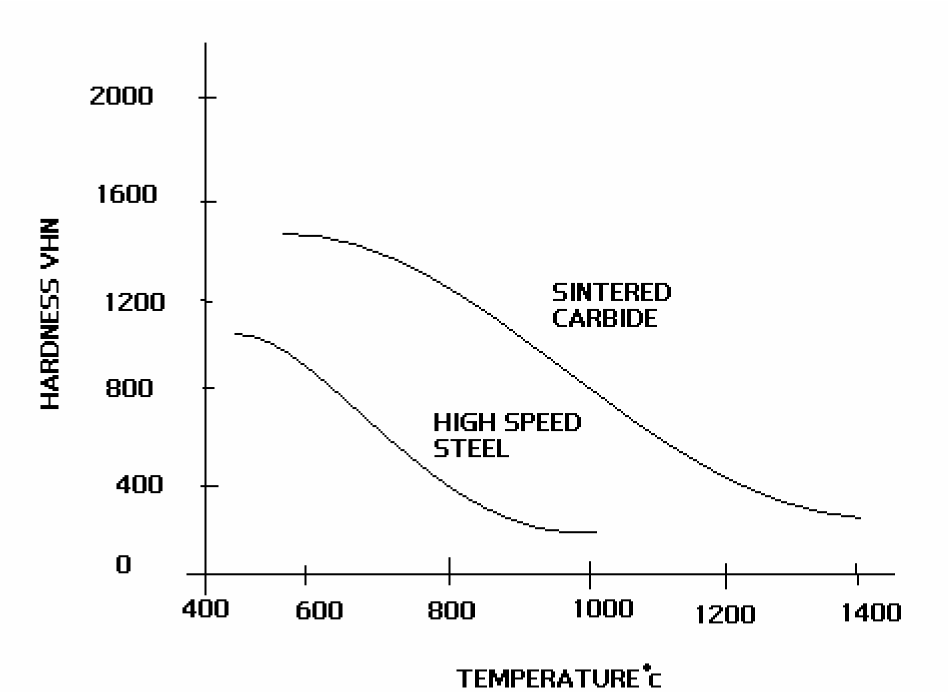


Figure 1.3: Hardness Vs Temperature

BASIC REQUIREMENTS OF WORKPIECE HEATING TECHNIQUE:

There are certain basic requirements for hot machining process [1]. These are as follows:

1. The application of external heat should be localized at the shear zone, i.e. just ahead of the cutting edge, where the deformation of the work piece material is maximum amount.

2. Heating should be confined to a small area as possible limiting work piece expansion, so that the dimensional accuracy can be tolerated.

3. The method of heat supply should be incorporated with fine temperature control device as the tool life is temperature sensitive.

4. The method of heat supply should be such that the limitations imposed by the work piece shape and size, conditions and machining process are minimal.

5. Machined surfaces must not be contaminated or over heated, resulting in possible metallurgical change or distortion to the uncut material.

6. The heat source must be able to supply a large specific heat input to create a rapid response in temperature ahead of the tool.

7. The heating equipment used should be low in the initial investments well as in operation and maintenance.

8. It is absolutely essential that the method employed is not dangerous to the operator.

DIFFERENT METHODS OF HEATING

Different heating methods are shown in literature [2]

1. FURNACE HEATING:

Work piece is machined immediately after being heated in the furnace to required temperature.

ADVANTAGES:

1. Adaptable to many types of machining processes.
2. It provides heat for the entire depth of cut certain operations such as drilling and end milling.
3. Simple and relatively cheap.

DISADVANTAGES:

1. Thermal losses are high compared to other techniques.
2. Poor accuracy due to thermal expansion.
3. Distortion due to uneven cooling.
4. Excessive oxidization of machined surface.
5. Unsuitable for long operation.
6. Safe handling difficulties.
7. Heat insulator between work piece and machine tool is necessary.

2. RESISTENCE HEATING:

The entire work piece is heated by passing current either through the work piece itself or through resistance heaters embedded in the fixtures.

ADVANTAGES:

1. It provides the heat required for the entire depth of cut for certain operations such as drilling and end milling.
2. Adaptable to many types of machining processes.
3. Simple and relatively cheap.

DISADVANTAGES:

1. Thermal losses are high compared to other techniques.
2. Poor accuracy due to thermal expansion.
3. Distortion due to uneven cooling.
4. Heat insulator between work piece and machine tool is necessary.

3. FLAME HEATING:

In this method, work piece material immediately ahead of the cutting tool is heated by welding torch moving with the tool. Multi-flame heads can be used for large heat inputs.

ADVANTAGES:

1. The equipment is simple and inexpensive compared to other similar processes.

DISADVANTAGES:

1. Localization of heat is difficult.
2. Contamination of machined surface.
3. Dangerous to the operator.
4. Heating is apt to be disturbed by the moving chip.
5. Inconvenient for observation of cutting edge.
6. Inadaptable to drilling, reaming and broaching.

4. ARC HEATING:

In this method, the work piece material immediately ahead of the cutting tool is heated by an electric arc drawn between the work piece and the electrode moving with the tool. To prevent wandering a magnetic field can be imposed to direct the arc.

ADVANTAGES:

1. Good concentration of heat both in depth and area.
2. High temperature is obtained easily.
3. Equipment is in expensive.

DISADVANTAGES:

1. Heating is not stable.
2. Welding protection needed for operator which reduces efficiency and accuracy.

3. Heating is apt to be disturbed by moving chip.
4. Inconvenient for observation of the cutting edge.
5. Inadaptable to drilling reaming, broaching etc.

5. PLASMA ARC HEATING:

In this method, the work piece is heated using plasma arc just above the tool tip. In this method very high heat is produced. Heating can be limited to a very small surface area.

ADVANTAGES:

1. A very high specific heat input is achieved by plasma arc compared to the other discussed method.

DISADVANTAGES:

1. Heating is not stable.
2. Welding protection needed for operator which reduces efficiency and accuracy.
2. Heating is apt to be disturbed by moving chip.
3. Inconvenient for observation of the cutting edge.
4. Inadaptable to drilling reaming, broaching etc.

MATERIAL DATA SHEET: [3]

Table 1.1: Nihard Material

Mechanical Properties	Specification
Hardness HBN(Typical)	600-650
Tensile Strength	60,000 psi
PH Range	5-8

Chemical Composition (weight %)

C 2.5-3.6%	P 0.10 max
Cr 7-11	S 0.15 max
Ni 4.5-7.0	Si 2.0 max
Mo 1.5 max	Mn 2.0 max
	Fe balance

After procuring the Nihard material from L&T kansbhal, the defects in the material like un-uniform thickness, bend of work-piece could not be repaired by any means. So I continued my project on hot machining with high manganese steel with carbide inserts. As the process of buying a perfect Nihard material is not completed and still in process, I continue my experimental investigation on High manganese steel using design of experiments by Taguchi method.

Table 1.1: HIGH MANGANESE STEEL:

STEEL DESIGNATION	NON-DEFORMING PROPERTIES	SAFETY IN HARDENING	DEPTH OF HARDENING (a)	TOUGHNESS	RESISTANCE TO SOFTENING EFFECT OF HEAT	WEAR RESIST-ANCE	MACHIN-ABILITY
02- HIGH MANGANESE	GOOD	GOOD	MEDIUM	FAIR	POOR	GOOD	GOOD

Table 1.2: CHEMICAL COMPOSITION

COMPONENTS	COMPOSITION
Carbon	1.00 to 1.40
Manganese	minimum 12.00
Phosphorus	maximum 0.10
Sulfur	maximum 0.05

CHAPTER II

EXPERIMENTAL SET UP AND PRINCIPLE OF WORKING:

The work piece material which is to be machined is fitted in the lathe, between the lathe head stock and tail stock. Torch is fitted as shown in the figure 2.1 and it can move with the cutting tool. Torch is connected to a LPG cylinder and an oxygen cylinder. The setup was made earlier by previous investigators [5] There are valves available to adjust the flow of oxygen and LPG. The distance of the torch nozzle can be adjusted with the handle provided as shown in the figure. There is a temperature indicator which can measure the temperature of the work piece. Temperature can be set in the temperature indicator and when the temperature is reached, the torch automatically moves away from the work piece. This is done by using the control system provided and temperature indicator works on the principle of thermocouple. There is a PID controller attached in the system. The machining is done by a SNMG carbide insert as shown in the figure 2.1

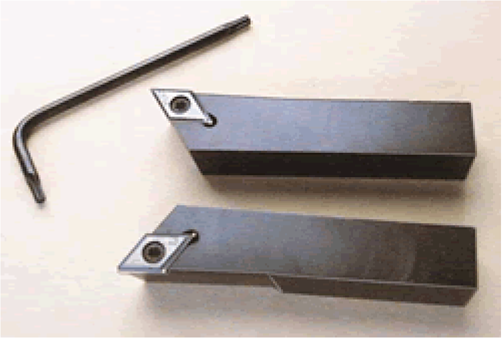
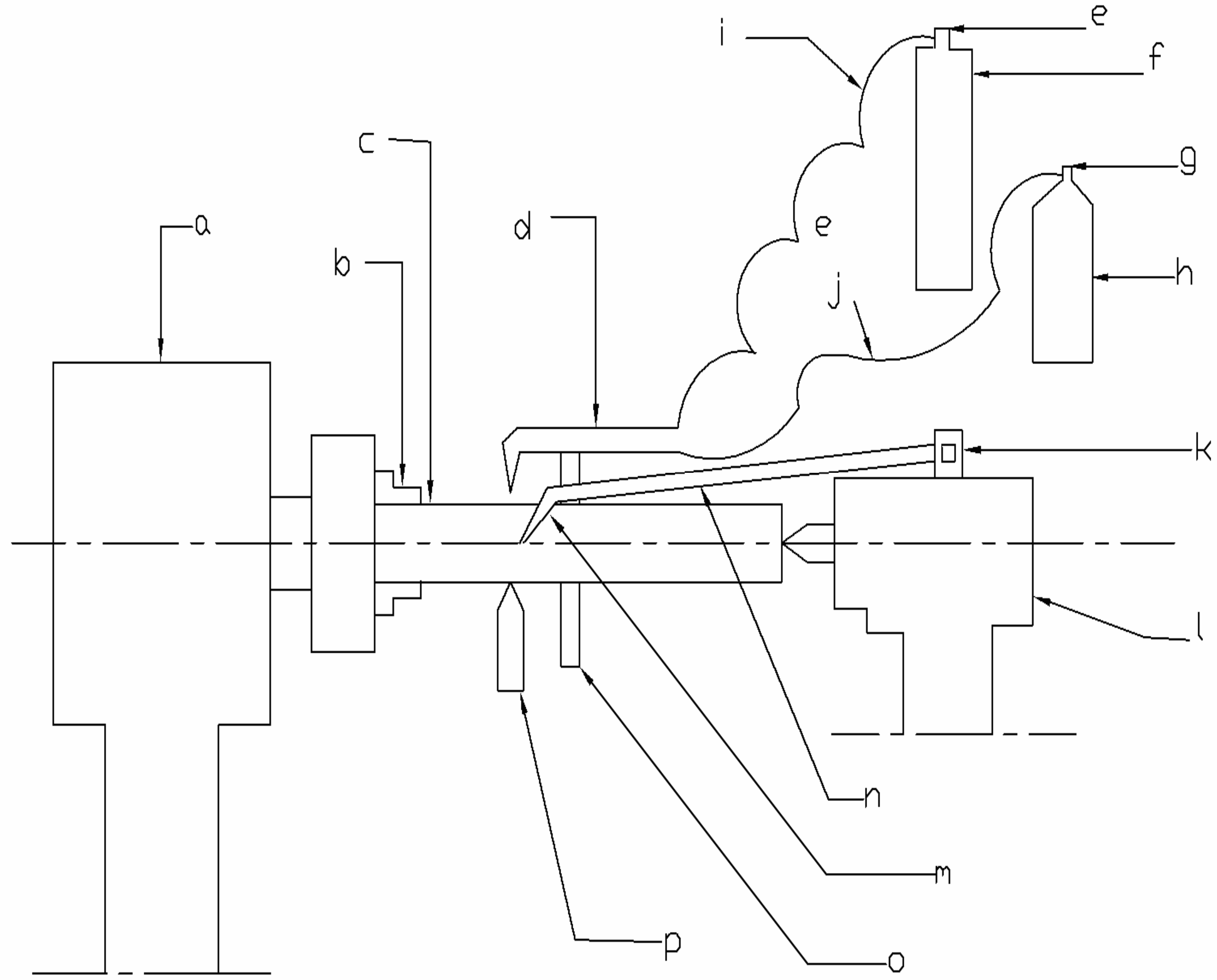


Figure 2.1



(a) Lathe head stock
(b) Chuck
(c) Work piece
(d) Torch
(e) Oxygen
(f’) Oxygen Cylinder flow valve
(g) LPG flow valve
(h) LPG cylinder
(i) Oxygen pipe
(j) LPG pipe
(k) Temperature indicator
(l) Tail stock
(m)Thermocouple
(n) Wire
(o) Distance adjustment
(p) Cutting tool handle

Figure 2.2: Experimental setup

STATISTICAL DESIGN OF EXPERIMENT:

TAGUCHI METHOD:

Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. , the primary goal is to find factor settings that minimize response variation, while adjusting (or keeping) the process on target. . A process designed with this goal will produce more consistent output. A product designed with this goal will deliver more consistent performance regardless of the environment in which it is used.

Taguchi method advocates the use of orthogonal array designs to assign the factors chosen for the experiment. The most commonly used orthogonal array designs are L8, L16, L9 (i.e. eight experimental trials), L16 and L18. The power of the Taguchi method is that it integrates statistical methods into the engineering process.

Table 2.1: CONTROL FACTORS AND THEIR RANGE OF SETTING FOR THE EXPERIMENT

CONTROL FACTOR	LEVEL-1	LEVEL-2	LEVEL-3
Cutting speed	19.55 m/min	32.58 m/min	54.73 m/min
Feed	0.05 mm/s	0.1 mm/s	0.5 mm/s
Depth Of Cut	0.5 mm	1mm	1.5 mm
Temperature	600 C	400 C	200 C

The above table represents the control factors for hot machining of high manganese steel. As we have four control factors and three levels per factor, according to taguchi method we choose L_9 taguchi design. In L_9 taguchi design, we use orthogonal arrays instead of standard factorial design. This design reduces the number of experiments from 24 (i.e. factorial 4*3*2*1) to a designed set of 9 experiments.

SIGNAL-TO- NOISE RATIO:

The control factor that may contribute to reduce variation can be quickly identified by looking at the amount of variation present as response. Taguchi has created a transformation of the repetition data to another value which is response measure of the variation present. The transformation is signal-to-noise ratio(S/N).There are three S/N ratios available depending upon the type of characteristics.

1) LOWER IS BETTER:

$(S/N)_{LB} = -10 \log (1/r \sum y_i^2)$

Where,

r = Number of tests in a single trial.

2) NOMINAL IS BETTER:

$(S/N)_{NB1} = -10 \log V_e$

$(S/N)_{NB2} = 10 \log ((V_m – V_e)/r V_e)$

3) HIGHER IS BETTER:

$(S/N)_{HB} = -10 \log (1/r \sum y_i^2)$

Where, y_i = each observed value.

STATISTICAL ANALYSIS AND INTERPRETATION OF RESULTS:

Having obtained the average SNR values, the next step is the identification of significant main effects which influence the SNR. To achieve this, a powerful graphical tool called half-normal probability plots (HNPP) is useful. A half-normal probability plot (HNPP) is obtained by plotting the absolute values of the effects along the X-axis and the percent probability along the Y-axis. The per cent probability can be obtained by using the following equation:

$$Pi = (i - 0.5)/ n *100$$

Where: *n* = number of estimated effects (*n* = 15)

i = is the rank of the estimated effect when arranged in the ascending order of magnitude.

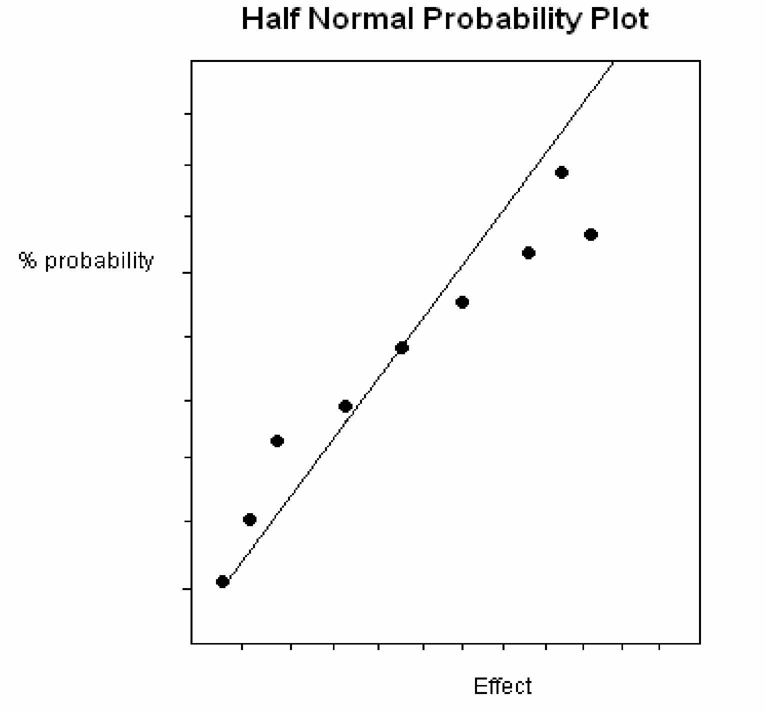


Figure 2.2: Half Normal probability plot

Thus we plot HNPP graph. Those effects which are active and real will fall off the straight line, whereas the inactive and insignificant effects will fall along the straight line.

In our case the response is tool life so we choose higher is better Signal-to-noise ratio. Hence we find S/N for each trial and thus we construct a S/N table.

From this S/N ratio table we find the average S/N ratio (SNR) for each level. Thus we calculate the effect of each factor. From this we construct the main effect plot of control factor.

$$\text{Effect} = \text{SNRf2} - SNRf1$$

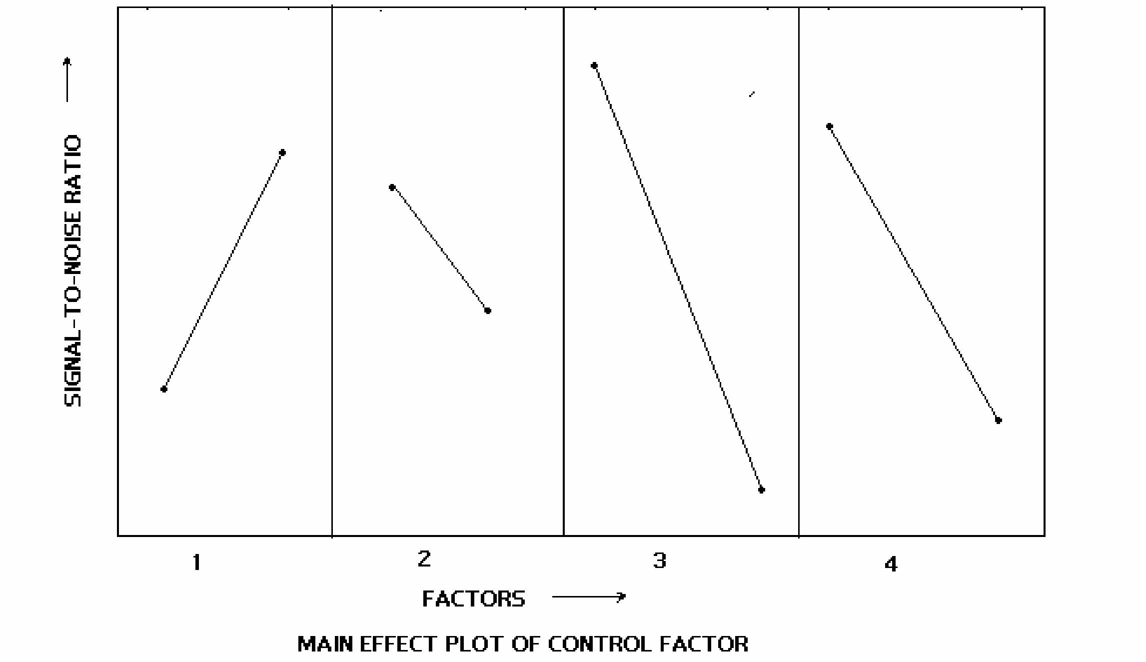


Figure 2.3: Main effect plot of control factors

From this graph we can find the most significant factor. More the slope higher is the significance. In the above example, factor 3 is more significant followed by factor 4, factor 1 and then factor 2.

STEPS IN PERFORMING A TAGUCHI EXPERIMENT:

The process of performing a Taguchi experiment follows a number of distinct steps. [6] They are

- *Step1*: formulation of the problem – the success of any experiment is dependent on a full understanding of the nature of the problem.
- *Step 2*: identification of the output performance characteristics most relevant to the problem.
- *Step 3*: identification of control factors, noise factors and signal factors (if any). Control factors are those which can be controlled under normal production conditions. Noise factors

are those which are either too difficult or too expensive to control under normal production conditions. Signal factors are those which affect the mean performance of the process.

- *Step 4*: selection of factor levels, possible interactions and the degrees of freedom associated with each factor and the interaction effects.
- *Step 5*: design of an appropriate orthogonal array (OA).
- *Step 6*: preparation of the experiment.
- *Step 7*: running of the experiment with appropriate data collection.
- *Step 8*: statistical analysis and interpretation of experimental results.
- *Step 9*: undertaking a confirmatory run of the experiment.

HOT MACHINING OF HARDENED HIGH MANGANESE STEEL:

The control factors of this experiment are cutting speed, feed, depth of cut and temperature. The response is tool wear. We select a three level design i.e.; there are three separate values for each control factor. We choose the L9 Taguchi design. There are 9 runs (nine experiments) to be carried out. The hardened high manganese steel was machined with the tool for nine times, with measuring tool wear for every two minutes.

In L-9 Taguchi design, we use orthogonal array instead of standard factorial design. It reduces the number of experiments from 24(4 * 3 * 2 * 1) to 9 experiments.[5]

Table 2.4

RUNS	CONTROL FACTOR 1	CONTROL FACTOR 2	CONTROL FACTOR 3	CONTROL FACTOR 4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

CHAPTER III

Table 3.1: EXPERIMENTAL OBSERVATIONS

TRAIL NUMBER(RUNS)	CONTROL FACTORS				RESPONSE
	CUTTING SPPED(1)	FEED(2)	DEPTH OF CUT(3)	TEMPERATURE(4)	
1	150	0.05	0.5	600	0.63
2	150	0.1	1.0	400	0.78
3	150	0.15	1.50	200	0.93
4	250	0.05	1.0	200	0.87
5	250	0.1	1.5	600	0.86
6	250	0.15	0.5	400	0.85
7	420	0.05	1.5	400	0.96
8	420	0.1	0.5	200	0.91
9	420	0.15	1.0	600	0.92

In our case the response is tool wear. It would be the best if tool wear is minimum. So as the objective is to minimize tool wear, we select Signal-to-Noise ratio to Smaller the Better (STB) quality.

For Lower the Better the Signal to Noise ratio is given as,

$(S/N)_{LB} = -10 \log (1/r \sum y_i^2)$

With the help of MINITAB software we draw the average SNR table and also plot the Main Effect Plot.

Table 3.2: AVERAGE SNR TABLE

FACTOR'S SNR	CUTTING SPEED	FEED	DEPTH OF CUT	TEMPERATURE
SNR1	2.2672	1.8591	2.0813	2.0158
SNR2	1.3104	1.4291	1.3640	1.124
SNR3	0.6327	0.9221	0.7650	0.8864
DELTA	1.6327	0.9371	1.3163	1.1294
RANK	1	4	2	3

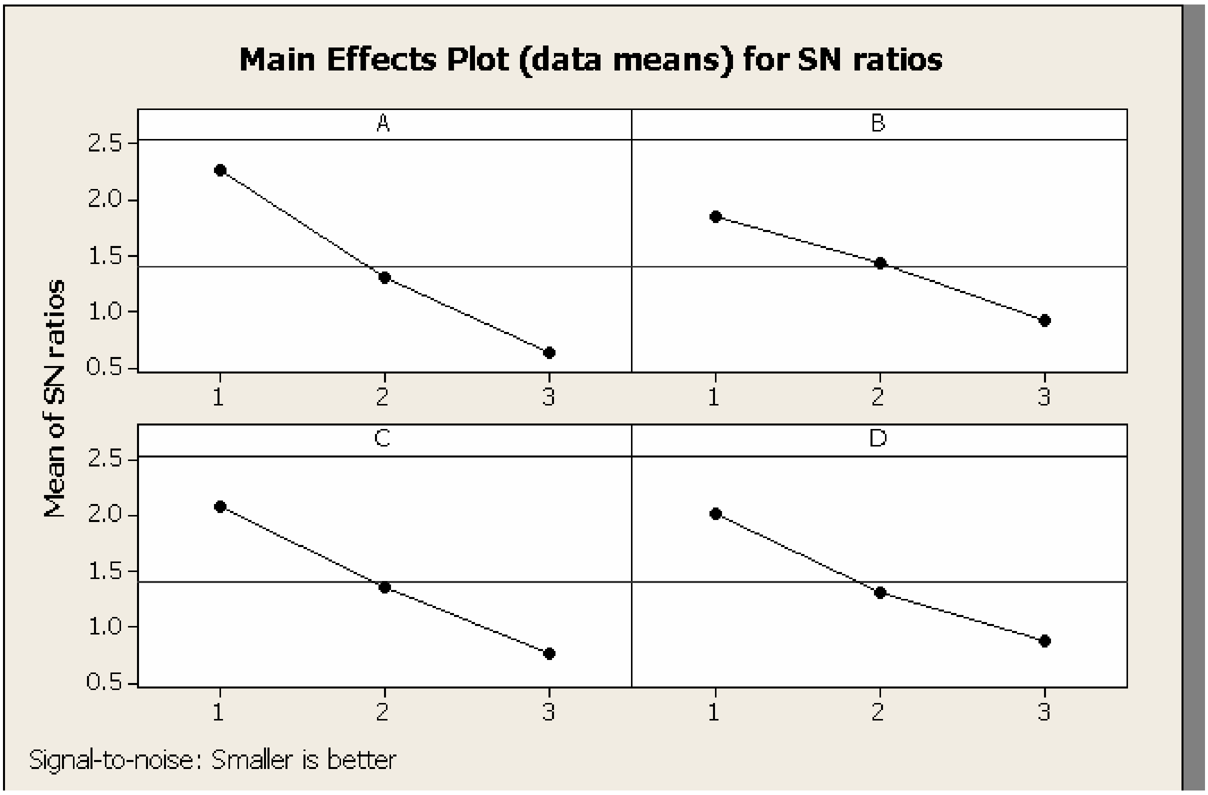


Figure 3.1: Main effect plot of control factors (Tool wear)

The experiment is to be further continued with tool life as the response. The experiment is to be repeated again and again (each run) till flank wear reaches 0.5 mm. After this the tool cannot be used for further machining. From this the tool life is calculated. Then again the tool is grinded and continued for nine experiments. Thus we get tool life as response (Figure 4.1).

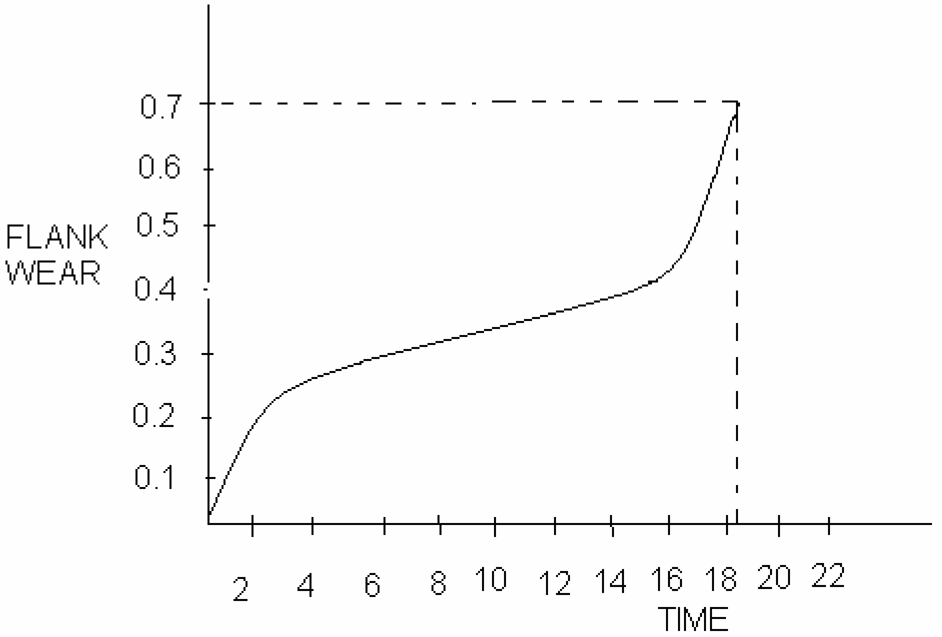


Figure 4.1: Flank wears Vs Time

Thus the experiment can be continued and more appropriate analysis can be done and an equation can be developed for tool life with the specified factors.

CHAPTER IV

HOT MACHINING OF "HIGH MANGANESE STEEL" BY TAGUCHI'S L9 DESIGN WITH TOOL LIFE AS RESPONSE:

Tool life is defined as the time up to which the tool can properly machine the given work piece. In this case tool life is considered as the time up to which the flank wear value reaches 0.4 mm

TOOL LIFE AT FIRST RUN OF TAGUCHI'S L9 DESIGN:

Before starting the experiment the tool is grinded properly making the flank wear zero. The cutting speed, feed, depth of cut and temperature are set to the appropriate specifies values. The tool is removed after every two minutes and the flank wear is measured in tool maker's microscope. This process is continued till tool wear reaches 0.6 mm. A graph is plotted between time and flank wear. The reading in X-axis (Time) corresponding to the flank wear of 0.4 mm is the tool life for the given machining parameters.

FIRST RUN:

Cutting Speed = 19.55 m/min

Feed = 0.05 mm/rev

Depth of Cut = 0.5 mm

Temperature = 600 degrees

Table 4.1: Tool Wear Vs Time for first run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER (Watt)
1	0	0	0
2	2	0.078	30
3	4	0.098	20
4	6	0.12	30
5	8	0.135	20
6	10	0.146	30
7	12	0.157	30
8	14	0.173	20
9	16	0.184	30
10	18	0.221	20
11	20	0.234	30

12	22	0.248	20
13	24	0.256	30
14	26	0.265	30
15	28	0.289	20
16	30	0.31	30
17	32	0.319	20
18	34	0.34	30
19	36	0.356	20
20	38	0.389	30
21	40	0.4	20
22	42	0.459	20
23	44	0.512	20
24	46	0.615	30

CALCULATION OF CUTTING FORCE:

Average power required (P) = 25.21 W

Diameter of the work piece= 0.0415 m

Cutting velocity = πDN/60 = (3.14*0.0415*150)/60 = 0.3257

Therefore cutting force= power/cutting velocity = 25.21/0.3257 = 77.42 N

Cutting force=77.42 N

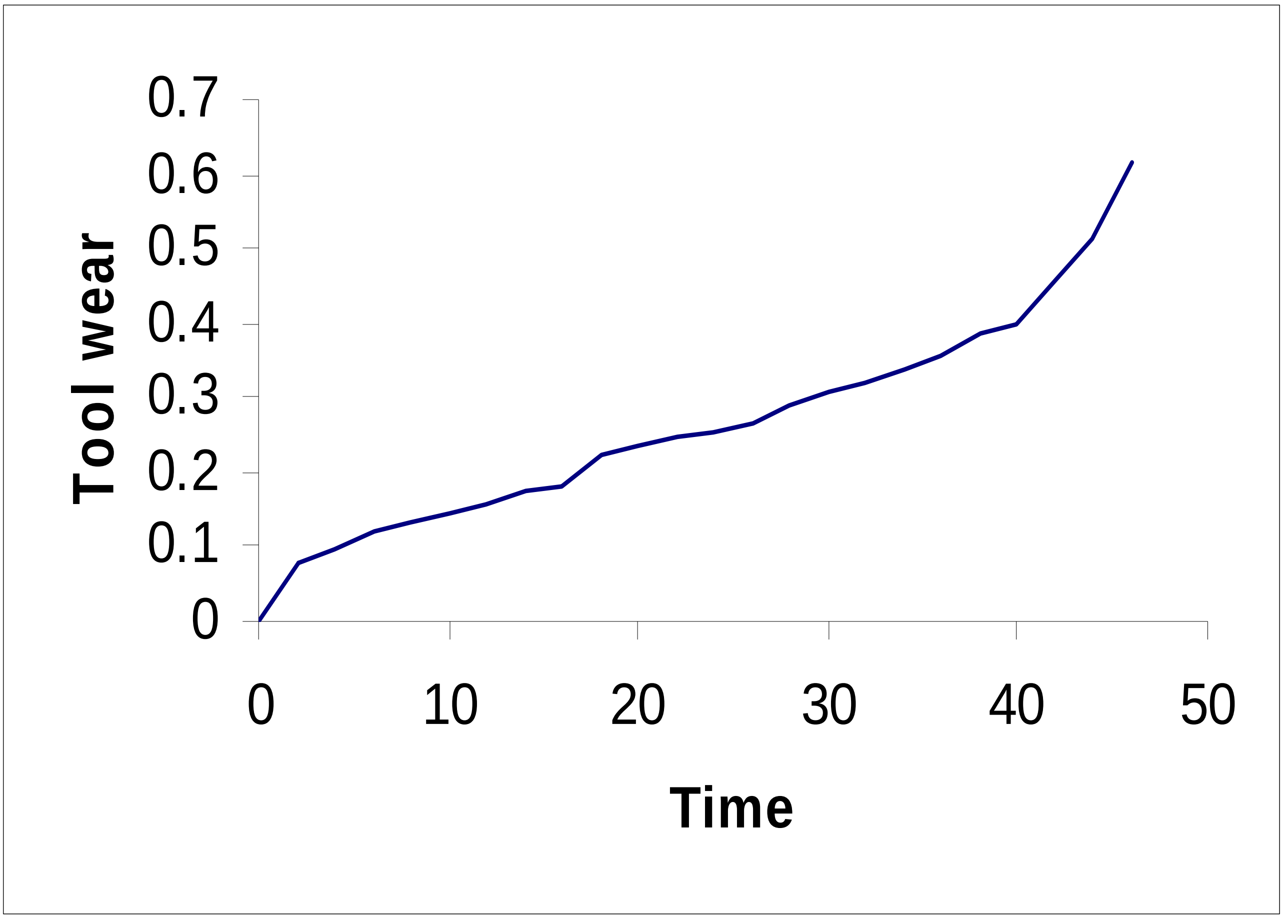


Figure 4.1: Tool wear Vs Time

From graph,

Tool Life = 40 min

SECOND RUN:

Cutting Speed = 19.55 m/min

Feed = 0.1mm/rev

Depth of Cut = 1.0 mm

Temperature = 400 degrees

Table 4.2: Tool Wear Vs Time for second run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER(Watt)
1	0	0	0
2	2	0.079	30

3	4	0.086	20
4	6	0.1	30
5	8	0.123	30
6	10	0.139	20
7	12	0.156	30
8	14	0.199	30
9	16	0.215	20
10	18	0.248	30
11	20	0.278	20
12	22	0.286	30
13	24	0.311	20
14	26	0.324	30
15	28	0.365	20
16	30	0.378	30
17	32	0.393	20
18	34	0.405	30
19	36	0.412	20

CALCULATION OF CUTTING FORCE:

Average power required (P) = 25.416 W

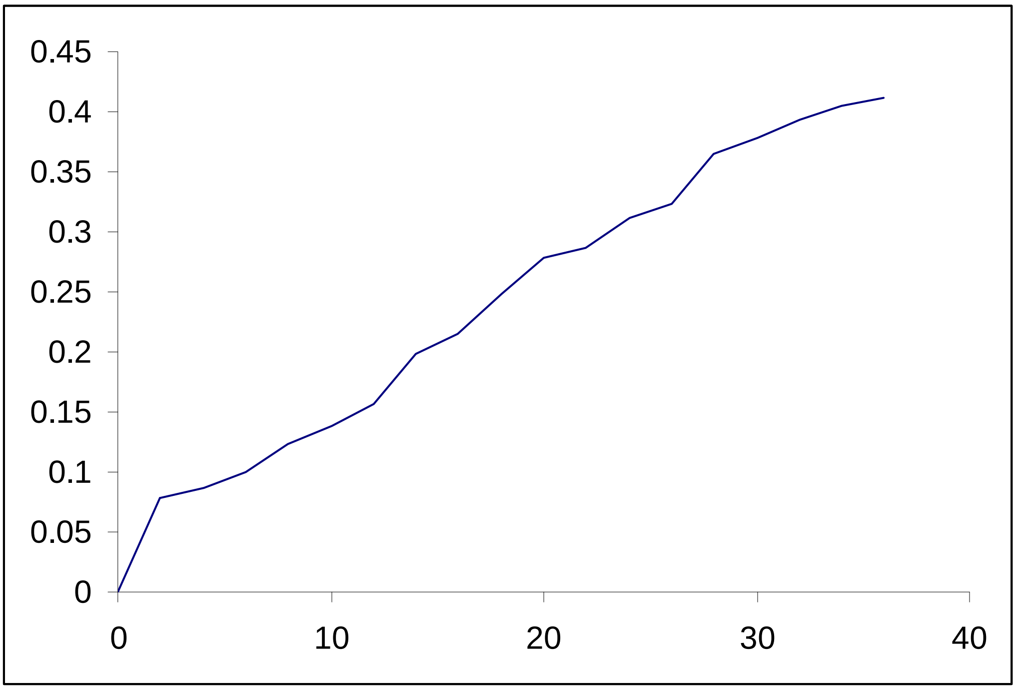
Diameter of the work piece= 0.0415 m

Cutting velocity = $\pi DN/60 = (3.14*0.0415*150)/60 = 0.3257$

Therefore cutting force= power/cutting velocity = 25.415/.3257 = 78.035 N

Cutting force =78.035 N

Figure 4.2: Tool wear Vs Time



From graph,

Tool Life = 34 min

THIRD RUN:

Cutting Speed = 19.55 m/min

Feed = 0.15 mm/rev

Depth of Cut = 1.5 mm

Temperature = 200 degrees

Table 4.3: Tool Wear Vs Time for third run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER (Watt)
1	0	0	0
2	2	0.12	30
3	4	0.129	30
4	6	0.156	30
5	8	0.165	30
6	10	0.172	30
7	12	0.182	30
8	14	0.193	20

9	16	0.207	30
10	18	0.245	20
11	20	0.271	30
12	22	0.285	20
13	24	0.299	30
14	26	0.323	20
15	28	0.356	30
16	30	0.381	20
17	32	0.423	30
18	34	0.498	20
19	36	0.545	30
20	38	0.61	30

CALCULATION OF CUTTING FORCE:

Average power required (P) = 26.84 W

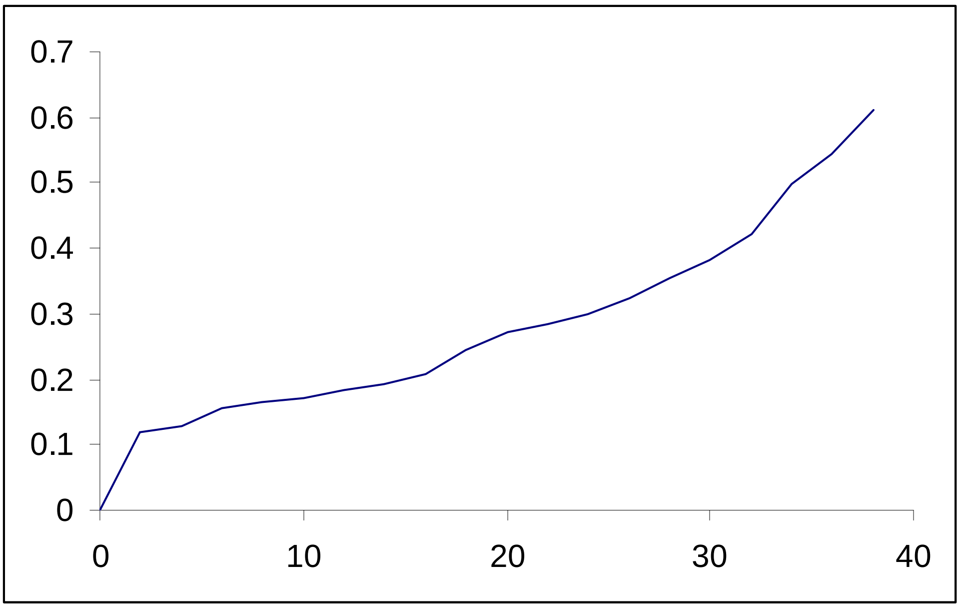
Diameter of the work piece= 0.0415 m

Cutting velocity = πDN/60 = (3.14*0.0415*150)/60 = 0.3257

Therefore cutting force= power/cutting velocity = 26.84/0.3257 = 82.41 N

Cutting force = 82.41 N

Figure 4.3: Tool wear Vs Time



From graph,

Tool Life = 31 minutes

FOURTH RUN:

Cutting Speed = 32.58 m/min

Feed = 0.05 mm/rev

Depth of Cut = 1.0 mm

Temperature = 200 degrees

Table 4.4: Tool Wear Vs Time for fourth run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER(W)
1	0	0	0
2	2	0.07	30
3	4	0.09	20
4	6	0.12	30
5	8	0.13	20
6	10	0.14	30
7	12	0.19	30
8	14	0.25	30
9	16	0.26	20
10	18	0.27	30
11	20	0.32	30
12	22	0.33	20
13	24	0.34	30
14	26	0.34	30
15	28	0.35	30
16	30	0.38	20
17	32	0.39	30
18	34	0.40	30
19	36	0.5	30

CALCULATION OF CUTTING FORCE:

Average power required (P) = 25.78 N

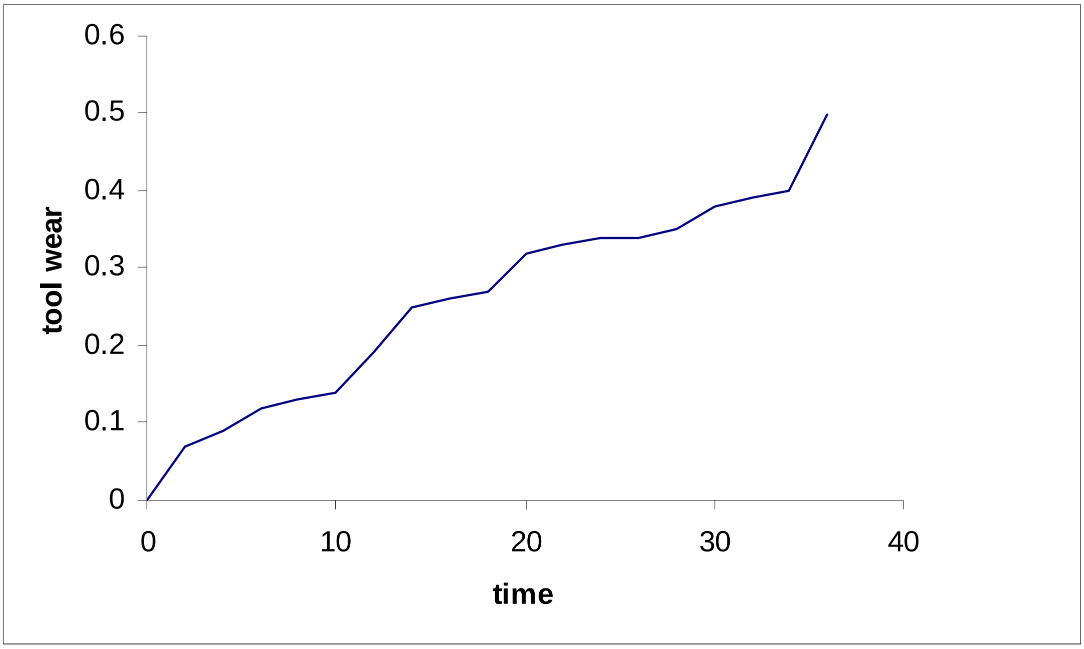
Diameter of the work piece= 0.0415 m

Cutting velocity = $\pi DN/60 = (3.14*0.0415*250)/60 = 0.523$

Therefore cutting force = power/cutting velocity = 25.78/0.523 = 49.31 N

Cutting force =49.31 N

Figure 4.4: Tool wear Vs Time



From graph,

Tool Life = 36 minutes

FIFTH RUN:

Cutting Speed = 32.58 m/min

Feed = 0.1 mm/rev

Depth of Cut = 1.5 mm

Temperature = 600 degree

Table 4.5: Tool Wear Vs Time for fifth run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER(W)
1	0	0	0
2	2	0.12	30
3	4	0.13	30
4	6	0.1	30
5	8	0.16	30
6	10	0.17	30

7	12	0.19	40
8	14	0.23	40
9	16	0.26	30
10	18	0.29	30
11	20	0.31	30
12	22	0.34	30
13	24	0.35	30
14	26	0.36	30
15	28	0.41	30
16	30	0.43	40
17	32	0.46	30
18	34	0.5	30

CALCULATION OF CUTTING FORCE:

Average power required (P) = 30 W

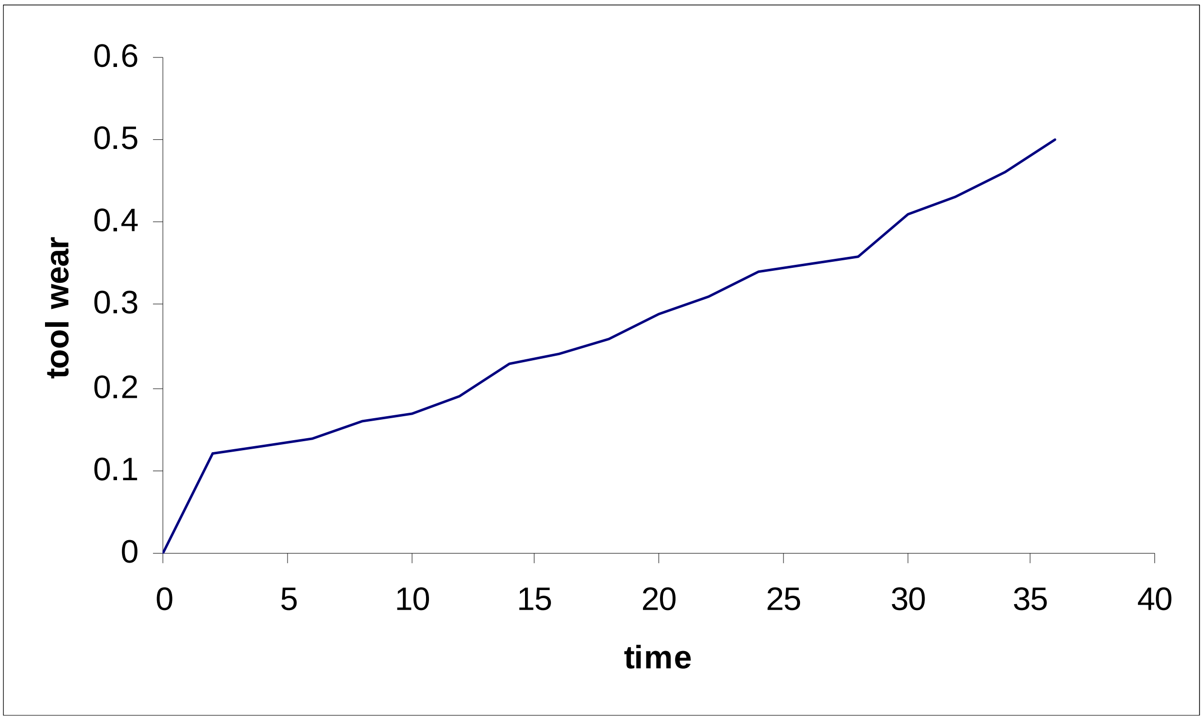
Diameter of the work piece = 0.0415 m

Cutting velocity = $\pi DN/60 = (3.14*0.0415*250)/60 = 0.523$

Therefore cutting force= power/cutting velocity = 30/0.523 = 57.361 N

Cutting force =57.361 N

Figure 4.5: Tool wear Vs Time



From graph,

Tool Life = 37 minutes

SIXTH RUN:

Cutting Speed = 32.58 m/min

Feed = 0.15 mm/rev

Depth of Cut = 0.5 mm

Temperature = 400 degree

Table 4.6: Tool Wear Vs Time for sixth run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER(W)
1	0	0	0
2	2	0.085	30
3	4	0.112	30
4	6	0.116	30
5	8	0.127	30
6	10	0.134	30
7	12	0.146	30
8	14	0.158	30
9	16	0.169	30
10	18	0.172	30
11	20	0.198	30
12	22	0.213	30
13	24	0.219	30
14	26	0.246	30
15	28	0.258	30
16	30	0.278	30
17	32	0.297	30
18	34	0.322	30
19	36	0.357	30
20	38	0.407	30
21	40	0.435	30
22	42	0.512	30

CALCULATION OF CUTTING FORCE:

Average power required (P) = 30

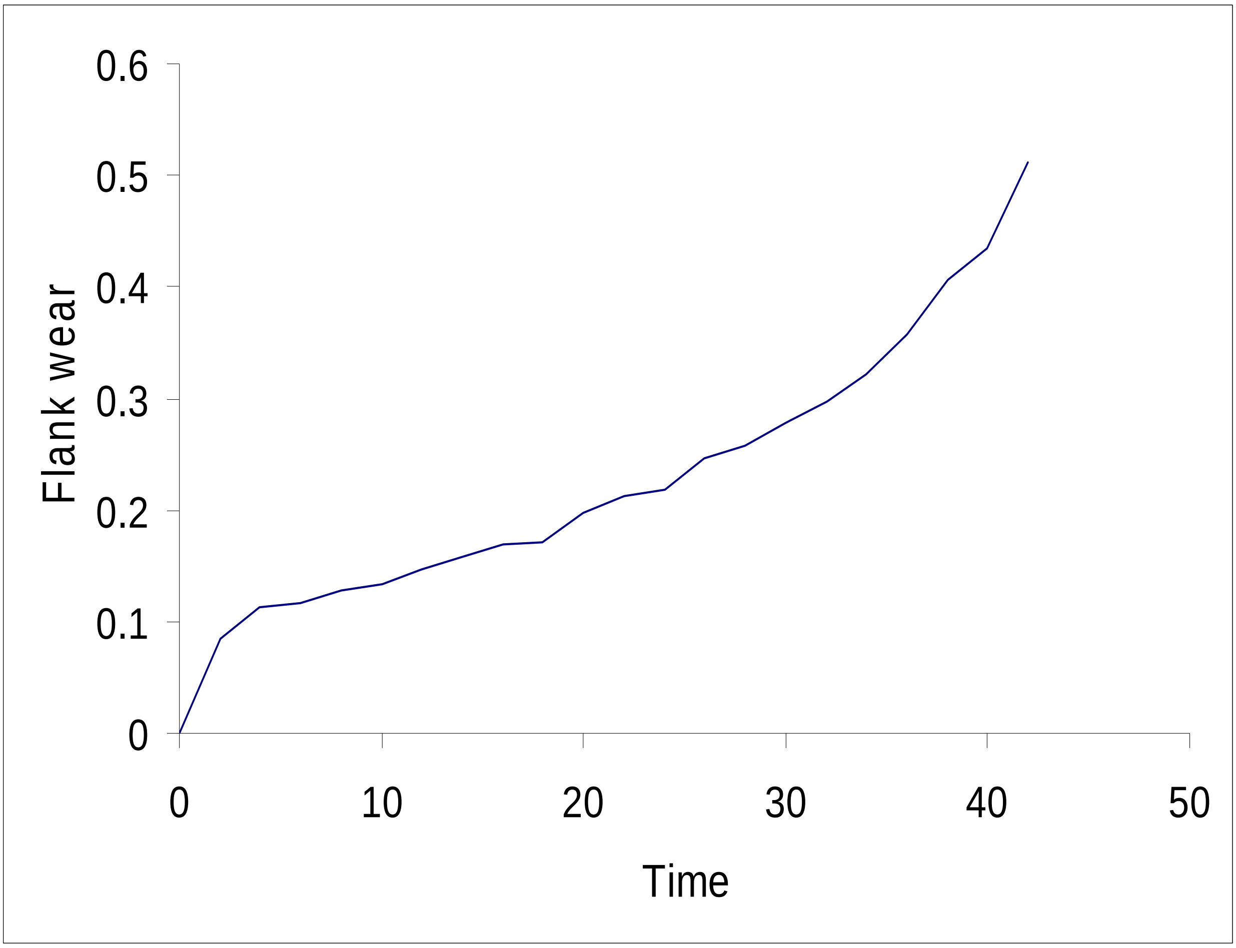
Diameter of the work piece = 0.0415 m

Cutting velocity = πDN/60 = (3.14*0.0415*250)/60 = 0.523

Therefore cutting force= power/cutting velocity = 30/0.523 = 57.361 N

Cutting force = 57.361 N

Figure 4.6: Tool wear Vs Time



From graph,

Tool Life = 38 minutes

SEVENTH RUN:

Cutting Speed = 54.73 m/min

Feed = 0.05 mm/rev

Depth of Cut = 1.5 mm

Temperature = 400 degrees

Table 4.7: Tool Wear Vs Time for seventh run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER(W)
1	0	0	0
2	2	0.096	40
3	4	0.126	30
4	6	0.134	40
5	8	0.154	40
6	10	0.168	40
7	12	0.178	30
8	14	0.182	40
9	16	0.198	40
10	18	0.211	40
11	20	0.234	30
12	22	0.245	40
13	24	0.259	40
14	26	0.271	30
15	28	0.294	40
16	30	0.331	40
17	32	0.367	40
18	34	0.403	40
19	36	0.419	30
20	38	0.471	40
21	40	0.487	40
22	42	0.545	40

CALCULATION OF CUTTING FORCE:

Average power required (P) = 37.61 W

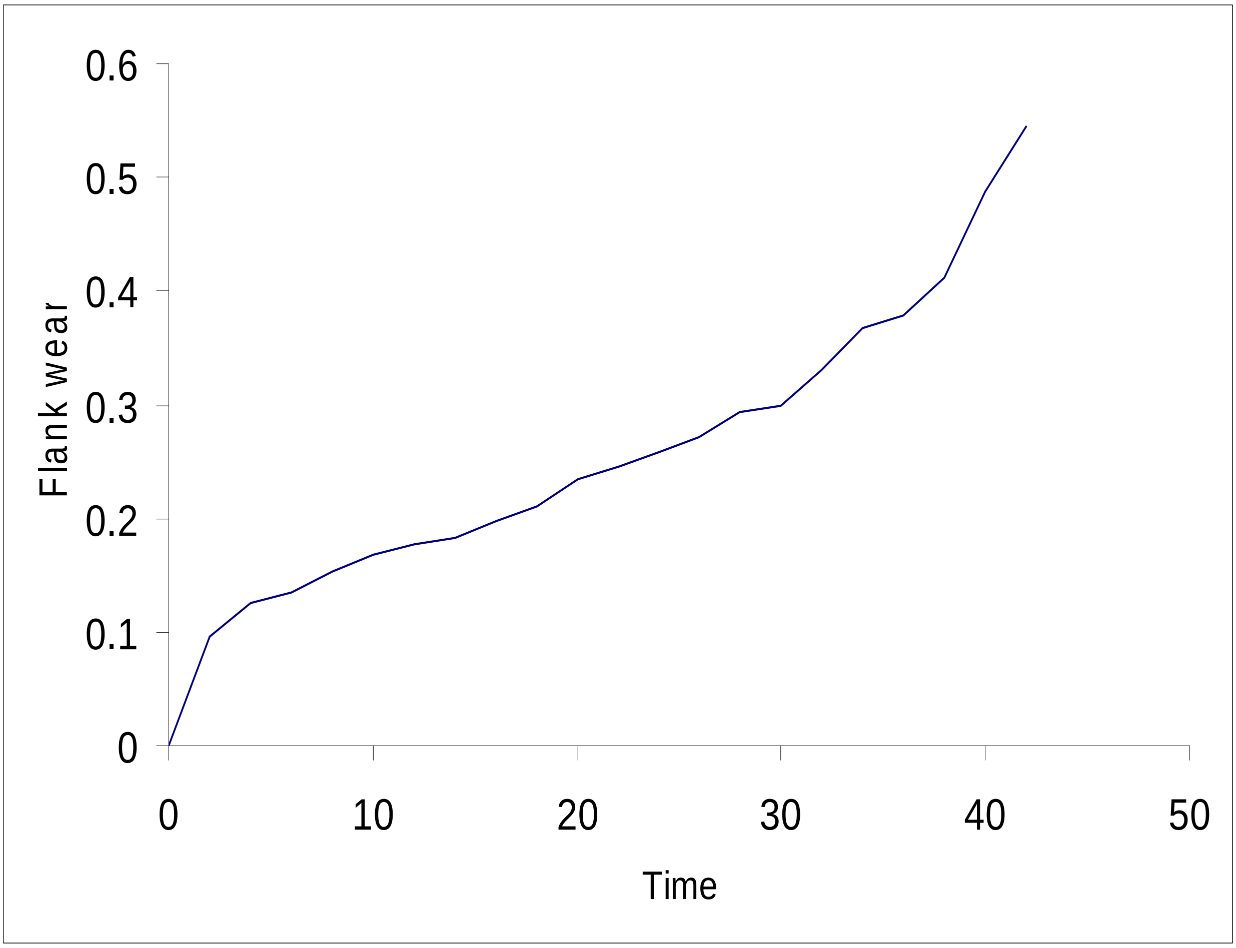
Diameter of the work piece= 0.0415 m

Cutting velocity = πDN/60 = (3.14*0.0415*420)/60 = 0.9121

Therefore cutting force= power/cutting velocity = 37.61 /0.9121 = 41.23 N

Cutting force =41.23 N

Figure 4.7: Tool wear Vs Time



From graph,

Tool Life = 34 minutes

EIGTH RUN:

Cutting Speed = 54.73 m/min

Feed = 0.1 mm/rev

Depth of Cut = 0.5 mm

Temperature = 200 degrees

Table 4.8: Tool Wear Vs Time for eighth run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER(W)
1	0	0	0
2	2	0.091	40

3	4	0.121	40
4	6	0.132	40
5	8	0.146	40
6	10	0.154	40
7	12	0.181	40
8	14	0.193	40
9	16	0.214	40
10	18	0.235	30
11	20	0.248	40
12	22	0.279	40
13	24	0.287	40
14	26	0.307	40
15	28	0.325	40
16	30	0.358	30
17	32	0.382	40
18	34	0.404	40
19	36	0.439	40
20	38	0.459	40
21	40	0.512	40

CALCULATION OF CUTTING FORCE:

Average power required (P) = 39W

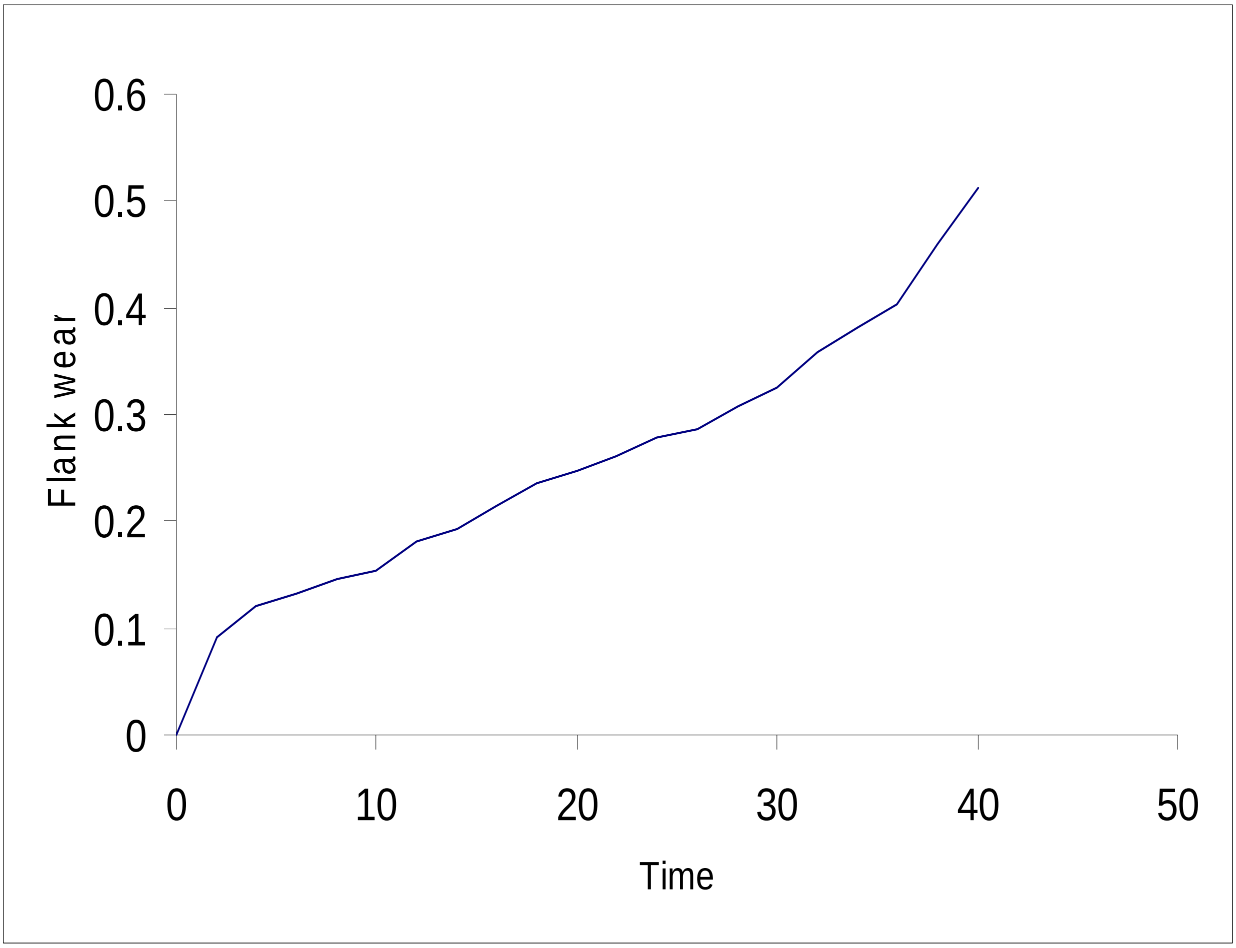
Diameter of the work piece = 0.0415 m

Cutting velocity = $\pi DN/60 = (3.14*0.0415*420)/60 = 0.9121$

Therefore cutting force= power/cutting velocity = 39/ 0.9121 = 42.75 N

Cutting force =42.75 N

Figure 4.8: Tool wear Vs Time



From graph,

Tool Life = 35 minutes

NINTH RUN:

Cutting Speed = 54.73 m/min

Feed = 0.15 mm/rev

Depth of Cut = 1.0 mm

Temperature = 600 degree

Table 4.9: Tool Wear Vs Time for ninth run

S.NO	TIME (minutes)	FLANK WEAR(mm)	POWER(W)
1	0	0	0
2	2	0.092	30
3	4	0.123	40

4	6	0.129	40
5	8	0.138	40
6	10	0.149	30
7	12	0.157	40
8	14	0.168	40
9	16	0.194	40
10	18	0.214	30
11	20	0.229	40
12	22	0.246	30
13	24	0.257	40
14	26	0.279	40
15	28	0.299	30
16	30	0.324	30
17	32	0.350	40
18	34	0.370	40
19	36	0.409	30
20	38	0.471	40
21	40	0.534	30

CALCULATION OF CUTTING FORCE:

Average power required (P) = 36.00 W

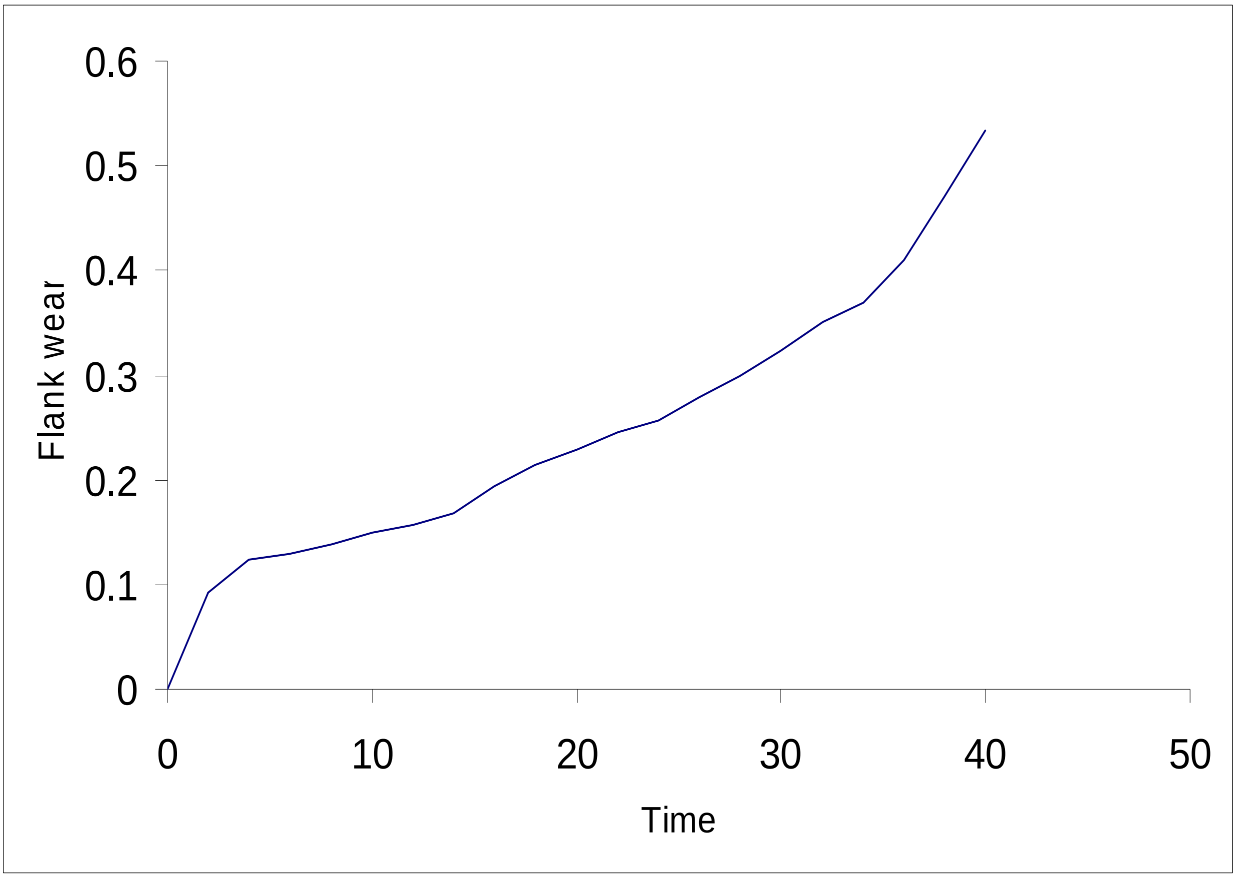
Diameter of the work piece= 0.0415 m

Cutting velocity = $\pi DN/60 = (3.14*0.0415*420)/60 = 0.9121$

Therefore cutting force= power/cutting velocity = 36.00 /0.9121 = 39.46 N

Cutting force =39.46 N

Figure 4.9: Tool wear Vs Time



From graph,

Tool Life = 36 minutes

Table 4.10: EXPERIMENTAL OBSERVATION

TRAIL NUMBER(RUNS)	CONTROL FACTORS				RESPONSE
	CUTTING SPPED(1)	FEED(2)	DEPTH OF CUT(3)	TEMPERATURE(4)	
1	150	0.05	0.5	600	40
2	150	0.1	1.0	400	34
3	150	0.15	1.50	200	31
4	250	0.05	1.0	200	36
5	250	0.1	1.5	600	37
6	250	0.15	0.5	400	38
7	420	0.05	1.5	400	34
8	420	0.1	0.5	200	35
9	420	0.15	1.0	600	36

In this the response is Tool Life. It would be the best if Tool Life is more. So the objective is to maximize the tool life. So we select Larger is Better Signal to Noise ratio.

Higher is better:

$S/N_{HB} = -10 \log \{1/r \sum 1/y_i^2\}$

Where,

r is the number of trails for same experiment.

y_i is the observed response.

With the help of MINITAB software we draw the average SNR table and also we plot the main effect plot.

Table 4.10: SNR TABLE

RUNS	SNR VALUE
1.	32.041
2.	30.62
3.	29.82
4.	31.12
5.	31.36
6.	31.59
7.	30.62
8.	30.88
9.	31.12

SAMPLE CALCULATION FOR AVERAGE SNR

For cutting speed = 150 rpm

Average SNR_1 for level 1 = (1/3)*(32.041+30.62+29.82) = 30.83

Average SNR_2 for level 2 = (1/3)*(31.12+31.36+31.59) = 31.36

Average SNR_3 for level 3 = (1/3)*(30.62+30.88+30.12) = 30.88

Effect = SNR_1- SNR_3 = 0.53

Table 4.11: AVERAGE SNR TABLE

FACTOR'S SNR	CUTTING SPEED	FEED	DEPTH OF CUT	TEMPERATURE
SNR1	30.83	31.27	31.51	31.51
SNR2	31.36	30.96	30.96	30.95
SNR3	30.88	30.85	30.61	30.61
DELTA	0.53	0.42	0.90	0.90
RANK	3	4	1	2

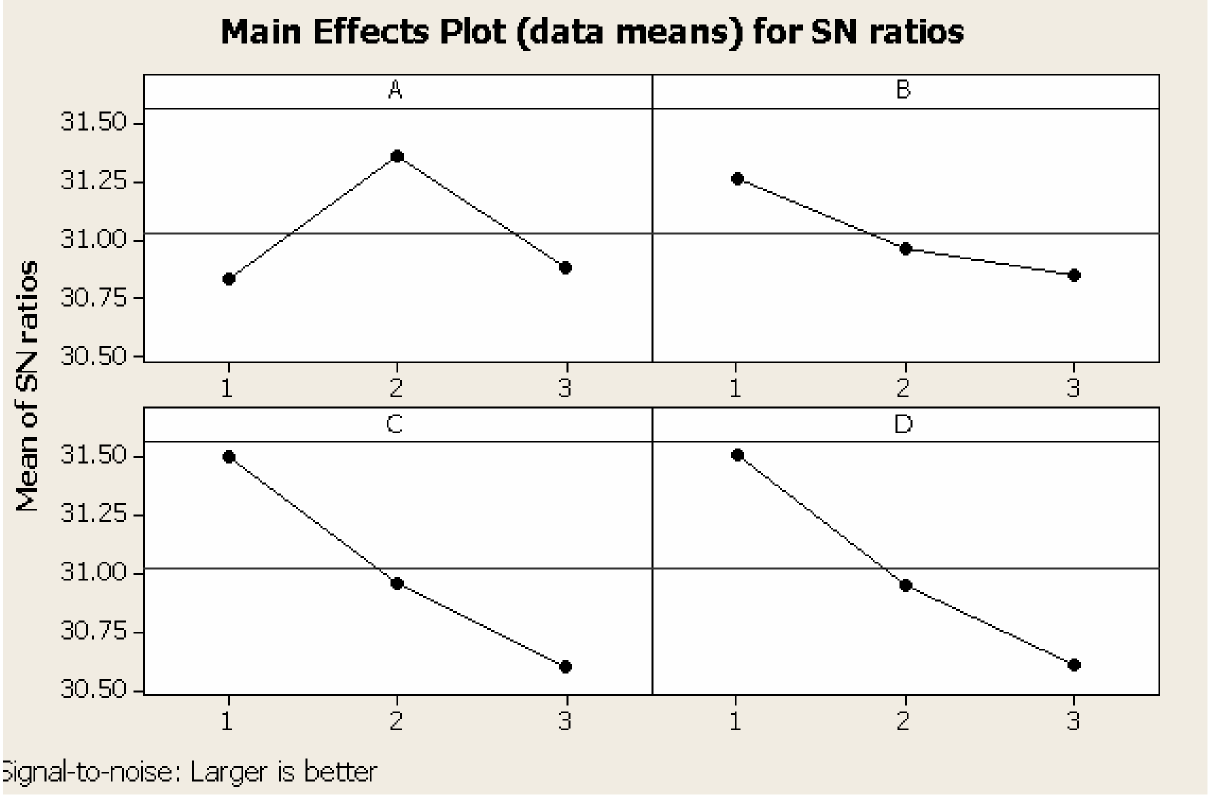


Figure 4.10: Main effect plot of control factors (Tool life)

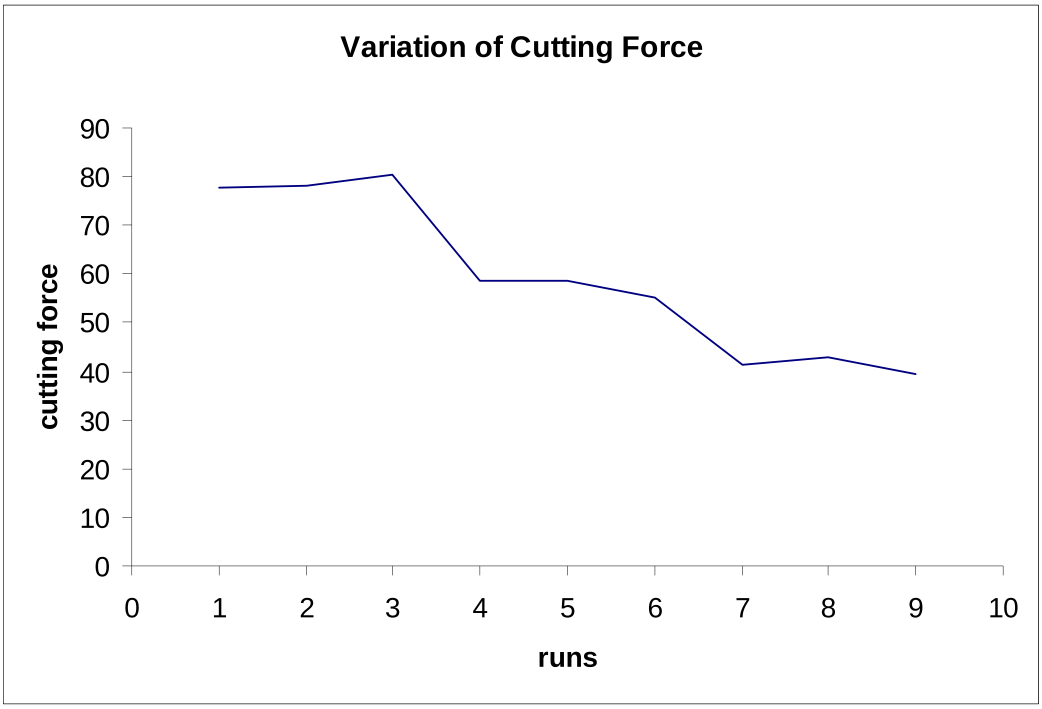


Figure 4.11: Variation of cutting force

RESULT:

The experiment was carried out with the aim of optimizing the control factors of turning operation in hot machining In order to study the effect of variables and the possible interactions between them in a minimum number of trials, the Taguchi approach to experimental design was adopted. Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. , the primary goal is to find factor settings that minimize response variation, while adjusting (or keeping) the process on target. . A process designed with this goal will produce more consistent output. A product designed with this goal will deliver more consistent performance regardless of the environment in which it is used. From the past experiments it was found the power consumed during turning operations is primarily due to shearing of the material and plastic deformation of the metal removed. Since both the shear strength and hardness values of engineering materials decrease with temperature, it was thus postulated that an increase in work piece temperature would reduce the amount of power consumed for machining and eventually increase tool life

For this experiment the optimum values are found to be

Cutting Speed = 150, Feed = 0.05, Depth of Cut = 0.5, Temperature = 600

From the above result we find that by using Taguchi design (MINITAB) and Hot machining the power required is decreased and tool life is increased by 14.83 %. (Using ATP Grade tool)

CONCLUSION:

By using ATP grade tool for turning operation by Hot Machining and Design of experiments using Taguchi statistical analysis, we find that tool life has increased and power has been decreased. For this experiment the optimum values are found to be Cutting Speed = 150, Feed = 0.05, Depth of Cut = 0.5, Temperature = 600. From the above result we find that by using Taguchi design (MINITAB) and Hot machining the power required is decreased and tool life is increased by 14.83 %.

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