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Development of External Honing Attachment for Lathe Machine

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***Abstract* - The work is on development of external honing attachment for conventional Lathe machine. Honing is one of the super finishing process, which is also an abrasive machining process that produces a precision surface on the metal work piece by scrubbing an abrasive stone against it along the controlled path. This attachment is for external honing on lathe. It is basically used to overcome the drawbacks of external grinding with two purposes - primary purpose to improve surface regularity and to remove chatter marks and secondary purpose is to improve surface finish. The attachment was designed and the model was prepared in a CAD software. Based on the design, actual attachment was manufactured in the machine shop. After manufacturing of the attachment various experiments were conducted in order to obtain required surface finish. Optimization of process parameters were performed using Taguchi method.**

***Index Terms* - Honing, Lathe, Surface Finish, Taguchi**

I.INTRODUCTION

The geometrical and dimensional accuracy obtained by normal method of machining, like turning, milling, etc., are limited. The geometrical errors include circularity, cylindricity, flatness and parallelism of functional surfaces. Also, the surface finish has vital influence on most important functional properties such as wear resistance and corrosion resistance and power losses due to friction. Poor surface finish leads to rupture of oil films on peaks of micro irregularities, which leads to state approaching dry friction, and results in excessive wear of the rubbing surface. Therefore, fine finishing process is employed in machining the surfaces of many critical components to obtain a very high surface finish or high dimensional and geometrical accuracy. Such processes include honing, lapping, super finishing and burnishing [1].

Honing is a low velocity abrading process in which stock is removed from metallic or non-metallic surfaces by bonded abraded sticks. It is finishing operation correct out roundness, taper and axial distortion in work pieces and also produces high finish. In this process, the erosion of the honing tool and the work-piece takes place simultaneously, so there is no need for truing of the tool [1].

The honed surface produced will have characteristics cross hatched lay pattern. Honing is employed very frequently for finishing of bore, but there are numerous external surfaces which are honed to obtain required properties. Some examples are gear teeth, valve seating, races of ball and roller bearing. It is effective on almost any ferrous or nonferrous material in hardened or soft condition.

Honing can be done in the presence of cutting fluid or dry honing is also possible. The application of the cutting fluid depends on the material to be honed, the stock to be removed and the surface finish required.

II. APPLICATION

External honing is used to a large extent to cure the ills of various types of previous machining operations, and to refine the work's surface for both accuracy and surface finish with minimum stock removal. Very common surface error found in ground finishes caused by grinding machine.

Vibration and showing up as faintly visible parallel lengthwise marks in the freshly ground surfaces is easily eradicated by external honing.

External honing is mostly used for super finishing of the components requiring high surface precision and surface finish. It is used in for honing components like Piston liner, Hydraulic plunger, for shaft of machinery used in dusty environment, for finishing of turbine shafts, crankshafts etc.

III. HONING PROCESS

The honing stones are having similar constructions as the grinding wheel, and the process also seems similar. But the applications are different. Grinding process is used for higher amount of stock removal, around 0.25 mm. But the honing process is having much lesser stock removal, around 0.05 mm. As the grinding has more stock removal and its main purpose is to achieve desired tolerance, the grinding wheel has to follow an exact path. Therefore a grinding machine requires more rigidity than a honing machine. But in case of honing, accuracy of the machine is not very important, as the position of the stone and the work-piece are having an averaging effect. So for the quality of the honing process, the deciding factor is the pressure applied by the stone on the work-piece[2]. So it is possible to use a honing attachment on machines having less rigidity and average accuracy like lathe machine and drilling machine.

Apart from this, truing of grinding wheel is required by a diamond pointed dresser. But honing is a self-truing process, in which the stone takes the shape of the work-piece profile by its own at the time of the process. This makes honing more accurate than grinding. Thus, grinding is a sizing process and honing is a shaping process[2].

Internal honing attachments on various machines are very popular to hone bores. Internal honing is also done by portable powered honing tools. But external honing attachments are not so popular. At most of the places, special honing machines are used for external honing. Hence the main objective of the work is to design and manufacture the honing attachment for lathe machine. So that the honing can be done with less cost.

Previous studies shows the honing operations performed by using special purposes honing machine. In which external hone body was used with stone & shoe[3]. The effect of honing speed on surface roughness of the material was analysed by Damir Vrac[3]. Other parameters were not studied like honing time, Pressure, etc. Material removal rate during honing process was also studied by Otto [4]. In addition to that hydrodynamic effect which is generated at the end of honing process is studied along with the time required for honing process[5].

One of the objectives of the development was to analyse the surface finish for various process parameters i.e. speed, feed, pressure and time, and compare the same with the surface finish obtained through grinding. Also the shape of the work-piece (circularity) obtained by grinding and honing is to be compared. Also the surface pattern of the work-piece obtained by both the processes is to be compared.

Specification of honing stone was decided from the Production Technology, Hindustan Machine Tools [1]. Size of abrasive grains were selected using ANSI B74.12 Standard [6].

Designation of tool selected is C 400 Q E 7

Design of the attachment is carried out by analysing the existing designs and some major modifications are done. The design is done considering various aspects like robustness, stiffness, strength, flexibility and manufacturing aspects. The manufacturing was carried out successfully and it is attached on the lathe machine. The manual feed mechanism was selected and tested. For advancement, automatic feeding mechanism can be provided. The experiments were designed by using Taguchi technique to optimize the surface finish and experiments were performed. Then surface finish was measured for every experiment. Thus, correlation between process parameters and surface finish were established using Minitab software.

IV. DESIGN OF ATTACHMENT

Various factors were considered for design which includes Geometric constraint of lathe machine, Rigidity for minimizing vibrations, Safety against failures and overall Cost of the attachment.

Design of Stoning stone:

Pressure required for honing: 0.2 to 1 MPa

Length of honing stone = 50 mm

Thickness & width of honing stone = 12.7 mm

Width of contact on stone = 5 mm

Maximum area of contact = (50×5) = 250 mm^2

Normal force:-

Force = Pressure×Area

Minimum force ($F_{N(min)}$) = 0.2×250 = 50 N

Maximum force ($F_{N(max)}$) = 1×250 = 250N

Tangential force:-

Power of spindle motor = 1hp = 746 W

For maximum tangential force, minimum speed of motor to be used so that it will give maximum torque which will result into maximum tangential force.

Maximum speed to be used = 600 rpm

Minimum speed to be used = 63 rpm

Power (P) $= \frac{2\pi N T_{max}}{60}$

$\therefore 746 = \frac{2\pi(63)T_{max}}{60}$

$\therefore T_{max} = 113.07$ Nm

Coefficient of friction of honing stone = 0.5(Assumed)

Maximum diameter to be honed (d_{max}) = 80 mm

Minimum diameter to be honed (d_{min})= 10 mm

$r_{min} = \frac{d_{min}}{2}$

$= \frac{10}{2}$

$= 5$ mm

Maximum tangential force = $F_{T(max)}$

$\therefore F_{T(max)} = \frac{T_{max}}{r_{min}}$

$= \frac{113.07}{(5\times10^{-3})}$

$\therefore F_{T(max)} = 22614$ N

Tangential force of the stone = frictional force (f)

$f_{(min)} = \mu \times F_{N(min)}$

$= 0.5 \times 50$

$f_{(min)} = 25$ N

$f_{(max)} = \mu \times F_{N(max)}$

$= 0.5 \times 250$

$f_{(max)} = 125$ N

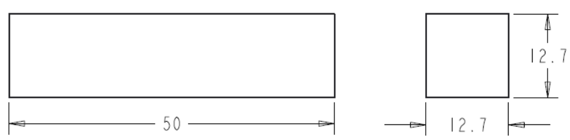

Figure 1: Design of Honing Stone

Design of Arms:

Dimensions of arms to be decided on the basis of rigidity to avoid vibrations, otherwise which may cause undesired effect in finishing process.

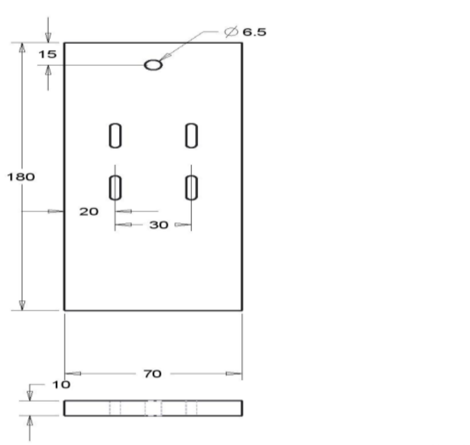

Figure 2a Fixed arm

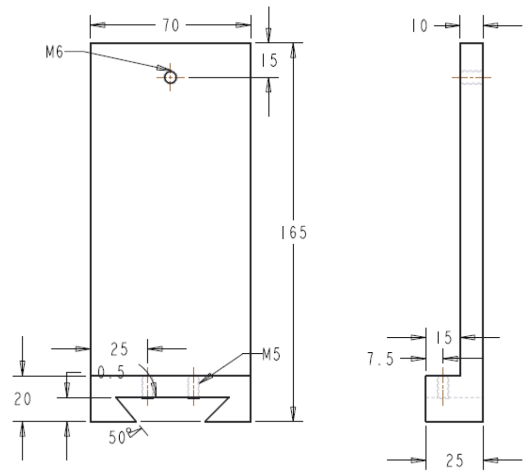

Figure 2b: Floating arm

Figure 2: Design of arms (a) Fixed Arm (b) Floating arm

The dimensions for dovetail are taken as per standards [9].

Thickness of arm = 10 mm

Honing stone to be used is of length = 50 mm (Maximum)

Width of arm = 70 mm

Cross section area of arm= 70×10 = 700 mm^2

Selected arm material: Mild steel

Yield strength of mild steel in tension: 250 MPa (S_{yt})[9]

Yield strength of mild steel in shear: 125 MPa (S_{sy}) [9]

Considering, factor of safety = 2.5

Allowable stress in tension $= \frac{250}{2.5} = 100$ MPa and,

Allowable stress in shear $= \frac{125}{2.5} = 50$ MPa

Failure of the arm may occur in two modes only,

A) Shear

B) Bending

A) If arms fail in shear,

$\tau_{max} = \frac{F_{N(max)}}{\text{C/S area of arm}}$ ($F_{N(max)} = 250$ N)

$= \frac{250}{700}$

$= 0.357$ MPa

$\tau_{max} < 125$ MPa

Based on the calculations, it is found that design of arm is safe in shear.

B) If arms fail in bending,

Maximum diameter to be honed is 80 mm

The distance of the point of application of force from base is 100 mm

The resisting force applied by the screw is at 65 mm from the point of application of the force (As shown in the figure 2)

Maximum moment acting on the arm,

$M_{max} = F_{N(max)} \times$ distance between the forces

$= 250 \times 65 \times 10^{-3}$

= 16.25 Nm

Section modulus of arm,

$Z = \frac{bt^2}{6}$

$= \frac{70 \times 10^2}{6}$

$= \frac{7000}{6}$

$= 1166\ mm^3$

$= 1166 \times 10^{-9}\ m^3$

For bending,

$\frac{M}{I} = \frac{\sigma_b}{y}$

$\therefore \quad \sigma_{b(max)} = \frac{M_{max}}{Z}$

$= \frac{16.25}{1166 \times 10^{-9}} \times 10^{-6}$

$\therefore \sigma_{b(max)} = 13.94$ MPa

Design of Screws:

Material for screw is plain carbon steel 30C8

Yield strength of mild steel in tension : 400 MPa (S_{yt})

Yield strength of mild steel in shear: 200 MPa (S_{sy}) (As per maximum shear stress theory)

Considering factor of safety = 5

Permissible stress in tension $= \frac{400}{5} = 80$ MPa and,

Permissible stress in shear $= \frac{200}{5} = 40$ MPa

Tensile stress in screw

$\sigma_t = \frac{F}{\frac{\pi}{4}{d_c}^2}$

$\therefore 80 = \frac{250}{\frac{\pi}{4}{d_c}^2}$

$\therefore d_c = 2$ mm

Selected M6 screw having d_c = 4.773 mm and pitch = 1 mm (coarse series)

Design of Bracket:

For holding of stone, Width (w) = 30mm ,

Length (l) = 50mm,

Height (h) = 12.7mm

The bracket is to be fixed on the floating arm.

Bracket top is to be separately manufactured and then attached to the bracket by screws, so that it is easy to install springs and honing stone and easy to put additional straps in the bracket if required.

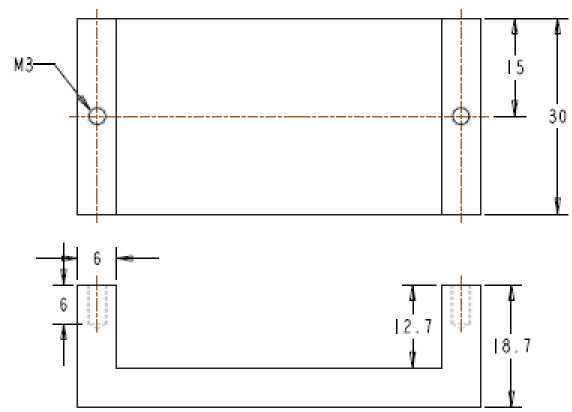

Figure 3: Design of Bracket

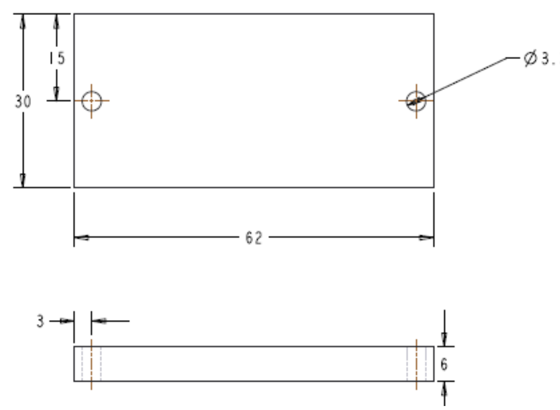

Figure 4:Design of Bracket top

For rigid design, Thickness(t_1) = 6mm

Force acting on the bracket is equal to the tangential friction force on the stone.

$f_{T(max)} = 400$ N

Shear stress in lower plate,

Resisting area = 2×w×t

$\tau = \frac{f_{T(max)}}{2 \times w \times t}$

$\tau = \frac{400}{2 \times 30 \times 6}$

$\tau = 1.11$ MPa

Based on calculations, design is found safe in shear.

Tension in side plates,

Resisting area = 2×w×t

$\sigma_t = \frac{f_{T(max)}}{2 \times w \times t}$

$\sigma_t = \frac{400}{2 \times 30 \times 6}$

$\sigma_t = 1.11$ MPa

It is safe in tension.

Design of Brass Support:

They are to be attached on the fixed arm.
Length of the supports is equal to the length of the stone.
Length of the supports = 50 mm
Minimum diameter to be honed = 10mm
Maximum diameter to be honed = 80mm
To accommodate both, the dimensions are shown in figure and design is done in design software.

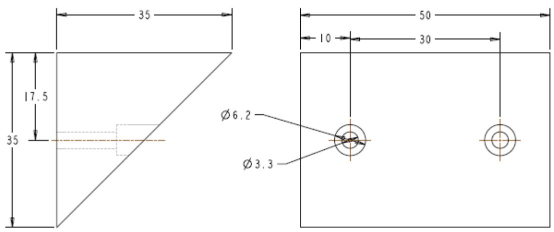

Figure 5: Design of Brass Support

Each support is to be manufactured in two parts. The rear part which does not come to the contact with the rotating work-piece, is to be manufactured from aluminium, and the front part which comes in contact with the work-piece, is to be manufactured from brass for less friction. This is done because brass is costly material. So by not making the whole support with brass, attachment cost has been reduced.

Design of Spring for Stone:

For spring steel, τ = 500 N/mm^2
For uniform force, two springs are placed in the attachement.

Force on each spring (F) = $\frac{250}{2}$ = 125 N

Shear stress τ $= \frac{8FCK_w}{\pi d^2}$

$500 = \frac{8\times125\times5\times1.2525}{\pi\times d^2}$

d =1.99mm

d ≅ 2 mm

Spring Diameter D = C × d
= 5 × 2
= 10 mm

Deflection δ $= \frac{8FC^3n}{Gd}$

δ $= \frac{8\times125\times5^3\times n}{84000\times2}$

Number of turn n = 8
Take square and ground ends,
n' = 8 + 2 = 10
For n = 8,

δ $= \frac{8FC^3n}{Gd}$

$\delta = \frac{8\times125\times5^3\times8}{84000\times2}$

δ = 5.95 mm

Free length of spring = 28.3 mm
After deflection for 250 N forces, the 5 mm of honing stone will be outside the bracket.

Pitch(P) $= \frac{(L_0 - 2d)}{n}$

P $= \frac{(28.3 - 2\times2)}{8}$

P = 3 mm

V. EXPERIMENTS

Attachment was manufactured in the machine shop as per the design dimensions. Further, attachment is placed on the lathe machine, experiments had to be performed for optimization of the process parameters to obtain maximum surface finish. For this, 3 process parameters are selected as shown below.
1) Cutting speed
2) Operating honing Pressure
3) Time of honing

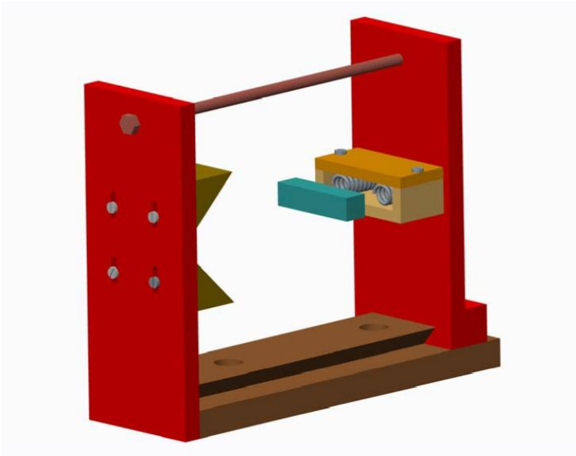

Figure 6: 3D View of the designed attachment

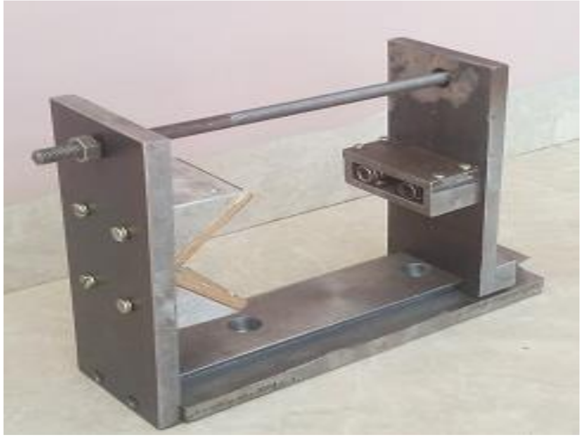

Figure 7: Actual Manufactured attachment

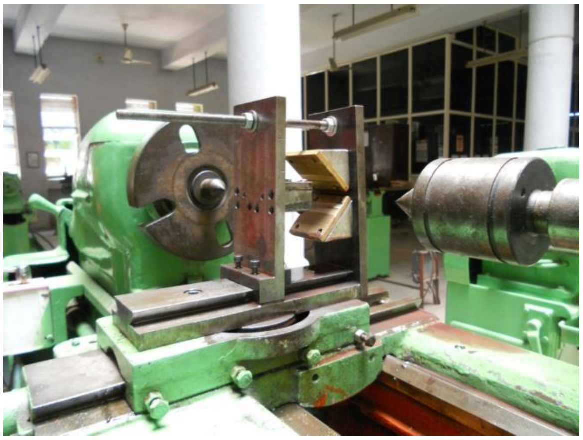

Figure 8: Attachment assembled on Lathe machine

Four values of each parameter are selected. These values are taken from various references.

For experiments, shafts of the material En8 are honed, having diameter 45 mm. This material is often used in crank shafts and shafts used in other applications having dusty environment, in which generally honing of the shafts is required. As it is done in the real life process, the shafts were firstly grinded and then honing was performed.

By varying value of one parameter, keeping other parameters constant, we can get value of surface finish such that we can establish relationship between these parameters and the surface finish obtained after honing. But for this type of analysis, we have to perform experiments for every possible combination of the parameters, which is very time-consuming process in this case.

Here, Parameters (factors) = 3

Values of each parameter (level) = 4

So total number of experiments required = $4^3 = 64$

Hence, experiments are designed by using Taguchi Method using L16 array. By this method, number of experiments is reduced to 16 only.

Taguchi Method:

In order to conduct experiments, proper array has to be selected. The selection is done based on the following table[7].

		Number of Parameters (P)																
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Number of Levels	2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32	L32	L32
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36	L36	L36
	4	L'16	L'16	L'16	L'16	L'32	L'32	L'32	L'32	L'32								
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50						

Figure 9: Array of Taguchi Method

Number of parameters = 4

Number of levels = 4

Selected array is L16

Length of the job = 120mm

Diameter of the job = 45mm

VI. RESULTS

Based on above experiments, samples were used for surface roughness measurements. In order to see repeatability of the results, each trials were conducted on four different samples and then mean value is being considered for that particular set of parameters.

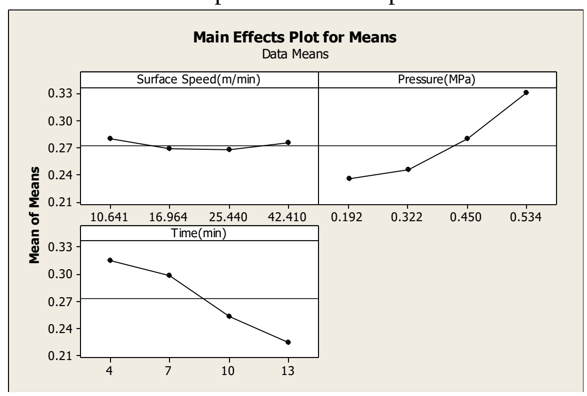

Figure 10: Main effect plots for Means

Most effective parameters on surface finish in descending order are Pressure, Time, and Surface speed respectively.

The results shows that Surface finish increases with the duration of honing. Further as the pressure increases, surface finish decreases. Surface speed is having less impact on surface finish of the samples.

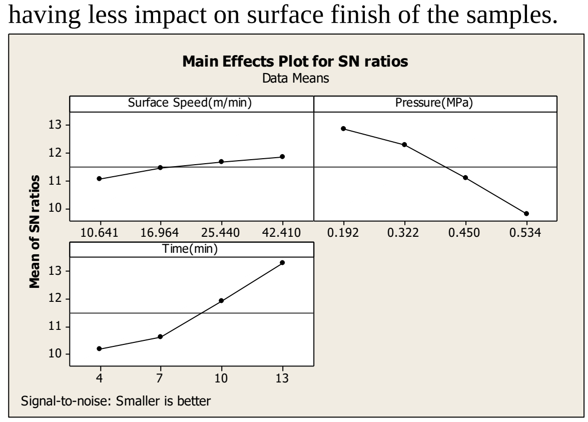

Figure 11: Main effect plots for SN ratios

Signal to noise (SN) curve is also analysed for the conducted experiments. The results are showing that as the pressure increases, SN ratio decreases because surface finish decreases. And it is having reverse effect with increase of time.

Surface finish has no major impact with increase of surface speed.

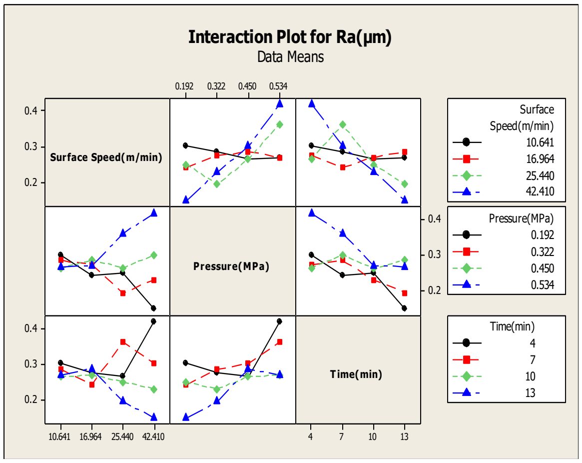

Figure 12: Interaction plot for Surface roughness

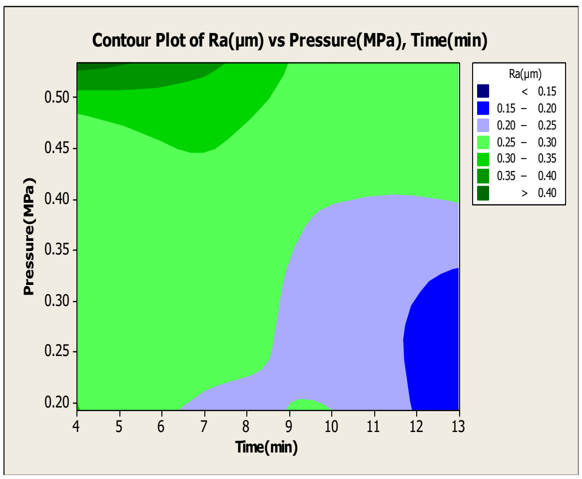

Figure 13: Contour plot for Surface roughness with reference to Pressure and time

VII. CONCLUSION

External honing of circular rods can also be possible on conventional lathe machine with assembly of this attachment. Experiments conducted after designing & manufacturing of the attachments. The results shows that for the better surface finish of the samples during honing processes, honing pressure shall be as minimum as possible and Time of honing shall provide more till required surface finish achieved.

In this study, feed was applied manually. Hence cross hatch pattern could not be achieved at high speed, which is an important parameter for oil retention. Surface finish obtained by using the lubricating oil is better than doing the same process without using lubricating oil.

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