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MODELING, ANALYSIS AND OPTIMIZATION OF HEADSTOCK OF VERTICAL MACHINING CENTER 850

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ABSTRACT

This paper gives the behavior of machine tools component for different condition by analysis. Accuracy is directly connected to deflection of headstock. In Vertical machining center the headstock has direct impact with accuracy and deflection. To get more accurate result structural as well as different thermal condition like temperature, heat flux and conduction is to be considered. By improving the geometry and thickness of headstock, the different errors like geometrical error, accuracy can be improved and efficiency will increase. The static and dynamic analysis is to be done for accurate result.

Keywords: Accuracy, ANSYS, Headstock, Machine Tools, Structure, Thermal, VMC

I. INTRODUCTION

VMC is Vertical Machining Center which is used to perform milling operation which relies on rotary cutters to remove metal from a workpiece. Vertical machining occurs on a vertical machining center (VMC), which employs a spindle with a vertical orientation. With a vertically oriented spindle, tools stick straight down from the tool holder, and often cut across the top of a workpiece.

It is large scale machine from small to very high range according to size of workpiece. High precision machine is used in die and mold work. It has wide application because it can perform different operation in one machine. It has ballscrew and linear motion system to run different axis which is control by servo mechanism.

Headstock is very important part of machine because spindle and tool is mounted on it and operation is perform according to movement of headstock. It is different assembly is mounted like motor assembly and spindle assembly.[1]

1.1 VMC Axis Designation

VMC has standard 3 axis which are X,Y,Z, all have positive and negative value according to spindle center,

X & Y axis is based on table and saddle movement, Z axis is based on headstock movement, Extra Axis provision for 4^{th} & 5^{th} axis to be done by rotary table mounted on table which has circular motion.

This figure shows the Simplified CAD model of VMC machine. It has mainly 5 components which are base, saddle, table, column and headstock.

Base: It is main component of machine all the weight of machine is comes on it so it should be very rigid.

Saddle: It is mounted on base and it has linear movement in y direction, It also should be rigid.

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Table: It is mounted on saddle and it has linear movement in x direction, The workpiece is fixed on it.

Column: It is very rigid and heavy part which is fixed on base, it is fixed and supporting part.

Headstock: It is very rigid and important part, it is mounted on column vertically, it has linear motion in z direction, spindle is mounted on it.

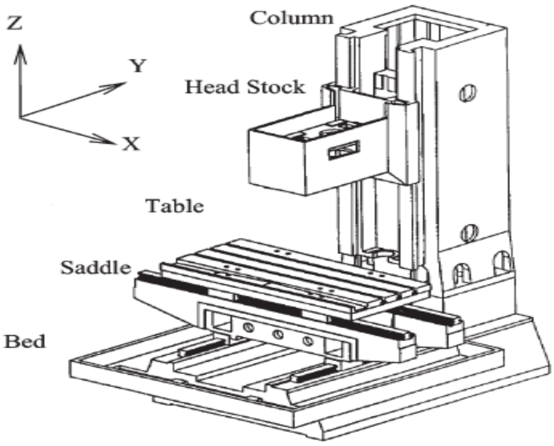

Figure 1 Schematic Diagram of Vertical Machining Center

1.2 Vmc Headstock Assemblies

Headstock Assembly has Mainly 5 component.

Headstock, Spindle, Spindle motor, Unclamp cylinder, LM Block

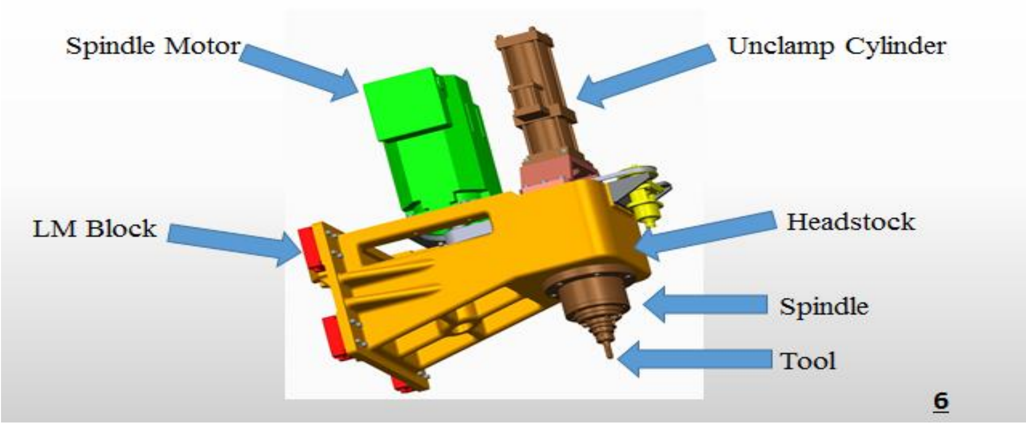

Figure 2 CAD Model of Headstock Assembly

II. PROBLEM FORMULATION

Until now so many analysis work is done in mainly based on structural behaviour while not more consideration on thermal behaviour. To find good accuracy structural as well as thermal conditions also affect on environment. To get more accurate result , the thermal condition like conduction, convection, maximum temp, heat flux will be considered. Dynamic analysis also require to do time based change in accuracy and deflection. By improving the geometry and rib structure of headstock uniform stress distribution can be improved.[2]

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III.VMC 850 MACHINE SPECIFICATION

Parameter	Specification	Unit
X Axis Stroke	820	mm
Y Axis Stroke	510	mm
Z Axis Stroke	510	mm
Rapid Feed	24	m/min
Cutting Feed	10	m/min
Number of tool	20	
Tool Weight Max	7	kg
Tool Length Max	250	mm
Table Size	1000 X 530	mm x mm
Table load Max	500	kgf

Table 1 Specification of VMC 850 Machine

3.1 Vmc 850 Spindle Specification

Parameter	Specification	Unit
Spindle Type	BT40	
Spindle Speed	8000	rpm
Spindle Power	13.5	kw

Table 2 Specification of VMC 850 Spindle

3.3 SG 600/3 Material Property

Property	Value
Density	7200 kg/m^3
Young’s Modulus	170 Gpa /25 Mpsi
Poisson’ Ratio	0.29
Elongation	3 %

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Brinell Hardness	230
Thermal Conductivity	33 W/m-K
Thermal Expansion	11 µm/m-K
Tensile Ultimate Strength:	630 Mpa / 91 Kpsi
Tensile Yield Strength	430 MPa / 62 Mpsi
Shear Strength	450 Mpa /65 Mpsi

Table 3 Specification of SG 600/3 Material

IV. CUTTING FORCE CALCULATION FOR MILLING

Diameter of cutter, D : 80 mm

Material to be cut : medium carbon steel

Cutting speed, V : 300 m/min

Spindle Speed, N

$$v = \frac{\pi DN}{1000}$$

$$N = \frac{1000 \times V}{\pi D}$$

$$N = \frac{1000 \times 300}{3.14 \times 80}$$

N = 1195 rpm

Tangential cutting force,

$$P_z = \frac{6120 \times P}{V}$$

$$P_z = \frac{6120 \times 13.5}{300}$$

Pz = 275.4 kgf

Pz= 2701 N

The tangential cutting force, Pz, can resolve into two components:[3]

Px = 0.65 Pz = 112.2 kgf = 1756 N

Py = 0.35 Pz = 71.4 kgf = 945 N

4.1 Loads and Constraints

Weight of spindle mounting assembly : 32 kg = 314 N in- Z direction

Weight of motor assembly: 90kg = 883 N in- Z direction

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Cutting forces during face milling:

a) Axial component of tangential cutting force: 1756 N in –Z direction

b) Radial component of tangential cutting force: 954 N in –X direction

Back face will be considered as fixed

4.2 Heat Flux Calculation

$$Q = \frac{k \times A \times (T_{hot} - T_{cold})}{d}$$

$$Q = \frac{33 \times 0.1029 \times (275 - 50)}{0.070}$$

Q = 10925 W/mm^2

Q = heat transferred per unit time

k = thermal conductivity of the barrier

A = heat-transfer area

T_{hot} = temperature of the hot region

T_{cold} = temperature of the cold region

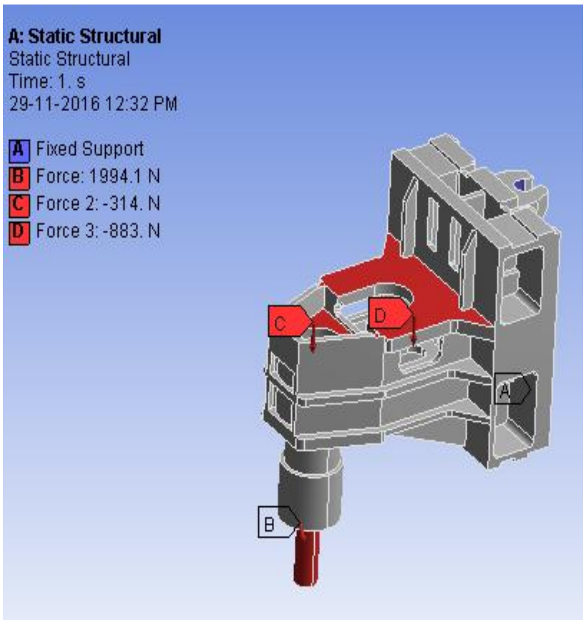
d = Thickness of the barrier

4.3 Boundary Condition

To Evaluate of deformation and Stresses, the back surface is fixed in all direction. [4]

V. RESULTS AND DISCUSSIONS

5.1 Boundary Condition for Static Structural and Steady-State Thermal Analysis



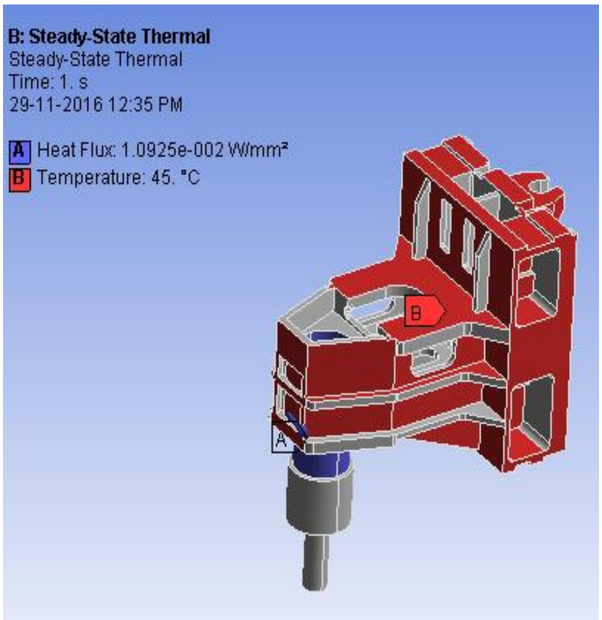


Figure: 3 Boundary Condition for Structural Analysis **Figure 4: Boundary Condition For Steady-State Thermal Analysis**

Here the Back side support is fixed

Here the 3 forces are applied motor assembly, spindle assembly and cutting force.

Heat flux is applied at spindle mounting area.

Outside ambient temperature is 45 ºC for all outer surfaces.

5.2 Total and Directional Deformations for Static Structural Analysis

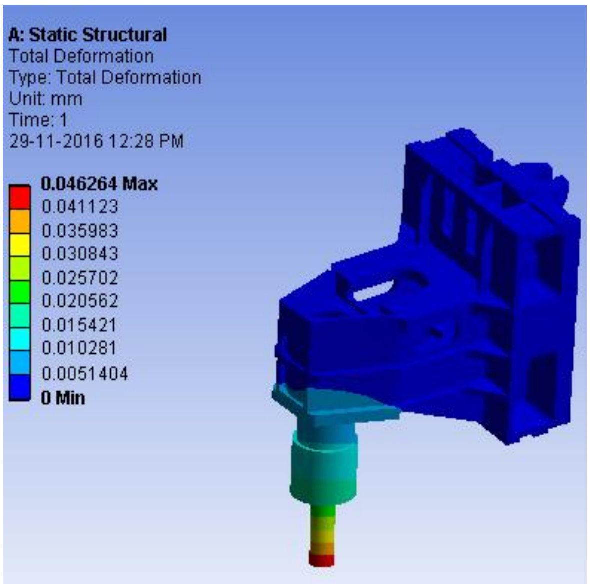


Figure 5 Total Deformations for Structural Analysis

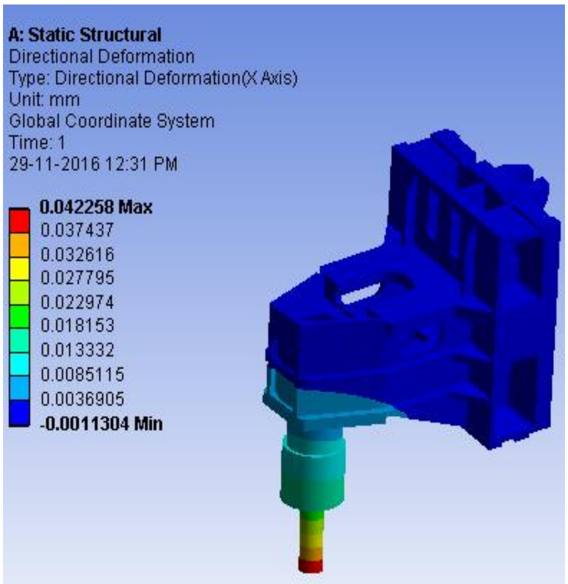


Figure 6 Directional Deformations In X Direction

The maximum total deformation is 46 µm which is occur at tool tip of tool.

Maximum Directional Deformation in X direction is 42 µm.

5.3 Total Heat Flux and Temperature Distribution for Steady-State Thermal Analysis

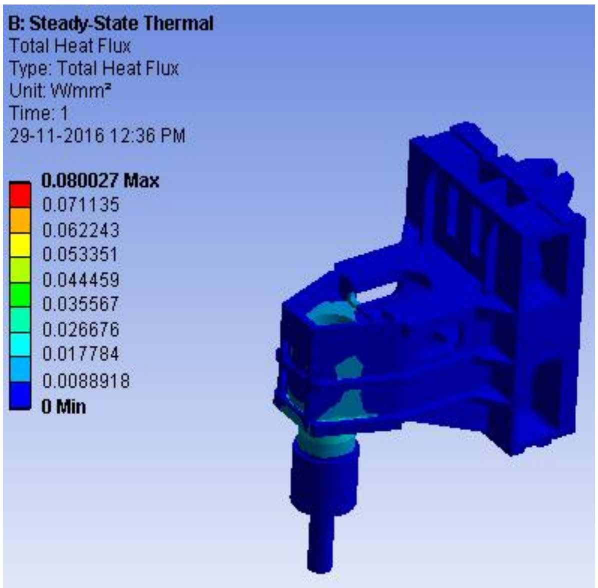


Fig 7 Total Heat Flux Distributions in Thermal Analysis

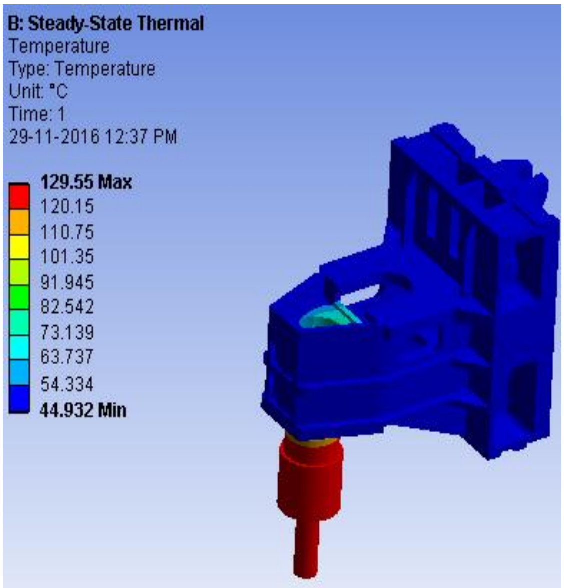


Fig 8 Temperature Distributions in Thermal Analysis

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Total Heat Flux Distributions is given in above result which maximum at spindle mounting rib of headstock. Temperature Distributions in headstock is given in above result which maximum at spindle surface.

VI. CONCLUSIONS

From the structural and thermal analysis it shows that the total deformation is within the limit and temperature distribution is under control and given condition is accurate for machining operations. Also result is independent from meshing after number of convergent and shows the maximum deformation and temperature distribution.

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