Design of a Single Point Cutting Tool

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Abstract – *Single point cutting tool is a tool which touches the workpiece only at a single point. This paper deals with design of a single point cutting tool for machining medium carbon steel with a cutting velocity of 400 m/min, feed of 0.5 mm per revolution and depth of cut of 0.5mm. Study and design of single point cutting tool is an important aspect of tool engineering. In this paper we have discussed the design aspect of shank, the tool geometries, the power required by the lathe and the stresses developed in the tool due to machining. Single point cutting tool is used for important operation in the lathe like facing and turning hence study of geometry of a single point cutting tool is very essential part of study required for manufacturing. Design of single point cutting tool involves collecting data from design data book and using the data to get the final design. It is an iterative process which involves varying the angle within a certain limit provided by the data book to get an optimum result.*

Key Words: Single point cutting tool, design, medium carbon steel, carbide tool, power consumed, lathe, American standard association, orthogonal rake system, vector method of conversion.

1. INTRODUCTION

Single point cutting tool is a tool which touches the workpiece at only on point. Operation like turning, facing, shaping, planing , boring etc use single point cutting tool. Gradually the price of tool material is increasing which has increased the need of less costly tool body i.e., shank. As the price of tool is increasing the durability and life of tool material is an important factor while making a tool. A small change of even 1^0 in the tool parameters can alter the force encountered by the tool by more than ten times. Hence the proper design of tool is very essential.

Fig -1: **Single point cutting tool**

In this paper we have designed a tool based on a specific condition that can be extended to any variation of data. In this paper we have estimated the following prerequisite -:

- Workpiece material -: Medium carbon steel
- Cutting velocity (V_c)-: 400 m/min
- Feed (S_0) -: 0.5 mm/rev
- Depth of cut (t) -:0.5 mm
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The properties of the workpiece are listed below-:

- Ultimate tensile strength -: 565 MPa
- Tensile strength yield -: 310 Mpa
- Modulus of elasticity -: 200 GPa
- Density -: $7.87*10^3$ kg/m^3
- Brinell hardness number -: 163
- Shear modulus -: 80 GPa

Before designing the tool we must be aware of the requirements of a cutting tool. The requirements of cutting tool are listed below-:

- The tool and the workpiece must be held rigidly so as to allow the tool to penetrate the workpiece when forces are applied.
- The shank of the tool must be properly analyzed for strength and rigidity.
- The deflection of the tool must be within prescribed limit.
- The tool must withstand forces encountered by it when it penetrates through the workpiece.

2. MATERIAL SELECTION

The required properties of tool material are listed below

- The tool material must be harder than the workpiece.
- The tool material should be chemically inert.
- The material must be able to resist wear and tear.
- The material should be thermally stable.
- The material should have good thermal conductivity and less coefficient of thermal expansion.

Tool material most widely used are -:

- Carbide

- Ceramic
- Cubic Boron Nitride
- Diamond
- High speed steel
- Tool with coating of Titanium Carbide(TiC) and Titanium Nitride(TiN).

In this paper we have selected Carbide tool with a coating of TiC as BHN of Carbide is much higher than that of medium carbon steel. HSS is also an good alternative but it is not good for machining at such high speed.

3. DETERMINATION OF ANGLES

From the design data book we get the recommended angles for carbide tool in ASA system.

- Back rake angle (Υ_y) -: 0^0
- Side rake angle (Υ_x) -:6^0
- End clearance angle (α_y) -:5^0
- Side clearance angle (α_x) -:5^0
- Side cutting edge angle (ϕ_s) -:15^0
- Approach angle (ϕ)-: -: 75^0
- Nose Radius (r) -:1 mm

3.1 Conversion from ASA system ORS

There are four methods for conversion from one system of angle to the other -:

- Geometrical Method
- Graphical Method
- Transformation Matrix Method
- Vector Method

We have used vector method of conversion from ASA system to ORS

a) $\text{Tan}(\Upsilon_0) = \text{Tan}(\Upsilon_x)\,\text{Sin}(\phi) + \text{Tan}(\Upsilon y)\text{Cos}(\phi)$
- ⇨ $\text{Tan}(\Upsilon_0) = \text{Tan}(6)\,\text{Sin}(75) + \text{Tan}(0)\text{Cos}(75)$
- ⇨ $\text{Tan}(\Upsilon_0) = 0.1015$
- ⇨ $\Upsilon_0 = \text{Tan}^{-1}(0.1015)$
- ⇨ $\Upsilon_0 = 5.795^0$

b) $\text{Tan}(\boldsymbol{\lambda}) = \text{Tan}(\Upsilon_y)\,\text{Sin}(\phi) - \text{Tan}(\Upsilon_x)\,\text{Cos}(\phi)$
- ⇨ $\text{Tan}(\boldsymbol{\lambda}) = \text{Tan}(0)\,\text{Sin}(75) - \text{Tan}(6)\,\text{Cos}(75)$
- ⇨ $\text{Tan}(\boldsymbol{\lambda}) = -0.0272$
- ⇨ $\lambda = \text{Tan}^{-1}(-0.0272)$
- ⇨ $\lambda = -1.568^0$

c) $\text{Cot}(\alpha_0) = \text{Cot}(\alpha_x)\,\text{Sin}(\phi) + \text{Cot}(\alpha_y)\,\text{Cos}(\phi)$
- ⇨ $\text{Cot}(\alpha_0) = \text{Cot}(5)\,\text{Sin}(75) + \text{Cot}(5)\,\text{Cos}(75)$
- ⇨ $\text{Cot}(\alpha_0) = 13.998$
- ⇨ $\text{Tan}(\alpha_0) = 0.0714$
- ⇨ $\alpha_0 = \text{Tan}^{-1}(0.0714)$
- ⇨ $\alpha_0 = 4.083^0$

Hence the angles in ORS (Orthogonal Rake System) are-:

- λ -Inclination Angle - -1.558^0
- Υ_0 -Orthogonal Rake Angle -5.795^0
- α_0 -Orthogonal Clearance Angle- 4.083^0
- α_0'-Auxiliary Clearance Angle- 2^0
- ϕ_e – Auxiliary Cutting Edge Angle- 15^0
- ϕ- End Cutting Edge Angle- 75^0
- r- Nose Radius-1 mm

4. CALCULATION OF DYNAMIC SHEAR STRESS

Dynamic shear stress is given by the product of Brinell hardness number and 0.186.

We know, τ=0.186*BHN
=0.186*163
= 30.318 kg/mm^2
=303.18 N/ mm^2

5. DETERMINATION OF CHIP REDUCTION COEFFICIENT (ζ)

Chip Reduction Coefficient is defined as the ratio of uncut chip thickness to the cut chip thickness. It indicates the degree of deformation.

Assuming it to be rough turning cycle the chip reduction coefficient (ζ) is assuming to be 2.5 and Factor of safety (FOS) is assumed as 10.

6. CALCULATION OF TANGENTIAL FORCE

Tangential force is defined as the component of force which acts on the edge of the cutting tool along a tangent to cutting tool body.

$P_Z = t\, s_0\, \tau_s(\zeta - \text{Tan}(\Upsilon_0) + 1)$
Here,
t is the thickness of the workpiece
s_0 is the feed
Hence,
P_Z =0.5*0.5*303.18(2.5-0.1015+1)
= 257.596N

7. CALCULATION OF LONGITUDINAL FEED FORCE

$P_x = t\, s_0\, \tau_s(\zeta - \text{Tan}(\Upsilon_0) - 1)\,\text{Sin}(\phi)$
Here,
t is the thickness of the workpiece
s_0 is the feed

=0.5*0.5*303.18(2.5-0.1015-1) Sin (75)
=102.394 N

8. CALCULATION OF RADIAL FORCE

$P_y = t\, s_0\, \tau_s (\zeta - \tan(\Upsilon_0) - 1) \cos(\phi)$
$=0.5*0.5*303.18(2.5-0.1015-1) \cos(75)$
$=27.436$ N

9. CALCULATION OF CROSS-SECTIONAL DIMENSION

We know H/B must be between 1.25-1.6, Here

- H is the height the tool
- B is the breadth of the tool

The effective length L_e of the tool must be between 25-30 mm for proper holding of the tool.

So, we assume H/B = 1.5 and L_e =30 mm

We Know,
Total stress is given by the sum of principal stresses i.e.,

$\sigma = \sigma_1 + \sigma_2$

$$\sigma = \frac{6PzLe}{BH^2} + \frac{6PxLe}{HB^2} \ldots\ldots\ldots\ldots\ldots (i)$$

Also,

$$\sigma = \frac{\sigma\, ut}{FOS} = \frac{565MPa}{10} = 56.5\ MPa \ldots\ldots\ldots\ldots\ldots(ii)$$

Now, from (i) and (ii) we have,

$$56.5 = \frac{6*257.596*30}{2.25*B^3} + \frac{6*102.39*30}{1.5*B^3}$$

$$56.5 = \frac{32894.48}{B^3}$$

B= 8.35 mm

Rounding it off to the nearest standard value of integer we get B =10 mm

From the recommended set of cross section 10*16 is available.

Hence the Cross-Section of the cutting Tool is 10*16 mm.

10. POWER CONSUMED

The power consumed in the cutting the workpiece is given by the equation

P= Pz*Vc
Here,
Pz is the Tangential Force
Vc is the cutting velocity
= {(257.596*400)/60} Watt
= 1717.306 Watt
=1.717 KW

11. DEFLECTION

$$\delta = \frac{4PzLe^3}{EBH^3}$$

$$= \frac{4 * 257.596 * 30^3}{200000 * 10 * 16^3}$$

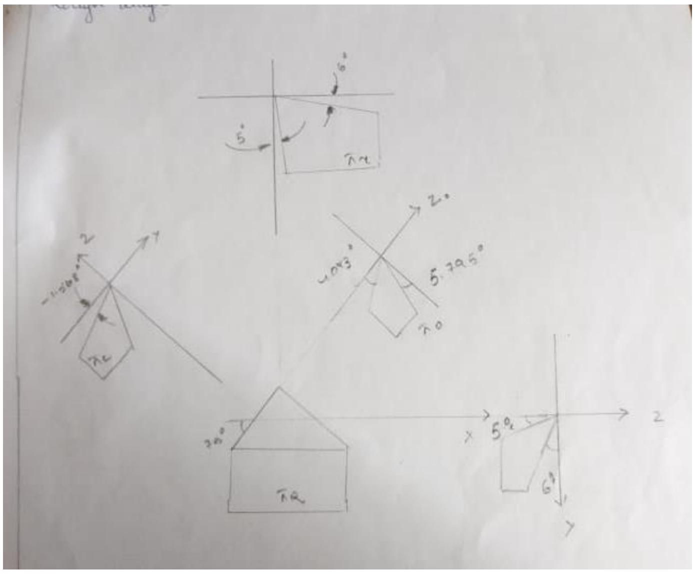
= 0.00396 mm
=3.96 microns

12. TOOL SIGNATURE

The expected tool signature in ORS System is

-1.558-5.795-4.083-2-15-75-1

13. ROUGH DIAGRAM



14. CONCLUSION

This research work deals with the design of single point cutting tool and after the determination of forces the effect of these forces were studied. With all the analysis of these forces it can be concluded that design of the single point cutting tool is strong enough to bear cutting forces during all kind of lathe operation.

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