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Optimization of tool life & determination of equation to setup inventory by performing experiments on different materials using CNC lathe machine

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Abstract — *In the current manufacturing industries, cost of the product is most important parameter and there are too many parameters that effects such as tool Life, Production of the component, Product quality, etc. From all above parameter, tool life directly effects on the product quality and productivity of the product. Tool life is a number of products machined between the two grinding of the cutting tool; we have determined the tool life by the method of design of experiment. In this paper, various cutting parameter as cutting speed, depth of cut and feed rate of the cutting tool has been taken into the account along with two different conditions as dry and wet coolant conditions and the material of the product are changed as Aluminium alloy, EN-9 and EN-31. Then the observed data has been studied on the Minitab software to develop the equation based on the material parameter.*

Keywords- *Tool Life; Regression Analysis; Dry v/s Wet coolant, EN9 EN31 Aluminum Alloy; CNC lathe machine.*

I. INTRODUCTION

Turning is the removal of metal from the outer diameter of a rotating cylindrical work pieces. Turning operation is also defined as the reduction of the material from the cylindrical component from outside or inside surface of the cylindrical component. If good finish and accurate size are desired one or more roughing cuts usually are followed by one or more finishing cuts. In turning primary cutting motion is rotational with the tool feeding parallel to the axis of rotation. Turning can be broken-down into a number of basic cutting operations and in effect, there are basically four such operations, these are: 1. Longitudinal turning 2. Facing 3. Taper turning 4. Profiling. The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as type of material, type of tool and type of cutting fluid have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, at the machining time. A fluid agent (gas or liquid) that produces cooling; especially one used to cool a system by transferring heat away from one part to another lathe operators use an emulsion of oil and water as a coolant for the cutting tool. Agent - a substance that exerts some force or effect; Fluid - a substance that is fluid at room temperature and pressure. Coolant is categorized into four main groups, and each group is available in many different formulations.

Table 1. Types of Coolants

Oil Soluble:	Contains 60-85% mineral oil and emulsifies into water
Semi-Synthetic:	Contains 5-50% mineral oil and emulsifies into water
Full Synthetic:	Contains no mineral oil
Straight Oils:	Contains 70-85% mineral oil and is not water-miscible

Sometimes, it is possible to use more than one manufacturing processes, then the best possible process must be utilized in manufacturing of the product. It is therefore important to know what materials are available in the universe with it usual cost. What are the common characteristics of engineering materials such as physical, chemical, mechanical, thermal, optical, electrical, and mechanical? How they can be processed economically to get the desired product. Nowadays, more and more Computer Numerical Controlled (CNC) machines are being used in every kind of manufacturing processes. In a CNC machine, functions like program storage, tool offset and tool compensation, program-editing capability, various degree of computation, and the ability to send and receive data from a variety of sources, including remote locations can be easily realized through on board computer. The computer can store multiple-part programs, recalling them as needed for different parts. Tool wear in machining is defined as the amount of volume loss of tool material on the contact surface due to the interactions between the tool and work piece. Specifically, tool wear is described by wear rate and is strongly determined by temperature, stresses, and relative sliding velocity generated at the contact interface. It is normal practice to assess tool life according to three mutually-influencing criteria. These criteria that significantly affect machined components and can be the reason for curtailment of the cutting tool's life are ability to sustain work piece tolerances; Maintaining machined surface texture quality, Efficiency in chip-breaking ability. Generally, it is found that the factors influencing surface roughness in turning are depth of cut, feed, cutting speed, engagement of the cutting tool, cutting tool wears, use of cutting fluid.

II. EXPERIMENTAL SETUP

One persistent trend throughout the history of metal machining has been the use of higher and higher cutting speeds. To achieve approximately zero tolerance product higher configuration and expensive machine should be used. Major concern of this, it increases the final cost of the product. To reduce the cost of the product manufactured on these machines we need to reduce the cost of the quality setup as well as the initial setup done on the machine. The set-up parameter means the life of the CNC turning tool, because the condition and finally the life of the tool is important to maintain the anticipated productivity as well as expected quality. To determine the life, Tool Wear Rate of the tool we have to perform the trial by changing the material with the CNC Carbide insert. Materials will be used in experiment: EN – 9, EN – 31, aluminium. These are the most commonly used materials in the engineering industries. By performing the experiment we can determine the Tool Wear Rate. Before changing the material we will be able to know the how many tools are required to produce the required quantity, by these way we will be able to reduce the cost of quality setup and increase the productivity of the machine.

Figure 1. LMW CNC Lathe machine

The complete experimentation was conducted on LMW CNC lathe machine. For the following experimentation the mainly two conditions were carried out that is dry running and wet running using Multan B-204 as a coolant. Initially the parameters were decided before performing the experiment. The parameters were decided for cutting speed of 210, 230 and 250 rpm and depth of cut as 0.5 and 1 mm and keeping feed rate constant as 0.14. The operation was performed for both the conditions that are dry as well as wet.

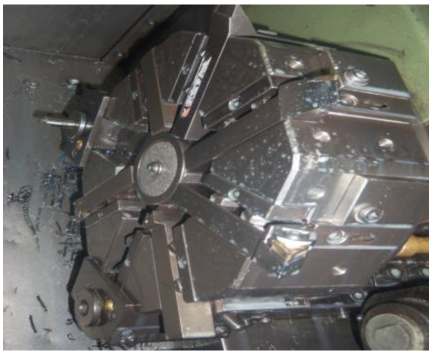

Figure 2. Tool post with insert

Coolant name: Multan B-204, Coolant type: semi synthetic, Metal type: steel, cast-iron, aluminium, Application: machining and grinding. *Lubrication and cooling effects provided by* cutting fluids result in the following benefits of metal working: Better surface finish, Longer tool life, Narrower tolerances of the work piece size, Lower energy consumption, Cleaner cutting zone, Better corrosion protection. Multan B-204 is semi-synthetic fluid designed for machining and grinding ferrous and aluminium alloys. Its unique composition of corrosion inhibitors, extreme pressure, lubricity additives and bio-resistance components provide durable low foaming, hard water stable product for machining and grinding process.

Table 2. Specification of LMW CNC lathe machine

Element	Size / dimension
Name of equipment	**CNC TURNING CENTRE**
Equipment serial no.	55-01252
Tag no.	TC-03

Application	TURNING
Model no.	SMART RUN
Make	LMWSMARTRUN
Swing over bed	480mm
Max. turning length	262mm
Max. turning dia.	200mm
Standard turning dia.	169mm
Spindle motor	5.5Kw/7.5Kw
Spindle bor	53mm
Spindle nose	Flat dia. 140mm
Coolant motor	0.25Kw
Cheep conveyor motor	0.18Kw
Axis drive	SIMODRIVE
Ball screw x-axis	32 x 10 pitch
Ball screw z axis	32 x 10 pitch
Speed range	50-4500 rpm
Max rapid speed	20000mm/min
Weight	3800 kg
Floor space	2960*1685*1485
Standard access	165mm hydraulic chuck

Design of Experiment (DOE) is a powerful technique used for exploring new processes; DOE is an experimental strategy in which effects of multiple factors are studied simultaneously by running tests at various levels of the factors. The Design of experiment is used to develop a layout of the different conditions to be studied. An experimental design must satisfy two objectives: first, the number of trials must be determining; second, the conditions for each trial must be specified. There are certain methods for the D.O.E. are available in the statics and are Factorial, Response surface, Mixture, Taguchi, Select optimal design, Response optimization. In statistics, regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modelling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. Regression analysis is widely used for prediction and forecasting. Different work material used for this experimentation are EN9, EN31 and aluminium while keeping the conditions as follows: Cutting Speed (m/min) – 210/230/250, Depth of cut (mm) – 0.5/1.0, Feed Rate (mm/rev) – 0.14 and machining conditions as dry and wet.

For EN-9 material when it is performed under the dry conditions the result for the material at the different parametric conditions are as follows:

Table 3: DOE Experimentation (EN9)-Dry Conditions

Run	Speed	Depth of cut	Vol. of mat. Removed	Tool Life
1	210	0.5	1250	87.2
2	210	1	1560	40.26
5	230	0.5	941	65.4
6	230	1	1176	30.2
9	250	0.5	628	43.6
10	230	1	784	20.13

For Al material when it is performed under the dry conditions the result for the material at the different parametric conditions are as follows:

Table 4. DOE Experimentation Al-Dry Conditions

Run	Speed	Depth of cut	Vol. of mat. Removed	Tool Life
13	210	0.5	50135	1355
14	210	1	20054	542
17	230	0.5	37605	1016
18	230	1	15100	408
21	250	0.5	31005	838

22	230	1	12095	326

For EN31 material when it is performed under the dry conditions the result for the material at the different parametric conditions are as follows:

Table 5. DOE Experimentation (EN31)-Dry Conditions

Run	Speed	Depth of cut	Vol. of mat. Removed	Tool Life
25	210	0.5	1258	70
26	210	1	1512	30
29	230	0.5	957	51
30	230	1	1172	25
33	250	0.5	639	35
34	230	1	791	16

The comparison of the different material in the dry conditions is showed in the chart. This chart clearly shows the optimum value at which the machining processes can be done.

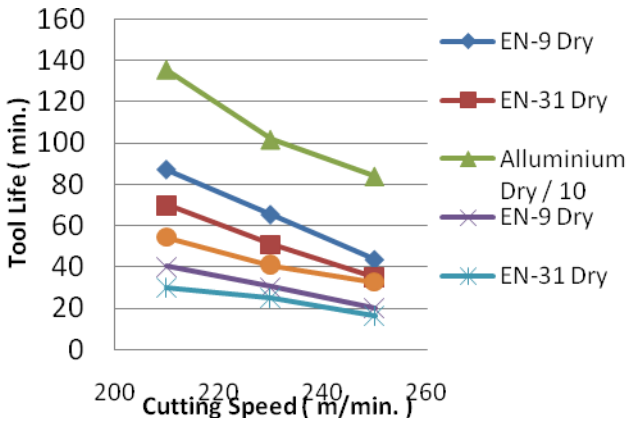

Figure 3. Cutting Speed Vs Tool Life (Dry Condition)

For EN9 material when it is performed under the wet conditions the result for the material at the different parametric conditions are as follows:

Table 6. DOE Experimentation EN9 - Wet Conditions

Run	Speed	Depth of cut	Vol. of mat. Removed	Tool Life
3	210	0.5	1410	116.54
4	210	1	1629	45.1
7	230	0.5	1059	87.4
8	230	1	1221	33.83
11	250	0.5	706	58.27
12	230	1	815	22.55

For Al material when it is performed under the wet conditions the result for the material at the different parametric conditions are as follows:

Table 7. DOE Experimentation Al - Wet Conditions

Run	Speed	Depth of cut	Vol. of mat. Removed	Tool Life
15	210	0.5	60165	1627
16	210	1	24050	650
19	230	0.5	45125	1220
20	230	1	18150	490
23	250	0.5	36050	975
24	230	1	14550	394

For EN31 material when it is performed under the wet conditions the result for the material at the different parametric conditions are as follows:

Table 8. DOE Experimentation (EN31) - Wet Conditions

Run	Speed	Depth of cut	Vol. of mat. Removed	Tool Life
27	210	0.5	1424	90
28	210	1	1639	38
31	230	0.5	1071	68
32	230	1	1232	28
35	250	0.5	716	45
36	230	1	824	17

The comparison of the different material in the wet conditions is showed in the chart. This chart clearly shows the optimum value at which the machining processes can be done.

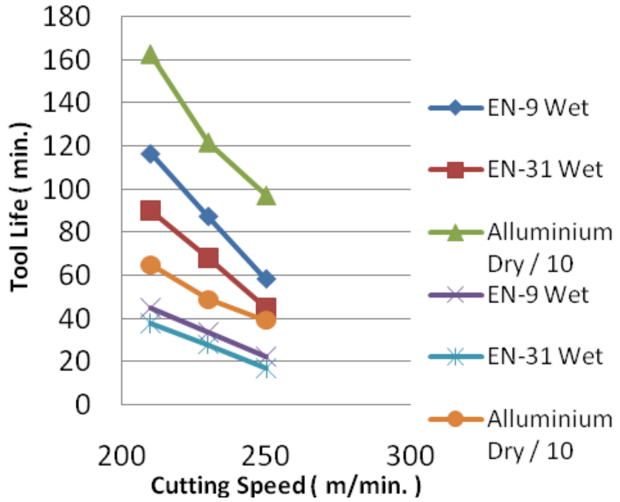

Figure 4. Cutting Speed Vs Tool Life (Wet Condition)

Here, the chart compares all the three material at given parameters in dry as well as wet condition at 1 depth of cut for the same tool and shows the tool life for the following.

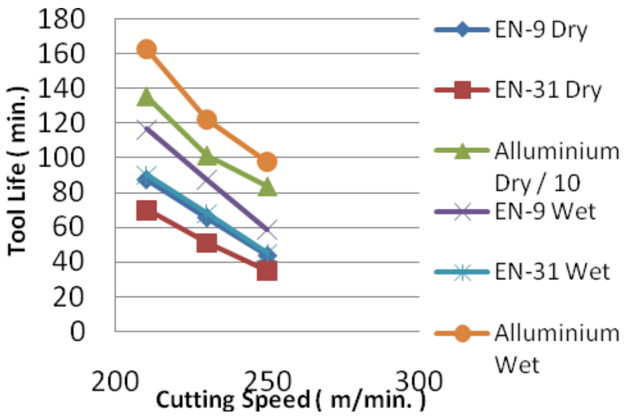

Figure 5. Cutting Speed Vs Tool Life (0.50 DoC and Dry and Wet Condition)

Here, the chart compares all the three material at given parameters in dry as well as wet condition at 1 depth of cut for the same tool and shows the tool life for the following.

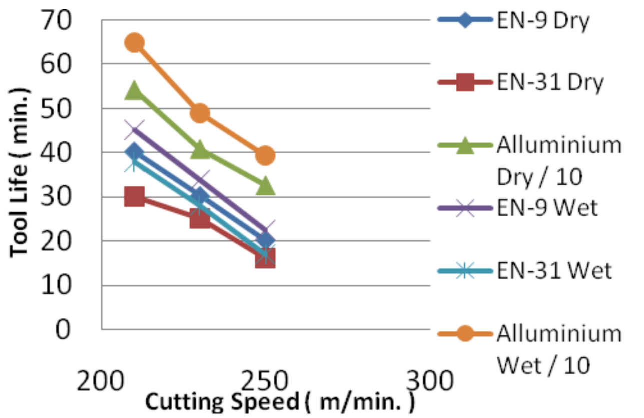

Figure 6. Cutting Speed Vs Tool Life (1 DoC and Dry and Wet Condition)

The bearing race which has been taken as our work piece material has to go through the inspection which shows the satisfactory results this sample was selected from the bunch of pieces and through the patrol inspections 10 random pieces were selected.

By keeping the feed 0.14 mm/rev, the tool life founded experimentally and the theoretical equation to get the tool life on computer developed and validated with the existing tool life which is experimentally determined.

Equation for EN-9 for dry condition:

(Feed / (cutting speed x depth of cut)) x exp $_{(1 / \text{Depth of cut})}$ x 0.42 x (cutting speed / cutting speed $_{max}$) and same thing is validated as mentioned in the below chart :

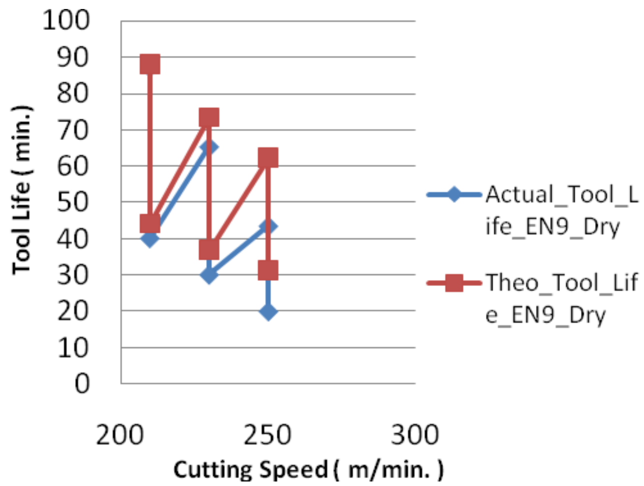

Figure 7. Tool Life Comparison Theory Vs Actual

By keeping the feed 0.14 mm/rev, the tool life founded experimentally and the theoretical equation to get the tool life on computer developed and validated with the existing tool life which is experimentally determined.

Equation for EN-9 for wet condition:

(Feed / (cutting speed x depth of cut)) x exp $_{(1 / \text{Depth of cut})}$ x 0.52 x (cutting speed / cutting speed $_{max}$) and same thing is validated as mentioned in the below chart :

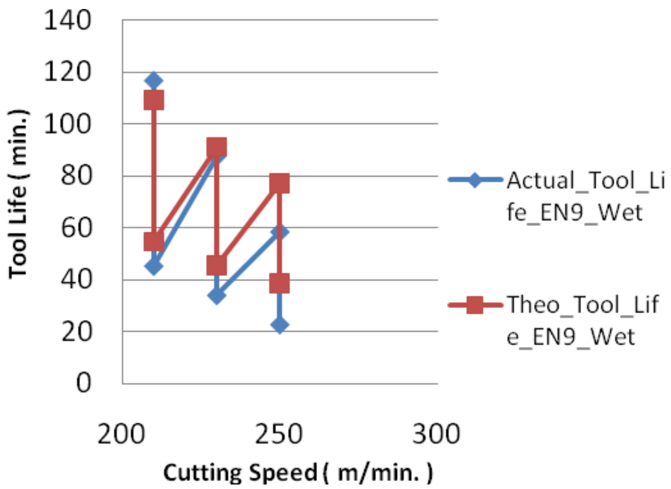

Figure 8. Tool Life Comparison Theo Vs Actual

Equation for EN-31 for dry condition:
(Feed / (cutting speed x depth of cut)) x exp $_{(1 / \text{Depth of cut})}$ x 0.32 x (cutting speed / cutting speed $_{max}$)

Equation for EN-31 for wet condition:
(Feed / (cutting speed x depth of cut)) x exp $_{(1 / \text{Depth of cut})}$ x 0.42 x (cutting speed / cutting speed $_{max}$)

Equation for aluminum (Al) for dry condition:
(Feed / (cutting speed x depth of cut)) x exp $_{(1 / \text{Depth of cut})}$ x 6.4 x (cutting speed / cutting speed $_{max}$)

Equation for aluminum (Al) for wet condition:
(Feed / (cutting speed x depth of cut)) x exp $_{(1 / \text{Depth of cut})}$ x 7.0 x (cutting speed / cutting speed $_{max}$)

III. CONCLUSION

After completion of all the trials on CNC lathe turning machine for the different materials, for the different parameters and different running conditions. After each trial the flank wear and the amount of material removed were measured along with the time taken to remove it. The roughness in surface finish was the prime indication of the tool failure or end of tool life. The tool life on different material was found different. Also there was a difference in tool life for the different conditions. The tool life founded experimentally and the theoretical equation to get the tool life on computer developed and validated with the existing tool life which is experimentally determined.

Equation for EN-9 for dry condition:
(Feed / (cutting speed x depth of cut)) x exp $_{(1 / \text{Depth of cut})}$ x 0.42 x (cutting speed / cutting speed $_{max}$) and same thing is validated.

The same equations are developed for the all of three materials for the both conditions and we derived the following conclusions: As the conditions of the cutting changed from dry to wet, the tool life is increased by 33.64% for the EN-9 material. As the conditions of the cutting changed from dry to wet, the tool life is increased by 28.57 % for the EN-31 material. As the conditions of the cutting changed from dry to wet, the tool life is increased by 19.90% for the AL material. The derived equation is matched with the existing condition of tool life and this will help to maintain the inventory of the tool insert to finish the batch of the production. Estimated tool life has reduced the tooling cost by reducing the damage of the production.

IV. FUTURE SCOPE:

Further experimentation should be done on effect of different coolant on the tool life. Tool analysis of the tool insert should be done on analysis software to strengthen the insert. Effect of Work piece hardness on the tool life should be studied. Effect of tooling material on the work piece should be studied. Effect of residual stresses in work piece on tool life should be studied.

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