Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 1; January-March, 2015 pp. 80-84

http://www.krishisanskriti.org/jmsme.html

Designing of Tool Uplifting Mechanism for Four Way Tool Post by Reverse Engineering

Aakash Kumar[1], Prashant Chawla[2], Hitesh[3], Shubham Varshney[4], Mayank Bhartiya[5] and Surabhi Lata[6]

[1,2,3,4,5,6]*Maharaja Agrasen Institute of Technology, Delhi*

Abstract—*In this paper a new concept of lifting the cutting tool is proposed and analyzed in order to achieve greater precision during machining operations. Therefore, the aim of the project is to design a solution to the height adjustment problem encountered while aligning the tool tip and the workpiece center. The conventional height adjustment method involves addition or removal of packing/shims. While designing the new mechanism, the conventional lifting method and the forces experienced by the cutting tool while machining will be analyzed. It involves a pin designed to lift the cutting tool for which both theoretical and software analysis will be carried out. The feasibility of proposed design will include screw-thread analysis, pitch analysis and FEA using Pro-Engineer (PTC Creo) software. The design concludes precise tool adjustment and saving time which further leads to higher efficiency in machining operations. The proposed mechanism is easy to fabricate at a reasonable expenditure.*

Keywords*: Tool Post Height Adjustment, Screw Thread analysis, Pitch Calculations, Pro-Engineer (PTC Creo)*

1. INTRODUCTION

In today's fast growing technological world, all aim to save time and increase production simultaneously. Modern manufacturing industries, both small scale and large scale, update their machinery in order to meet market demand at the earliest and at the most reasonable rate. The mostbasic machine tool possessed by any industry is the conventional lathe. Lathe machine tool is the most versatile among all the machines available in the manufacturing industries and hence designated as the Mother of all Machines. The conventional lathe carries out various operations such as turning, facing, tapering, knurling, grooving, parting off, eccentric turning, chamfering, drilling, reaming etc. The time consuming problem faced in all the above operations is the alignment of workpiece center with the cutting tool tip. So, this project deals with the solution of the encountered problem by designing a mechanism for accurate alignment of tool tip with the workpiece with the help of reverse engineering technique. This mechanism would not only save time but would also prevent the damage of cutting tool tip occurring due to incorrect centering or misalignment.

It would prove to be very helpful for the people running small scale or micro industries, as it would speed up the manufacturing of a product without causing frequent wear and tear of cutting tools.

2. FOUR-WAY TOOL POST

The lathe tool post is the most essential carriage partwhich support, moves and controls the cutting tool. It is mounted on top of the compound rest located on top of the cross feed, which is further placed on the saddle fitted over the bed. The saddle slides along the ways, thus moving the tool post in any direction depending upon the requirement [1].

The four-way turret tool post is the most widely used tool post in modern industrial centre lathes and is highly suitable for repetitive work. It accommodatesfour tools at a time which can be quickly swung into position as required. The cutting tool is held in position by separate screws and a locking bolt located at the centre. It speeds up production and is faster than using a simple tool clamp [2].

The limitation of this tool post lies in the adjustment of height of the cutting tool with respect to the center of the workpiece. As there is no provision for height adjustment, metallic packing or metal shims are used to align the tool tip with the axis of workpiece.

3. PROBLEM DEFINITION

"Design a tool uplifting mechanism for enhancement of tool-work alignment by redesigning the four way tool post"

The project work focuses on the detailed design study of conventional four way tool post and the mechanism followed to align the cutting tool tip with the centre of the workpiece held in the chuck. A new design is proposed to incorporate height adjustment of the tool by lifting it up to the centre of workpiece. Further, the mechanism is based upon reverse engineering, which is studied and analyzed by conducting its mathematical and software analysis.

4. LITERATURE REVIEW

The amount of literature available on the design of tool post is very limited. Mostly the modification work carried out on tool post involves the use of piezo actuators and flexures to enhance positioning. The literature work deals with the damping of chatter and vibrational effects produced during the machining process. Hence, the available work in relation to the lathe tool post was reviewed in detail.

Matthew Bono et al [3]proposed a design of a tool holder and further aimed at its fabrication. The purpose was sub-µm positioning of a single point cutting tool on a four-axis lathe accommodated with a rotary table tool post to swivel at any angle. Adjustments to the tool position were made using manual micrometer adjusters that drive the mechanisms. This improved the precision with which tools were set, and simultaneously reduced the time required to set a tool. The proposed design facilitates the machining of precision meso-scale components with complex 3 D shapes. Akash Tiwari et al [4] proposed a design of a multi-purpose tool post which saved money of small industries by avoiding the sub-contraction of works. This tool post aimed at performing operations like drilling, milling, grinding where spindle axis is perpendicular to work rotation on a lathe machine tool itself. The design involves a 3 phase electric motor, kept parallel to lathe spindle axis, is mounted by bolts on the tool post (compound rest removed) and a small chuck is mounted on the shaft of that motor. The drill, abrasive wheel and milling cutter can be mounted on the shaft of that motor and respective operations can be performed as per the requirements. SuleymanYaldiz et al [5] estimated the cutting forces in turning by comparing the results obtained from the experiments conducted and the consistent fuzzy rule-based model. The cutting forces were measured with strain gauge and piezo-electric accelerometer. The input parameters selected were cutting parameters while the response factors included feed force, thrust force and main cutting force. Here, a Mamdani max–min inference for inference mechanism and C. G. (centroid) defuzzifier formula method for defuzzification were used as operators. The output values concluded difference between experimental and predicted results was around 99. 6%.

5. TRADITIONAL UPLIFTING METHOD OF TOOL

The conventional design for uplifting the cutting tool in the tool post uses metal shims/packing. It is carried out to align the centre of the work held in the chuck with the cutting tool tip held in the tool post. The adjustment of height of the tool can be done only by adding or removing packing and metal shims below the tool.

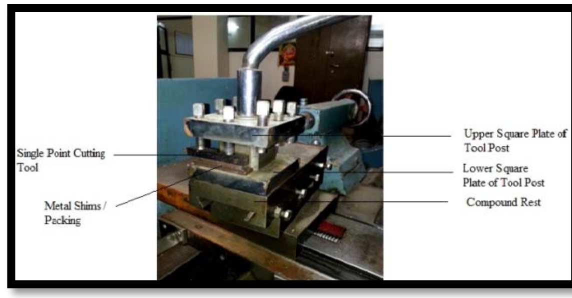

Fig. 1: Tool post with cutting tool supported and lifted through metal shims

Number of packing/metal shims to be used, thickness of shims being used and alignment of tool tip withwork center are the main features of the conventional method of tool uplifting which is solely based on rough estimation. Hence, this uplifting method is an approximate method. It is a less accurate and time consuming process and at times, it becomes laborious task to adjust the tool tip after every regrinding to the same level of accuracy.

6. PROPOSED UPLIFTING DESIGN

A new design of four way (turret) tool post is proposed as a solution to the height adjustment problem encountered while aligning the tool tip and the center of workpiece. A mechanized way of uplifting the tool for accurate alignment with the centre of the workpiece is designed.

7. DESIGN AND ANALYSIS OF TOOL POST WITH SCREW TYPE UPLIFTING MECHANISM

The proposed design of four-way tool post consists of a component which is placed in a rectangular cavity in between the compound rest and the lower square plate of the tool post. The rectangular cavity is made such that it fits the designed component. The componen thas two identical frustums on a cylindrical bar separated by certain pre-determined distance. Following the second frustum, the screw threads of predefined pitch on the bar are generated. These threads arecut on the remaining cylindrical bar which is followed by a circular knob at the end.

The lower square plate has two through holes directing to the two frustums of the component. These holes accommodate two cylindrical bodies of identical dimensions. The cylindrical bodies are tapered on one end according to the taper provided on the frustums. This enables the cylindrical bodies to easily follow the tapered contour of designed component when subjected to rotation.

The two cylindrical bodies from the top surface of lower square plate of the tool post translate in vertical direction when rotational motion is provided to the component in clockwise or anti-clockwise direction. The cutting tool placed between the two plates of the tool post (lower plate resting on the cylindrical bodies) is uplifted and further precise adjustmentsareexecuted. Rotational motion to the component is provided witha nut and screw arrangement which incorporates a self-locking mechanism to avoid slip during operational hours.

7.1 Solid Double Cone Threaded Pin (SDCTP)

The main modification in the four-way tool post is the addition of the solid double cone threaded pin. It works on the principle of conversion of rotational motion into translatory motion with a nut and screw arrangement. When solid cones (frustums) are given rotational motion, the cylindrical bodies in contact with them translate in vertical direction. A fixed threaded length always remains in contact with the tool post plate. Fig. 2 shows the designed pin.

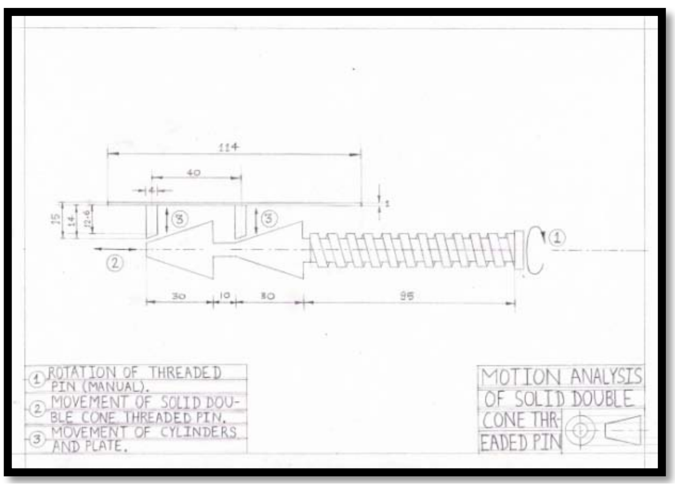

Fig. 2: Motion Analysis of SDCTP

8. ANALYSIS OF SOLID DOUBLE CONE THREADED PIN

8.1 Upliftment Height

The working principle of the uplifting mechanism is strictly dependent on the "number of rotation or degree of rotation" of the designed component. To determine the minimum tool upliftment height and also to calculate the number of rotation required for attaining the maximum uplift the following analysis is done.

From the geometry of the design shown above, taper angle θ is calculated as:

$$\theta = 18.43°$$

For one rotation, the designed pin moves 4 mm (pitch) forward axially to give an uplift of x mmto the cutting tool as:

$$x = 1.332\ mm$$

Now for proposed 10 mm uplift of the cutting tool by the designed pin, number of rotations required is further discussed.

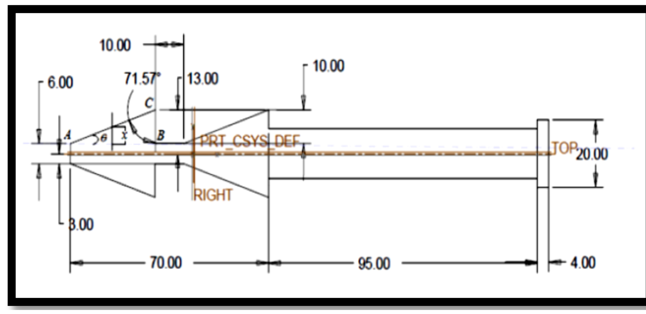

Fig. 3: Diagrammatic Representation of Solid Double Cone Threaded Pin

In one complete rotation, pinmoves 4 mm forward in axial direction. Therefore it moves 30 mm forward axially (maximum uplift) in 7. 5 rotations.

Degree of rotation that can be controlled manually is taken to be5°. Therefore, if 1 rotation of pin gives4 mm forward axial movement of pinthen, 5° rotation of pin will give 0. 0555 mm axial movement.

Hence, the minimum uplift (or least count) for thecutting tool for 4 mm pitch is 0. 0185 mm.

8.2 Thread Analysis

The strength of bolts loaded in tension can be easily determined by the ultimate tensile strength. The amount of force required to break a bolt in tension is given by:

$F_t = S_t \times A_t$

Where, S_t = Ultimate tensile strength of material = 750 N/mm^2 (for EN31 Steel)

A_t = Screw thread tensile stress area [6]

Screw thread area is calculated as:

$$At = 99.302\ \text{mm}^2$$

(Taking pitch as 4 mm)

$$Ft = 74.476\ \text{KN}$$

The amount of force required to break a bolt in shear is given by:

$$Fs = Ss \times As$$

Where, S_s = Ultimate shear strength of material = 450 N/mm^2 (For EN31 Steel)

A_s = Cross-sectional area through which the shear occurs [6]

Thread shear area is calculated as:

$$As\ = 0.5 * \pi * dp.Le$$

Where, d_p = Pitch circle diameter of thread

L_e = Length of thread engagement

Since PCD of thread and length of thread engagement are unknown, they are calculated by the following empirical formulae:

$$dp\ = (D - 0.64952 \times p)$$

$$Le\ (min)\ = \frac{2 \times A\ t}{0.5 \times \pi \times (D\ -\ 0.64952 \times p\ )}$$

Hence, Shear area and Shear force are

$As\ = 198.89\ mm^2$

$$Fs = 89.5\ KN$$

As per theoretical calculation, minimum length of thread engagement, L_e (min) is 10. 2mm which can be increased up to 1 or 1. 5 times the pitch circle diameter of thread and the forces required to break the bolt in tension and in shear are found to be 74. 5 KN and 89. 5 KN respectively.

These results are further analyzed and verified by the force and software analysis conducted for the designed pin.

8.3 Force Analysis

The cutting forces generated during metal cutting operations have a direct influence on the generation of heat which affects the tool wear, quality of machined surface and accuracy of the workpiece.

It has been pointed out that on-line and real-time information of the normal cutting force is closely related to the tool wear prediction, breakage detection or other malfunction inspections.

To avoid the breakage of tool and improve the quality of machined surface along with accurate dimensions of work, a force study and analysis is carried out in reference with the literature available.

Table 1: Force Values with respect to the Cutting Parameters [5]

Cutting Parameters			Experimental Results			Predicted Results		
V_c (m/min)	f (mm/rev)	d (mm)	F_f (N)	F_t (N)	F_c (N)	F_f (N)	F_t (N)	F_c (N)
96	0.12	1	180	145	402	190	145	401
		1.5	203	161	465	205	160	460
		2	215	167	469	220	160	460
	0.16	1	198	182	413	205	190	421
		1.5	224	191	473	220	190	480
		2	232	178	477	235	205	480
	0.2	1	223	208	490	220	205	480
		1.5	237	210	486	235	205	500
		2	244	220	495	250	220	500
143	0.12	1	139	125	345	136	127	344
		1.5	269	235	415	270	240	420
		2	273	254	427	270	255	420
	0.16	1	157	144	359	152	146	362
		1.5	261	193	435	270	192	440
		2	311	295	491	305	300	495
	0.2	1	210	175	449	206	176	441
		1.5	293	262	535	290	255	538
		2	359	324	566	354	317	566
203	0.12	1	122	107	305	127	109	307
		1.5	177	164	344	171	161	344
		2	245	214	381	250	220	380
	0.16	1	135	122	319	134	126	320
		1.5	204	189	360	205	190	361
		2	302	257	444	305	255	440
	0.2	1	193	134	396	191	137	401
		1.5	288	244	495	290	241	500
		2	321	302	507	320	300	500

8.4 Finite Element Analysis

In Pro-Engineer (PTC Creo), finite element analysis (FEA) of the design of solid double cone threaded pin is performed by applying different loads or forces on the pin.

Von Mises stresses are induced and distributed over a region where forces are applied. Design engineers take this theory of Von Mises as the safe haven for designing various components. According to this theory the design will fail, if the maximum value of stress induced in the material is more than strength of the material [7].

Material selected for the analysis of designed pin is EN31 having a yield stress value of 450 MPa. The following Fig. shows the Von Mises stress distribution obtained by FEA of the pin.

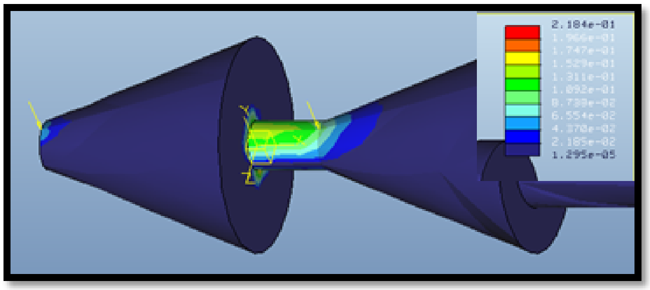

Fig. 4: Stress analysis when 500 N force is applied (Point Loads)

9. COMPARISON OF RESULTS

There are two theoretical analyses carried out on the designed pin, namely Pitch Analysis and Shear Failure Analysis.

Pitch Analysis for threads fulfils the purpose of determining the least count for upliftment of the cutting tool and the total number of rotations for maximum uplift of cutting tool. The results were summarized as follows:
Pitch = 4 mm
Least count = 0. 0185 mm or 18. 5 µm
Maximum no. of rotations = 7. 5

Shear failure analysis for threads

Minimum length of engagement of screw threads = 10. 2 mm
Shear force required for failure of screw threads = 89. 5 KN

As per the reference [5] the actual average cutting force transmitted to the component via tapered cylinders and cutting tool is 469. 72 N which is subservient to cause any failure. So, the design is safe. The FEA of 'solid double cone threaded pin' in Pro-Engineer (PTC Creo) was carried out and following results were obtained for various applied forces.

Table 2: Software stress output w. r. t applied force

Applied Force (N)	Maximum Von Mises Stress (MPa)
500	0.281
1000	0.469
2000	0.8737
3000	1.311

10. CONCLUSION

The major concerns in designing the new component is size as it is to be placed in between the lower square plate of tool post and compound rest besides periphery. Secondly a robust construction and wear-less mechanismis needed, which forms the base for applying load during FEA. Through the study of conventional designand reverse engineering technique all these factors are precisely taken care of and force analysis in accordance with the literature is carried out to determine the range of cutting forces acting on the cutting tool. Further the FEA is performed by considering two point loads acting on the designed component. During this analysis material selection is taken as an important criterion. The result comparison shows the proposed design is safe and within the tolerance limits.

The entire design and analysis concludes that tool adjustments have become easier and more precise. The uplifting of cutting tool by the designed component saves time and increases accuracy in centering with the workpiece which further leads to higher efficiency in machining operation and reduces the wear and damage of the tip of the cutting tool. The proposed mechanism is easy to fabricate at a reasonable expenditure without increasing the overall production cost.

11. FUTURE SCOPE

The four-way tool post design has ample of provision for improving the accuracy by modifying its present conventional design. The new proposed design itself has scope of enhancements. It can utilize the uplifting mechanism on all four sides of the four way turret tool post.

If the force transmitted by the cutting tool exceeds the safe limit, then the bending stress induced in the 'solid double cone threaded pin' can be lowered by a spring system. Another modification can be the use of castor wheel attachment with tapered part of cylindrical body. Such modification can also be implemented in other machine tools by making the requisite changes depending on their axis of work-tool alignment.

REFERENCES

[1] Metalwork Theory by P. F. Lye

[2] Timmings-Manufacturing Technology, Volume 1, 3/e by Timings R. L.

[3] Matthew Bono, Robin Hibbard, A flexure-based tool holder for sub-µm positioning ofa single point cutting tool on a four-axis lathe, 2006.

[4] Akash Tiwari, Niral Panchal, Parth Solanki, Lalit Parmar, Diptesh Patel, Designing and fabrication of multipurpose tool post for Lathe machine.

[5] SuleymanYaldiz, FarukUnsacar, Haci Saglam, Comparison of experimental results obtained by designed dynamometer to fuzzy model for predicting cutting forces inturning, 2005

[6] http://saajsteel. com/?page_id=1098

[7] http://www. learnengineering. org /2012/12/what-is-von-mises-stress. html