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Slotting/Milling Attachment to Enhance Features of Lathe

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***Abstract* – This paper discusses design and fabrication of "Slotting/ Milling Attachment to Lathe". It is well known that lathe is considered to be a versatile machine in which several capabilities of machining are inbuilt. To further enhance its versatility, in this research, an attachment is designed and fabricated to add the capability of horizontal milling machine in lathe. A milling cutter is mounted in a cutting arbor, which in turn is mounted between the headstock and the tailstock of a lathe. A work holding device is designed and mounted on the tool post. With this arrangement, it is possible to do keyway cutting in a shaft or milling a plane surface on a work piece. This research is considered to be a milestone in the direction of increasing the capability of the machine tool like lathe.**

***Keywords* – Milling, Slotting, Lathe, Attachment, Enhancement of Lathe Features.**

I. Introduction

Manufacturing processes can be classified into metal removal process, metal forming process, metal joining process and unconventional processes. In metal removal process, the material of a work piece is removed by a single point cutting tool or multi-point cutting tool. Some examples of machine tools, which use single point cutting tool are lathe, shaping machine, etc. Similarly, milling machine, broaching machine, gear hobbling machine, gear shaping machine, etc are some examples of machine tools, which use multi-point cutting tools. So, the shape and size of a work piece are obtained by using such metal removal process. In this type of operation, there will be excessive wastage of material from the raw material of the work piece. In metal forming, the shape and size of a work piece are obtained by forming processes. Some examples of metal forming process are forging, cold/hot draw, extrusion, press operation, etc. In this type of operation, the wastage of martial from the raw material of the work piece is very negligible.

Metal joining process can be further classified into welding and fabrication. In welding, the components of a product are joined together by welding process, whereas in fabrication type of operation, the components of a product are joined together by clamps, nuts and bolts. Unlike the earlier methods, in this method, the material will be removed by using some unconventional machining processes, like electro discharge machining (EDM), powder metallurgy, ultrasonic machining, etc. Among all the processes, under single point cutting, lathe is considered to be still popular in terms of its cheap cost, versatility and increased speed of metal removal.

Shenoy Engg. Pvt. Ltd. (2012) gives different lathe attachments, which are normally required like tool post grinder for lathe, belt polishing attachment, etc. Attarde (2016) designed and fabricated a grinding wheel attachment to lathe. Panneerselvam et al. (1979) fabricated a gear cutting attachment to lathe. Sagar (2016) designed and fabricated a gear cutting attachment to lathe to machine spur gear.

So, adding one more feature like, keyway cutting (slotting)/ plane milling as done in horizontal milling machine, to lathe will really enhance its versatility. Hence, in this research, an attempt has been made to design and develop an attachment for the above purpose.

II. Objective of the Research

Under the metal removal process, lathe is considered to be most widely used machine tool in industries. But, it has limited features as listed below.

a) Removal of material from a cylindrical surface.
b) Drilling to make end holes in shaft like components.
c) External and internal thread cutting in a shaft.
d) End facing of shaft.

The objective of this research is to design and develop an attachment to do slotting/ milling operation in lathe.

To do keyway cutting, one can use either horizontal milling machine or vertical milling machine or shaper or slotting machine.

Similarly, to do plane milling, vertical milling machine or horizontal milling machine or planning machine or shaper can be used.

The attachment designed and developed in this research will add the above two features in lathe, which will help small industries to avail the existence of lathe for such operations. This attachment will be of more use in small-scale industries, which produce custom-made products/components. Further this will reduce the investment on machineries.

III. Working Principle of the Slotting/ Milling Attachment to Lathe

The slotting/ milling attachment to lathe has two main sub-assemblies, viz. Cutter arbor assembly and work holding device. For the purpose of explanation of the components of the attachment, which is designed and fabricated, the isometric view of the entire attachment is shown in Fig. 1.

A. Cutter Arbor Assembly Units

This sub-assembly consists of the following components, viz. Cutter arbor, Milling cutter, Sleeve, Key and Hexagonal nut. The milling cutter is mounted on the cutter arbor and its rotary motion is arrested by inserting a

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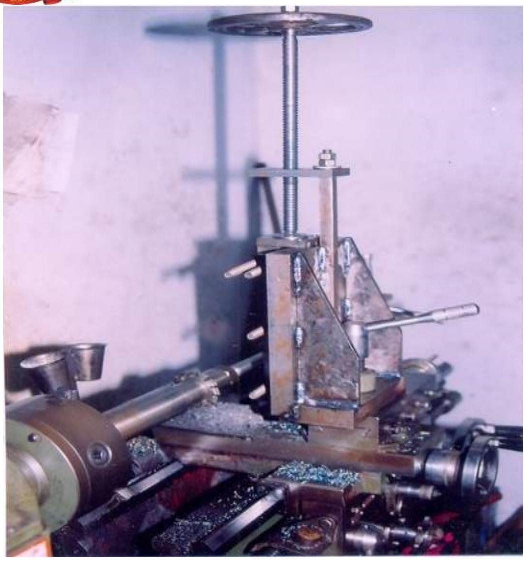

Fig. 1. Isometric view of entire attachment

key, which partly occupies in the collar portion of the cutter and in the keyway cut portion of the cutter arbor, where the cutter is being located. Then, the sleeve is pushed to have contact with the other side of the milling cutter. Then, the right side of the sleeve is tightened by a hexagonal nut, which in turn will tighten the milling cutter. The milling cutter is allowed to rotate in anti-clockwise direction. The entire cutter arbor assembly is mounted between the headstock and the tailstock of the lathe as shown in Fig.1.

B. Work Holding Device

From, Fig.1, one can see the work holding device, which is mounted on the tool post of the lathe. That is the original housing for fixing the single point cutting tool in the lathe is removed and then the work holding device of the attachment proposed in this project is mounted on the tool post of the lathe. This device enables the work piece to be placed in front of the milling cutter. The sub-assemblies/ components of the work holding device are Dovetail assembly, Base plate, Trapezium plates, Square rod, Lead screw, Cross plate connecting square rod and lead screw, Ball bearing housing plate, Ball bearing, Hand Wheel, Work holding vice plates, 4 sets of bolt and nut assembly.

B.1. Dovetail Assembly

The dovetail assembly consists of two parts, namely male dovetail block and female dovetail block. The male dovetail block will slide in the female dovetail block. In this process, any object, which is kept on the male dovetail block will also move along with it.

B.2. Base Plate

Base plate is the bottom plate of the work holding device, which will be mounted on the tool post of the lathe. The female dovetail block is welded vertically at one end of the base plate such that the movement of the male dovetail block can be even below the base plate as shown in Fig.1.

B.3. Trapezium Plates

Two trapezium plates, one at each end (left end and right end) of the base plate are welded vertically as shown in Fig.1. Further the longer side of each plate is welded at the respective backside of the female dovetail block to provide support at the time of experiencing force while removing material from the work piece by the milling cutter.

B.4. Square Rod

The square rod is welded vertically at the top of the base plate and further it is welded at the backside of the female dovetail block. The purpose of this square rod is to incorporate a screw jack like arrangement with the help of lead screw, cross-connecting plate, bearing and bearing housing plate. This arrangement will move the male dovetail block up and down, which in turn will move the work piece up and down in front of the milling cutter.

B.5. Cross Plate Connecting Square Rod and Lead Screw

The cross plate connects the square rod and the lead screw. A square hole is made at one end of the cross plate through which the square rod passes through. Then, at the top of the square rod, the cross plate is tightened with a hexagonal nut. This makes the square rod acts as the fixed portion of the screw jack like arrangement.

B.6. Lead Screw

The lead screw is used to move the male dovetail block up and down. Its one end passes through the cross plate connecting the square rod and this leads screw. At the top end of this lead screw, a hand wheel is fixed. The bottom end of the lead screw is fitted tightly in a ball bearing, which in turn is mounted in a bearing housing plate. The lead screw has left-hand square thread (reverse square thread) mainly to move the male dovetail block against heavy cutting force induced in it by the milling cutter while it removes material from the work piece. When the hand wheel is rotated in clockwise direction, the male dovetail block will move up and vise versa.

B.7. Hand Wheel

A hand wheel is mounted at the top end of the lead screw. The square hole at the center of the hand wheel passes through the square portion of the lead screw. This square portion avoids the slipping of the hand wheel on the lead screw, while turning it. Then the hand wheel is tightened with a hexagonal nut (M12)

B.8. Ball Bearing

A ball bearing is used to support the bottom end of the lead screw. The bearing is mounted tightly within a bearing housing plate, which in turn is fixed at the top of the male dovetail block using screws. When the lead screw is rotated using the hand wheel, the ball bearing enables it to move the male dovetail block up and down depending on the direction of rotation of the lead screw.

B.9. Bearing Housing Plate

As mentioned earlier, the ball bearing is mounted tightly within the bearing housing plate. The plate in turn is mounted on the top of the male dovetail block.

B.10. Work Holding Jaws

Two rectangular plates are used to firmly hold the work piece in front of the milling cutter. Hence, these plates are called as work holding jaws. One plate is welded at the left side of the male dovetail block facing the milling cutter and the other one is a movable jaw. There are three holes

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vertically in each jaw symmetrically and in the same vertical line and the fourth hole is made at the exterior top portion of each plate. The moving jaw can be brought to a position, which grips the work piece well and the bolts passing through the jaws can be tightened using the nuts such that the work piece which is kept in between two jaws withstands the cutting force induced by the milling cutter in it while removing material from it.

IV. Design Procedure

The forces on the cutter and in the direction of the machine saddle movement are shown in Fig. 2. The various components of the attachment are designed as follows to withstand the forces acting on them during the operation. The tangential force P_t creates a movement of resistance $M_b = P_t. d/2$ and also tends to bend the cutter. This movement of resistance should be overcome by the torque of the lathe-motor. Thus, the H.P. of the motor is calculated considering the tangential force P_t.

The forces of the cutter are listed below.

P_t – Tangential force.
P_r – Radial force.
R – Resultant force of P_t and P_r.

The forces in the direction of machine movement are as listed below.

P_h – Force in a direction opposite to the feed.
P_v – Force in the direction of vertical movement.

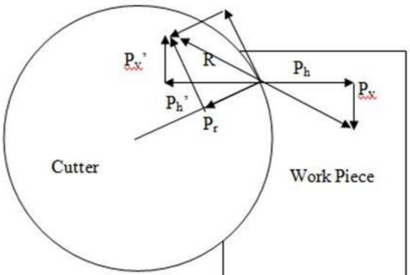

Fig. 2. Force Diagram

A. Forces in Milling

P_h' and P_v' are the horizontal and vertical forces in milling. The radial force P_r exerts pressure on the cutter, bearings and also tends to bend the cutter. Thus the cutter arbor is subjected to bending by the action of the two forces P_t and P_r or their resultant R. Also, the arbor is subjected to torsion by the action of the movement of resistance. So, the arbor is designed for both bending and torsion.

The horizontal force P_h tends to push the work from the cutter. This is prevented by providing an appropriate clamping device on the male dovetail block. The horizontal force P_h and the vertical force P_v are used to design the work holding unit including the block. The vertical force P_v tends to lift the base from the saddle and this is prevented by clamping the base rigidly on to the saddle/ tool post.

While milling, the forces P_h' and P_v' tend to separate the cutter from the work piece.

B. Chip Cross Section

The cross section of the chip produced by a single point tooth will be the one which is confined within two arcs of a radius equal to one half of the cutter diameter (d) as shown in Fig.3 (Sundaramoorthy and Shunmugam, 2000).

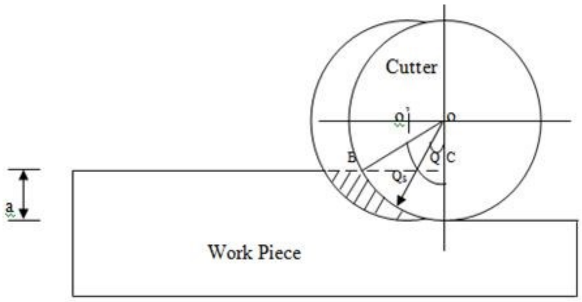

Fig. 3. Chip Cross Section

$$OC = (d/2 – a); OB = d/2$$

Therefore, $BC = \{d^2/4 – (d/2 – a^2)\}^{1/2} = \{a(d-a)\}^{1/2}$

$$SIN Q_S = BC/OB = \{a (d-a)\}^{1/2}/(d/2)$$

When the cutter tooth has entered the work piece material by an angle Q,

Chip thickness $X = S_t$. SIN Q, where, S_t is the feed per tooth. If the cutter rotates at n rpm, the feed per minute is equal to $S = n.n_t.S_t$, where n_t is the number of teeth in the cutter and $X = \{S/(n.n_t)\}$Sin Q

The maximum chip thickness is then equal to:

$$X_{max} = \{S.SinQ_S/(n.n_t)\}$$

That is $X_{max} = S. 2\{a(d-a)\}^{1/2}/(n.n_t.d)$

A. Power Required for Cutting

Even during cutting operation with straight teeth, and therefore, constant width of cut, the cutting force and the power required are not proportional to the depth of cut, because the specific cutting resistance is not constant and it varies with the changing chip thickness.

The mean power required at the milling cutter is calculated by means of specific cutting resistance Km. The cross sectional area of the chip at any instant is given by the following formula (Vijayaraghavan 2006).

$A = (t.S.SinQ\}/(n.n_t)$

Where, t is the thickness of the cutter.

Maximum cross sectional area of the chip is given by the following formula.

$A_{max} = (2.S.t\{a(d-a)\}^{1/2}/(d.n.n_t)$

Assuming that the mean cross-sectional area A_m of the chip is equal to $A_{max}/2$,

$A_m = S.t.\{a(d-a)\}^{1/2}/(d..n.n_t)$

or

$A_m = S.t.(a/d)^{1/2}/(n.n_t)$, by neglecting a^2 which is small.

The specific cutting pressure is given as

$K_m = P/A_m$ kg/mm^2, where P is the peripheral component of cutting force in Kg.

Therefore, $P = K_m.A_m$

The value of K_m depends on the material hardness and chip cross section. The value of K_m is given in Table1.

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Table 1 Specific Cutting Pressure (K_m)

Max. Chip thickness (mm)	Specific cutting pressure kg/mm^2		
	Cast iron		
	Soft	Medium	Hard
0.02	210	305	420
0.04	163	235	426
0,06	142	205	285
0.08	129	186	259
0.10	122	175	244

A. Power Required in Milling

N_{cut} = P.v/4500 H.P, where v is cutting speed in m/min.

Calculation:

Work material = Cast iron
Cutting speed (v) = 20m/ min
Cutter diameter (d) = 70 mm
No. of teeth (n_t) = 12
Feed for cast iron (S) = 100mm/min
Cutter thickness (t) = 10 mm
Taking the module (m) = 4
Depth of cut (a) = 2.157m = 2.1.57x4 = 8.628 mm
Cutter speed (n) = 1000.v/(π.d) = 1000.20/(3.141x70
= 91 rpm.
Max. chip thickness is:
Xmax = 2S{a(d-a)}$^{1/2}$/(n.n_t.d)
=2x100{8.628(70-8.628)}$^{1/2}$/(91x12x70)
= 0.062 mm
The specific cutting pressure from the table is :
K_m = 285 kg/mm^2 for hard martial.
Mean area of cross section is computed as shown below.
A_m = S.t(a/d)$^{1/2}$/(n.n_t)
= 100x10(8.628/70)$^{1/2}$/(91x12) = 0.322 mm^2
Pheripheral force/ tangential force (P_t) = K_m.A_m
= 285 x 0.322
= 91.77 kg
Therefore power required, N_{cut} = P.v/4500 H.P
= 91.77x20/4500
= 0.408 H.P.

Power required for the motor N_m = N_{cut}/η,
where η is the efficiency (0.75)
Therefore, N_m = 0.408/0.75 = 0.544 H.P.
Design power N=1.15 N_m =1.15 X 0.544 = 0.0.6256 H.P.
The power of the lathe motor is 7 H.P., it is sufficient to meet the power required for cutting.

E. Other Forces During Cutting

Horizontal component P_h = (1 to 1.2) x P_t
= 1.2x 91.77 = 110.124 kg
Vertical component P_v = (0.2 to 0.3) x P_t
= 0.3 x 91.77 = 27.53 kg
R = Resultant force = $(p_h^2 + p_v^2)^{1/2}$
= $(91.77^2 + 27.53^2)^{1/2}$ = 95.6 kg
Radial force P_r = $(R^2 - P_t^2)^{1/2}$
= $(95.6^2 - 91.77^2)^{1/2}$ = 26.78 kg

Tangential force Pt	=	91.77 kgf
Horizontal force Ph	=	110.124 kgf
Vertical force Pv	=	27.53 kgf
Radial force Pr	=	79.975 kgf
Resultant force R	=	95.6 kgf

F. Design of Cutter Arbor

The design of cutting arbor is explained in this subsection (Kurumi and Gupta 2001).
H.P. of the lathe = 7
Diameter of cutter d = 70mm
HP = 2πNT/4500, where T is the torque in kg.-m and N is the speed of the cutter which is 91 rpm.
Therefore, T= HPx4500/(2Nπ) = 7x4500/(2x91x3.141)
= 55.09 kg-m = 5509 kg-cm
Assuming the cutter distance from the chuck as 20 cm, the bending moment M_b is computed as shown below.
M_b= Rx20 = 95.6x20 = 1912 kg-cm
The diameter of the cutter arbor is calculated using the following formula.

$$d_o^3 = \frac{16}{\tau} \{(K_b.M_b)2 + (K_t.M_t)^2\}^{1/2}$$

where τ is the design shear stress which is 900 kg/cm^2 for mild steel.
Bending moment M_b = 1912 kg-cm
Torque M_t = 5509 kg-cm
K_b is the combined shock and fatigue factor applied to M_b, which is equal to 1.5 and K_t is the combined shock and fatigue factor applied to M_t, which is equal to 1.2.

$$d_o^3 = \frac{16}{900} \{(1.5x1912)^2 + (1.2x5509)^2\}^{1/2}$$

d_o = 5 cm
So, the diameter of the cutter (d_0) is taken as 5 cm.

G. Design of Dovetail Blocks

Since, the cutting force acts on the outer surface of the male dovetail block, the stress induces in the dovetail blocks (male as well as female blocks) is very minimal. However, the weakest section of each dovetail block is kept as 10 mm and the thickness of each of them is assumed as 20mm. The top view, side view and the front view of the whole assembly are shown from Fig.4 to Fig.6. The front view of the whole attachment in working condition is shown in Fig.7 and its rear view is shown in Fig.8.

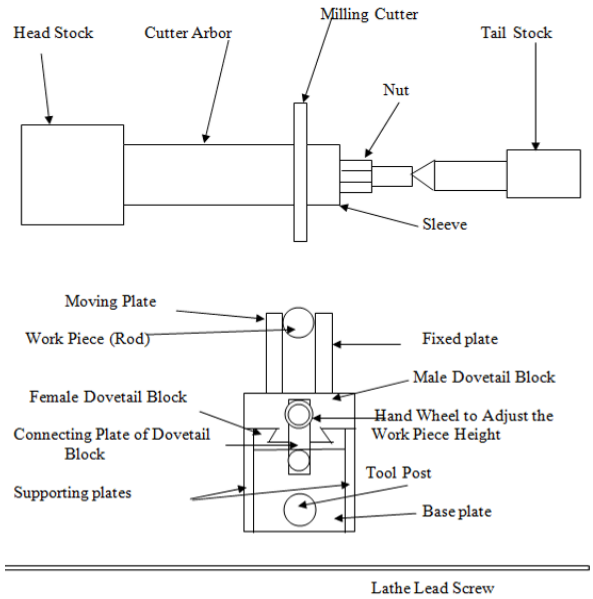

Fig. 4. Top view of slotting and milling attachment to lathe

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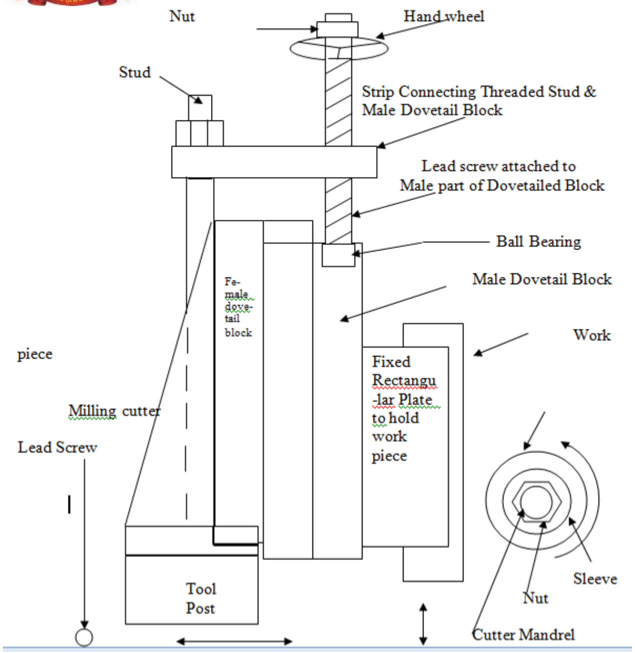

Fig. 5. Right side view of slotting and milling attachment to lathe

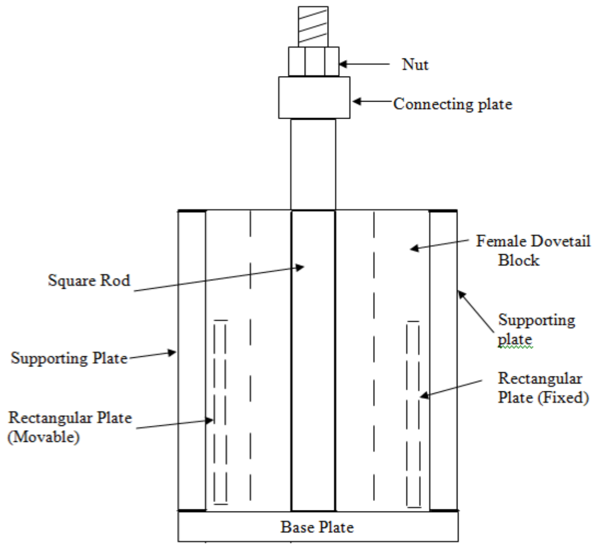

Fig. 6. Front view (operator side) of slotting and milling attachment to lathe

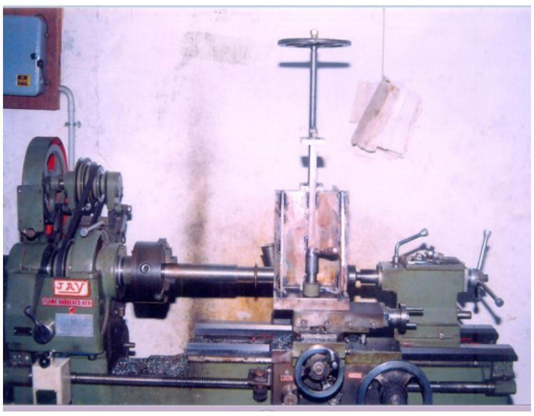

Fig. 7. Front view of the whole attachment

Fig. 8. Rear view of the whole attachment

The cost of fabrication of this attachment is Rs.5,471 and its break-up is shown below.

i) Mild steel items	: Rs.1,215
ii) Ball bearing	: Rs. 45
iii) Hand wheel	: Rs. 100
iv) Hardware items	: Rs. 111
v) Milling cutter	: Rs. 500
vi) Machining charges	: Rs.3,500
Total Cost	**: Rs.5,471**

IV. Cutting In Action/ Milling Procedure

The steps of milling the work piece using this attachment are presented below.

Step 1: Fix the work piece on the male dovetail block, facing the milling cutter.

Step 2: Mark the area to be machined on the work piece.

Step 3: Push the male dovetail block down such that the milling cutter exterior tooth coincides with the top mark of the cutting region of the work piece.

Step 4: Move the Carriage of the lathe such that the milling cutter exterior tooth coincides with the left vertical side of the cutting region on the work piece.

Step 5: Move the cross slide towards the milling cutter till the work piece surface gets in contact with the tip of the exterior tooth of the milling cutter.

Step 6: Switch on the lathe and allow the headstock to rotate in anti-clockwise direction.

Step 7: Give the necessary depth of cut for rough cut (for example 2.5 mm for mild steel)

Step 8: Turn the hand wheel clockwise slowly until the cutter reaches the bottom line of the cutting region on the work piece.

Step 9: Move the cross slide back to release the work piece from the cutter.

Step 10: Turn the hand wheel anti-clockwise such that the tip of the milling cutter touches the top line of the cutting region of the work piece.

Step 11: Move the carriage of the lathe for the next cut.

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Step 12: Repeat Step 7 to Step 11 until the right vertical line of the cutting region of the work piece is reached.

Step 13: Switch off the lathe.

Step 14: Repeat Step 4 to Step 13 until the required depth of cut is attained.

Note: The depth of cut is provided using the cross feed of the lathe. Traversal across the work piece to create flat surface is achieved through moving the carriage left/right. So, one has to coordinate both the movements to get the flat surface on the work piece.

VI. Conclusion

It is well known that the lathe is considered to be a versatile machine tool among all other machine tools. In this paper, an attempt has been made to further enhance the scope of lathe in terms of performing the operations of horizontal milling machine to do slotting operation for the purpose making keyways/ milling operation to create a flat surface on a work piece.

In the first stage, the design of the elements of the attachment has been carried out. Then, as per the design specifications, the different components are manufactured and assembled together. The attachment mainly consists of two assemblies, viz. cutter arbor assembly and work holding device. These are installed in a lathe and the pilot run was carried out. It is observed that this attachment in the lathe performs the intended function of keyway cutting and machining flat surface. This attachment will be very much useful for small scale companies, where milling/ slotting operation is to be carried in lathe itself, instead of buying those machines.

This research is a milestone in the area of machine tool development, especially in enhancing the features of lathe.

VII. Acknowledgment

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References

[1] D.Attarde et al., 2016, "Design And Fabrication Of Grinding Wheel Attachment On Lathe Machine", International Journal of mechanical Engineering and Technology, Vol.7, No.4, pp.281-288.

[2] G.K.Vijayaraghavan and S.Vishnupriyan, "Design of Machine Elements", Lakshmi Publications, Sirkali, 2006.

[3] M. Sagar, 2016, "Design and Fabrication of Gear Cutting Attachment to Lathe for Machining a Spur Gear, International Journal of Innovations in Engineering and Technology, Special Issue NCRTEEF OSS 2016, pp.217-285.

[4] R. Panneerselcan, K.Panneerselvam, M.Nainadurai and Danasheelan Paul, 1979, "Gear Cutting Attachment to Lathe", B.E. Project Report, Mechanical Engineering Department, College of Engineering, Chennai – 600 02

[5] R.S. Kurumi and J.K. Gupta, "A Textbook of Machine Design", Eurasia Publishing House (Pvt.) Ltd., New Delhi, 2001

[6] Shenoy Engg. Pvt. Ltd., 2012, "Lathe Attachments", http://www.shenoyengineering.com/attachments-for-lathe

[7] T.V.Sundararajamoorthy and N. Shanmugam, "Machine Design", Anuradha Agencies, Kumbakonam, 2000.

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