DESIGN AND FABRICATION OF A MULTINOMIAL MODEL FOR MACHINE INTERFERENCE PROBLEM

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Abstract: Machining has gotten crucial to the cutting-edge industry. It is utilized legitimately or in a roundabout way in the production of practically all the merchandise and ventures being determined everywhere in the world. This project is mainly carried out in Multi-Function Operating Machine for production industries. It is a multipurpose machine that can be used to perform various operations like drilling (screw fitting, boring, broaching), grinding and lathe operations (facing, step turning, knurling and cutting) of small workpieces very precisely. A lathe is one of the oldest and perhaps most important machine tools ever developed. Hole machining, constituting a considerable percentage of all machining operations, is accomplished, as a rule, by rotary and axial feed motions of the cutting tool or work. The boring cycle is a widely utilized machining activity by which however or daze openings are cut or begun in a workpiece. Penetrating is a machining activity wherein the opening is created or broadened by the utilization of an extraordinary cutting device, called a drill, normally having more than one forefront. Crushing is a machining activity where a multi-edged pivoting grating device called a granulating wheel eliminates abundant material from the workpiece. Granulating of level surfaces called surface crushing. Grinding of flat surfaces called surface grinding.

Keywords: Multifunctional, Separation, Milling Process, Multinomial data.

1. Introduction

The headstock gathering is forever secured to one side hand end of the machine. It serves to assume the primary employable unit of the machine, that is, the axle [1-6]. The spindle revolves in bearing, one at each end of the headstock. The spindle is rotated by a cone pulley. A faceplate is used for clamping irregular shaped components or plate type components, faceplate can be used. The chuck is bolted to the faceplate. In the three-jaw chuck, the jaws are made to move simultaneously and equally in radially inward or outward direction by rotating a disc whose spiral grooves mesh with teeth provided on the jaws [7-15]. The disc can be rotated employing a key inserted in any one of the three sockets provided on the cylindrical surface of the chuck. The cone pulley is used to transmit the power from the motor to the spindle utilizing a v-belt. The cone pulley drive is very simple and cheap in design. The carriage is fixed right to the headstock. It consists of saddle, cross-slide and compound rest. The base of the carriage is the seat that slides along the bed [16-20]. The cross-slide is mounted on the seat. It gives cutting instrument movement which is opposite to the centreline of the machine itself. The crossfeed development is controlled physically. The compound lay is mounted on the head of the cross-slide [21-23]. The compound rest has a graduated base and can be turned around a vertical hub. The instrument post is mounted on the compound rest and slides in a T-space cutting device/device holder are solidly held in it. This paper is intended to provide the detailed design analysis of each components involved in the mechanical design of the polynomial lathe machine with energy and design considerations.

2. Components & Operations Multi-Nomial Machine
Frame & Bearing: The frame is made up of mild steel. The drilling, grinding and lathe arrangement are mounted on the frame. The motor is placed over a frame. A common shaft is used to transmit the power from the motor to different operations. A bearing selection is based on the diameter and speed of the shaft. The shaft diameter is 25mm and 1008 rpm so it can be chosen the ball bearing. The plumber block is used to support the bearing and shaft. Ball-bearing is easily available and also the cost is low.

Lathe & Headstock: It is placed on the left side of the frame. It consists of only headstock and carriage. The headstock gathering is for all time secured to one side hand end of the machine. It serves to assume the primary employable unit of the machine, that is, the shaft. The spindle revolves in bearing, one at each end of the headstock. The spindle is rotated by a cone pulley. A faceplate is used for clamping irregular shaped components or plate type components, faceplate can be used. The chuck is bolted to the faceplate. In the three-jaw chuck, the jaws are made to move simultaneously and equally in radially inward or outward direction by rotating a disc whose spiral grooves mesh with teeth provided on the jaws. The disc can be rotated through a key inserted in any one of the three sockets provided on the cylindrical surface of the chuck. The cone pulley is used to transmit the power from the motor to the spindle using a v-belt. The cone pulley drive is very simple and cheap in design.

Carriage: The carriage is fixed right to the headstock. It consists of saddle, cross-slide and compound rest. The base of the carriage is the seat that slides along the bed. The cross-slide is mounted on the seat. It gives cutting device movement which is opposite to the centrefline of the machine itself. The cross-feed development is controlled physically. The compound rest is mounted on the head of the cross-slide. The compound rest has a graduated base and can be turned around a vertical hub. The apparatus post is mounted on the compound rest and slides in a T-space cutting device/instrument holder are solidly held in it.

2.1. Operations to be Performed in Lathe

Facing: Confronting is the activity of machining the finish of a workpiece to make the end square with its hub and that the machine. The apparatus moves opposite to the hub of the machine.

Turning: Turning is the activity to eliminate material from the external breadth of a workpiece to get a completed surface. The completed surface might be of constant measurement, ventured.

Knurling: Knurling is the activity of plastically uprooting metal into a specific example to make a handhold or roughened surface on the workpiece. The knurling instrument is held in the device post and is squeezed against the outside of the workpiece by crossfeed.

Drilling: The drill setup is placed on the right side of the frame. It consists of a spindle, drill chuck, spindle feed hand wheel, machine vise. The spindle is controlled by power feeds. A three-jaw chuck is used to hold the drill bits. The spindle feed handwheel is a rack and pinion arrangement which is used for up and down movement of the spindle to give the feed to the drilling. A machine vise is widely used for holding small work of regular shapes such as flat, square, or round pieces. The vise is clamped to the table to hold the workpiece.

Grinding: Grinding setup is placed in-between the lathe and drilling setups. It is the mid part of the frame. It consists of a horizontal spindle, pipe fitting and 360° rotatable & movable vise. The power is transmitted from shaft to spindle by the way of belt and pulley arrangement. The horizontal spindle is fixed on the pipe fitting and also it gives the up and down movement of the grinding wheel. Pounding is a cycle done with a crushing wheel made of rough grains for eliminating fine amounts of material from the workpiece surface.

Grooving: Grooving is the process of removing the center portion of the material.

Cutting: Cutting is the process of removing a particular portion of the workpiece.

3. Design Calculation
3.1. Design Calculation for Cone Pulley

From Motor to Shaft, Speed of the driver pulley (N1) = 1440 rpm
Driver pulley diameter estimation (D) = 63 mm
Driven pulley diameter consideration (d) = 90 mm

1) Selection of the belt section: Power 0.7457kW, Asegment is designated.
2) diameters for the associated pulleys contributions (d and D):

\[
\text{Speed ratio } = \frac{D}{d} = \frac{N_1}{N_2} = 1.428
\]

\[
N_1 = 1440 \text{ rpm, } \frac{1440}{N_2} = 1.428 \Rightarrow N_2 = 1008 \text{ rpm}
\]

3) Selection of Centre distance:

\[
C = 1.5D, C = 1.5 \times 90 = 135 \text{ mm}
\]

4) Estimation of minimal length for the pitch:

\[
L = 2C + \frac{\pi}{2} (D + d) + \frac{(D-d)^2}{4C}, L = 2 \times 135 + \frac{\pi(90+63)}{2} + \frac{(90-63)^2}{4 \times 135}, L = 512 \text{ mm}
\]

Nominal inside length \(L = 610 \text{ mm}, \) Corresponding nominal pitch length \(L = 645 \text{ mm}\)

5) Range of several alteration aspects:

5.1) Length Modification Factor (Fc): \(F_c = 0.80\)

5.2) Alteration factor on contact associated with the arc (Fd): \(\text{Arc of contact } = 180^\circ - \frac{(D-d)}{C} \times 60^\circ,\)

\(\text{AoC} = 180^\circ - \frac{(90-63)}{135} \times 60^\circ, \text{ the corresponding } \theta = 168^\circ \text{ and Fd} = 0.97\)

5.3) Facility Factor (Fa): Light duty 10 hours continuous service, \(F_a = 1.0\)

6) Extreme power volume evaluation

\[
kW = (0.45S-0.09 - \frac{19.62}{99} - 0.765 \times 10^{-4} S^2), S = \frac{\pi DN}{60}, S = \frac{\pi \times 90 \times 10^{-3} \times 1008}{60} = 4.75 \text{ m/s}
\]

\[
\frac{D}{d} = 1.428 \text{ and Fb} = 1.10, d_e = d_p \times F_b, d_e = 90 \times 1.10, d_e = 99 \text{ mm}
\]

\[
kW = (0.45 \times 4.75-0.09 - \frac{19.62}{99} - 0.765 \times 10^{-4}(4.75)^2) \times 4.75
\]

\[
kW = 0.347 - 0.198 - 1.726 \times 10^{-3} = 0.699
\]

7) Belt count estimation (nb):

\[
b = \frac{P \times F_a \times 0.7457 \times 1.0}{0.699 \times 0.80 \times 0.97}, nb = 1.38, \text{ Number of belts (nb)} = 1
\]

8) Estimation of definite Centre distance:

\[
C = A + \sqrt{(A^2 - B)}, A = \frac{1}{4} - \pi \left(\frac{D+d}{6}\right), A = \frac{645}{4} - \pi \left(\frac{90+63}{2}\right), A = 101.16 \text{ mm}
\]

\[
B = \frac{(D-d)^2}{8}, B = \frac{(90-63)^2}{8}, B = 92 \text{ mm}, C = 101.16 + \sqrt{(101.16^2 - 92)} = 203 \text{ mm}
\]

3.2. From Shaft to Lathe

1) Selection of the belt section: For power 0.7457kW, Asegment is designated.
2) diameters for the associated pulleys contributions (d and D):

\[
\text{Speed ratio } = \frac{D}{d} = \frac{N_1}{N_2} = 1.444
\]

\[
N_1 = 1008 \text{ r.p.m, } \frac{1008}{N_2} = 1.14
\]

\[
N_2 = 881 \text{ r.p.m, So the speed of the driven pulley is (N2) = 881 r.p.m}
\]
3) Selection of Centre distance:
Speed ratio \( i = \frac{D}{d} = 1.144 \) the corresponding \( \frac{C}{D} \) ratio is, \( \frac{C}{D} = 1.5 \), \( C = 1.5D \), \( C = 1.5 \times 250 = \Rightarrow C=500.57 \text{ mm} \)

4) Estimation of minimal length for the pitch:

length for the allotted inside segment \( L = 2C + \frac{\pi}{2} (D + d) + \frac{(D-d)^2}{4C} \),

\[
L = 2 \times 500.57 + \frac{\pi}{2} (103 + 90) + \frac{(103-90)^2}{4 \times 500.57}, \quad L=1304.38 \text{ mm}
\]

length for the allotted inside segment \( L=1304 \text{ mm}, \) nominal pitch length \( L=1331 \text{ mm} \).

5) Range of several alteration aspects:

5.1) length alteration factor (Fc): \( Fc = 0.96 \)

5.2) alteration factor for contact associated with the arc (Fd): \( \text{Arc of contact} = 180^\circ - \frac{(D-d)}{C} \times 60^\circ \)

5.3) Facility factor (Fa): For light-duty 10 hours continuous service, \( Fa = 1.1 \)

6) Extreme power volume evaluation:

\[
kW = (0.45S-0.09 \times \frac{19.62}{d_e} - 0.765 \times 10-4 S2) \times S = \frac{\pi DN}{60}, \quad S = \frac{\pi \times 103 \times 10^{-3} \times 881}{60}, \quad S = 4.75 \text{ m/s}
\]

\[
\frac{D}{d} = 1.144 \text{ and } Fb = 1.10, \quad d_e = d_p \times Fb, \quad d_e = 103 \times 1.10, \quad d_e = 113.33 \text{ mm}
\]

\[
kW = (0.45 \times 4.75 - 0.09 \times \frac{19.62}{113.3} - 0.765 \times 10^{-4} (4.75)^2) \times 4.75
\]

\[
kW = (0.391 - 0.173 - 1.726 \times 10^{-3}) \times 4.75 = \Rightarrow \text{KW} = 1.02
\]

7) Belt count estimation (nb): The number of belts nb is,

\[
nb = \frac{F \times Fa}{kW \times Fc \times Fd}, \quad nb = \frac{0.7457 \times 1.1}{1.02 \times 0.96 \times 0.99} = \Rightarrow nb = 0.84, \quad \text{Number of belts (nb) = 1}
\]

8) Estimation of definite Centre distance:

\[
C = A + \sqrt{(A^2 - B)}, \quad A = \frac{L}{4} - \frac{\pi(D+d)}{8}, \quad A = \frac{1331}{4} - \frac{\pi(103 + 90)}{8}, \quad A = 256.95 \text{ mm}
\]

\[
B = \frac{(D-d)^2}{8}, \quad B = \frac{(103-90)^2}{8} = \Rightarrow B = 2.64 \text{ mm}
\]

\[
C = 256.95 + \sqrt{(256.95^2 - 2.64)}, \quad C = 513.90 \text{ mm}
\]

| Sl. No | Shaft to grinding design parameters | Specification Output |
|-------|------------------------------------|----------------------|
| 1.    | Selection of the belt section      | Power 0.7457 kW      |
|       | pulley shaft speed range (N1) = 1008 r.p.m |
|       | pulley shaft diameter (D) = 61 mm   |
|       | grinding pulley diameter (d) = 61 mm|
| 2.    | Range of diameters for considered pulley (d and D) | ∴ N1 = N2 = 1008 r.p.m |
| 3.    | Selection of Centre detachment     | C=92 mm              |
| 4.    | Estimation of minimal length associated with pitch | L = 375.6 mm |
|       | Nominal inside length L=610mm, Nominal pitch length of L=645mm |
5. Range of several adjustment factors
   a) length alteration factor (Fc)
   b) alteration factor for arc incorporated with contact (Fd)
      a) provision factor (Fa):
          a) Fc = 0.80
          b) Arc of contact (θ) = 180°
          c) For light-duty 10 hours continuous service, Fa = 1.0

6. Evaluation of extreme power volume
   S = 3.219 m/s
   d_e = 61 mm
   KW = 0.2659

7. Evaluation of belts count (nb)
   Number of belts (nb) = 1

8. Evaluation of definite Centre distance
   A = 327.7 mm
   B = 0 mm
   C = 655.4 mm

Table 2. Design of Bevel Gear design computation

| Sl.No | Bevel gear design estimators | Specification Output |
|-------|-----------------------------|----------------------|
| 1.    | Material for gears          | EN8 material for both pinion and gears |
|       | Speed of the shaft (N1) = 1008 r.p.m |
|       | pinion teeth measurement count (Z1) = 18 |
|       | gear teeth measurement count (Z2) = 24 |
| 2.    | Calculation of Z1 and Z2    | Assume Z1 = 18 and Z2 = 24 |
|       | i = \( \frac{Z_2}{Z_1} \) = \( \frac{24}{18} \) = 1.33 |
| 3.    | Calculation of pitch angles and the virtual number of teeth | \( \delta_2 = 53.06^\circ \), \( \delta_1 = 36.93^\circ \) |
|       | Zv1 = 23, Zv2 = 40 |
| 4.    | Calculation of tangential load on teeth (Ft) | V = 0.95 m/s, Ft = \( \frac{0.99}{m_t} \) |
| 5.    | Calculation of initial dynamic load (Fd) | Fd = \( \frac{0.99}{m_t} \times \frac{1.300}{m_t} \) |
| 6.    | Calculation of beam strength (Fs) | b = 10 m, \( m_t \) = 450 N/mm², for mild steel, \( y' = 0.1143 \), R = 15 |
|       | \( m_{tt} \), Fs = 538.62 N |
| 7.    | Calculation of b, d1 and v   | d1 = \( m_t \times Z_1 \) = 20 mm, V = 1.055 m/s |
| 8.    | Recalculation of beam strength | Fs = 538.62 N |
| 9.    | Calculation of accurate dynamic loadv | Ft = \( \frac{p}{V} \) = \( \frac{0.7457}{1.055} \) = 0.715 |
|       | C = 11860 e, for mild steel and 20° full depth, es = 0.0125, C = 11860 \times 0.0125 |
|       | Fd = 542.36 N |
| 10.   | Patterned for beam strong point | It is standard to design Fs ≥ Fd |
|       | 538 ≤ 545.36, So the design is unsatisfactory. |
| 11.   | Calculation of module       | b = 20 mm, Fs = 538.62 N |
|       | F = 538.62 \times 4, Fs = 2154.48 N |
|       | Fd = 858.04 N, Fs ≥ Fd |
|       | Hence the design is safe. |
Calculation wear load (Fw) = 2414.7 N, Fw ≥ Fd, So, design is safe

| Table 3. Design of Drilling Cone Pulley |
|----------------------------------------|
| S.No | Drilling cone pulley parameters | Specification Output |
|----------------------------------------|
| 1. | Selection of the belt section | For power 0.7457 kW, A segment is designated. |
| 2. | Range of diameters for considered pulley (d and D) | \( \frac{D}{d} = 1.428, \frac{N_1}{N_2} = 1.428, \)
\( N_1 = 1440 \text{ rpm, } N_2 = 513.742 \text{ rpm} \) |
| 3. | Selection of Centre detachment | C = 94.5 mm |
| 4. | Estimation of minimal length associated with pitch | L = 191.23 \text{ mm} |
Recommended nominal inside length
\( L = 610 \text{ mm} \)
Corresponding trifling pitch length
\( L = 645 \text{ mm} \) |
| 5. | Range of several adjustment factors |
\( c) \) length alteration factor (Fc) |
\( d) \) alteration factor for arc incorporated with contact (Fd) |
\( e) \) provision factor (Fa): |
\( a) \) Fc = 0.80 |
\( b) \) Arc of contact (\( \theta \)) = 163 |
\( c) \) For light-duty 10 hours continuous service, Fa = 1.1 |
| 6. | Evaluation of determined power volume | Number of belts (nb) = 1 |
\( A = 93.20 \text{ mm} \)
\( B = 105.125 \text{ mm} \)
\( C = 186 \text{ mm} \) |
| 7. | Evaluation of definite Centre distance | |

| Table 4. Power Calculation from Motor to Shaft |
|-----------------------------------------------|
| S.No | Power estimating parameters | Specification Output |
|-----------------------------------------------|
| 1. | Power Calculation from Motor To Shaft |
Rapidity is taken on the motor (N1) = 1439 rpm |
The diameter of the pulley associated with the motor (d1) = 63 mm |
Diameter fixed for the shaft (d1) = 90 mm |
\( \beta = 5.739^\circ, \theta = 2.94^\circ \)
\( T_1 = 2.416 \text{ T2, } T_1 = 0.2676 \text{ N} \)
Torque on the motor \( T = (T_1 – T_2) R1 \)
\( T = (0.2676 – 0.1108) \times 31.5 \)
\( T = 4.9 \text{ N-mm} \)
Torque on the shaft \( T = (T_1 – T_2) R2 \)
\( T = (0.2676 – 0.1108) \times 45 \)
\( T = 7.065 \text{ N-mm} \)
Power transmitted to the shaft (P) is
\( P = 0.7457 \text{ kW} \) |
| 2. | Power Calculation from Shaft To Lathe |
Rapidity taken on the Shaft (N1) = 1008 rpm |
Diameter fixed on the shaft (d1) = 90 mm |
Diameter of the lathe pulley (d1) = 881 r.p.m, |
\( \beta = 0.0419 \text{ rad, } \theta = 3.057^\circ \)
\( T_1 = 2.502 \text{ T2, } T_1 = 0.1045 \text{ N} \)
\( T_1 = 2.502 \times T2 \)
\( T_1 = 0.2615 \)
Torque on the shaft \( T = (T_1 – T_2) R1 \)
\( T = (0.2615 – 0.1045) \times 45 \) |
T = 7.065 N-mm

Torque on the lathe shaft: \( T = (T_1 - T_2) R^2 \)

\[ T = (0.2615 - 0.1045) \times 51.5 \]

\[ T = 8.086 \text{ N-mm} \]

Power transmitted to the lathe (P) is

\[ P = \frac{2\pi NT}{60} \]

\[ P = \frac{2\pi \times 881 \times 8.086}{60} \]

\[ P = 0.7459 \text{ kW} \]

3. Power Calculation from Shaft to Grinding

Power transmitted to the shaft (P) is

\[ P = \frac{2\pi NT}{60} \]

\[ P = \frac{2\pi \times 1008 \times 7.06}{60} \]

\[ P = 0.7457 \text{ kW} \]

4. Power Calculation from Shaft to Drilling

Power transmitted to the shaft (P) is

\[ P = \frac{2\pi NT}{60} \]

\[ P = \frac{2\pi \times 758 \times 4.26}{60} \]

\[ P = 0.7457 \text{ kW} \]

From Table 1 to 4, the complete mathematical analysis of each component associated with the lathe device with respect to the standard industrial considerations are incorporated. The required design specification with respect to the power estimation to reach maximum efficiency have been enumerated in detailed manner with numerical results and comparisons.

4. Schematic Diagram

A shaft receives power from the motor with a cone pulley arrangement. This primary shaft is used to transmit the power to the various operations. Initially, the power is transmitted to the lathe operation. It performs more than one operation like facing, turning, chambering, etc. with a different period. The tools post arrangements are done by rack and pinion arrangement which is 360 degree rotatable by bush arrangement. At the same time, the above-mentioned shaft is used to carry the power to grinding and drilling. Table 5 enumerates the detailed components involved in the mechanical design of the lathe. The detailed numerical statistics of each mechanical components with its design consideration border values were listed in the Table 6. The efficiency of the machine for various operation on the metal components will be enhanced due to its energy and power considerations.

Table 5. Mechanical components associated with the lathe machine

| S.No | Parts                              |
|------|-----------------------------------|
| 1    | Motor                             |
| 2    | Primary shaft                     |
| 3    | Belt and pulley arrangement for lathe |
| 4    | Bevel gear arrangement for drilling |
| 5    | Lathe spindle                     |
| 6    | Tool post bush arrangement for 360° |
| 7    | Rack and pinion arrangements      |
| 8    | Drill wise and bed                |
| 9    | Frame                             |
| 10   | Toolpost                          |
| 11   | Grinding wheel                    |

Table 6. Detailed specification for each tool parameter with numerical specification

| S.NO | Name of the Components   | Specification                      |
|------|--------------------------|------------------------------------|
| 1    | Motor                    | Voltage: 230V, Type: D.C. Generator RPM: 1440rpm. |
| 2    | Drill size               | 3mm to 12mm                        |
| 3    | Spindle size             | 47mm                               |
| 4    | Traveling distance (spindle) | 81mm                            |
| 5    | Fitting plate size       | 12*8 inches                        |
| 6    | Pulley size              | 90mm                               |
| 7    | Drill chuck              | 1/2inch                            |
Figure 1 gives the schematic view of the mechanical design of the lathe and Figure 2 gives the solid work model of the polynomial lathe machine. The bevel gear is attached at the right end of the shaft for transmission of power to drilling. The secondary shaft receives the power from the bevel gear arrangement as shown in the figure below. One
more one pulley arrangement is attached in the secondary shaft to carry out the drilling operation. Hence drilling receives power from the secondary shaft.

5. Conclusion

The multinomial machine can perform various operations at a time by using a single motor for transmission. While comparing other machines like single lathe, grinding and drilling operations. The multinomial machine becomes a greater advantage such as minimize time, cost and occupies less space, etc. it is also convenient to operate it used in many small-scale and mass production industries. When using more gear and similar components there is a power loss, but using a multinomial machine it will be possible to reduce the power consumption and improving the various performance.

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