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Deformation Analysis of a 3-Axis Gantry System

Yatiraj L. Mane[1], Dr. Bhagyesh B. Deshmukh[2]

[1,2]Department of Mechanical Engineering, Walchand Institute of Technology, Solapur, Maharashtra, India

yatiraj.mane@yahoo.com

Abstract— Micro applications are found in areas like Biomedical, Watch maker and Jewelers, Information Technologies, Telecommunication, Automotive, Aerospace, etc which requires ultra precision machineries. For this machineries high accuracy and high precision is required. Accuracy of the machine components depends upon the precision positioning slides i.e. X, Y and Z slides which are supported by the gantry system. Applications of various forces may cause the deformation of machine slides and which affects on accuracy of the machine. In this paper deformation analysis of the slides of the gantry system are carried out and the results are validated using simulation tool.

Keywords— Gantry system, micro applications, precision, accuracy, positioning slides, deformation analysis, simulation tool

INTRODUCTION

The first NC machines were built in 19th centuries based on existing tools that were modified with motors that moved the controls to follow points fed into the system on punched tape. These early servomechanisms were rapidly augmented with analog and digital computers, creating the modern CNC machine tools that have revolutionized the machining process. Multi axes CNC machines are used for complicated geometry where perfection and intelligence is highly required to meet the daily demands of high speed production [1]. As time passes, micro applications are found in areas like Biomedical, Watch maker and Jewelers, Information Technology, Telecommunication, Automotive, Aerospace, etc which requires ultra precision machineries.[2] Micro machining requires accuracy and high resolutions which offered by machining tool. Accuracy of the machine components depends upon the precision slides i.e. X, Y and Z slides which are supported by the gantry system. A retrofit design is developed for a 3-axis gantry system by using components form salvage.[3] The dimensions of the gantry system are considered according to the work piece envelope of size 100 x 50 x 50 mm on which machining operation are carried out.

After designing a 3-axis gantry system, there is a need to perform the deformation analysis by analytical method and then analytical results are validated using simulation tool.

LITERATURE REVIEW

The FEA software will be the tool used to perform the structural analysis and predict the behavior of the structure under the work loads. The Finite Element Method decomposes the structure into small elements that are connected at nodes, through the application of a mesh. The mesh will transform a continuous domain into a finite domain that enables the calculation of simultaneous algebraic equations. This method requires the application of boundary conditions such as fixed or pinned constrains and the application of external loads and/or gravity in order to consider the self-weight of the structure. The FEA can be performed in a structural application but also in thermal or fluid flow problems. The structural analysis can be linear or non-linear. If the interest of the analysis is to preview the behavior of the structure in the elastic domain then is used a linear analysis. On the other hand, if the work loads are probable to overcome the yield stresses in some areas of the model, some hardening will happen and the material properties will differ along the model, therefore a non-linear analysis shall be performed.[4]

A static analysis calculates the effect of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis can, however, include steady inertia loads and time varying loads that can be approximated as static equivalent loads. Static analysis determines the displacements, stresses, strains and forces in structure or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response condition are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. [5]

Analysis of the machine tool structure for the various purpose by the analytical method is the more time consuming and very complex method also it doesn't gives the precise way for the analysis because of its complexity but by using the FEA software we can get batter result with the more precision and more accurately than analytic method and also in this FEA, Static and Dynamic analysis of machine tool structures plays an important role on the efficiency and job accuracy of the machine tool. Static analysis is useful for estimating stresses, strains and deflections, and also improving structural stiffness whereas dynamic analysis deals with the prediction of natural frequencies and corresponding mode shapes, which will in turn; prevent the catastrophic failure of the machine tool structures. [6]

A review is carried out which is related to the structural analysis. It is found that FEA method is widely used by the researcher for structural analysis.

DEFORMATION ANALYSIS BY ANALYTICAL METHOD

In correspondence to the objective of the deformation analysis, detailed analysis of the positioning slide as shown in Fig.1 is carried out by using classical bending equations.

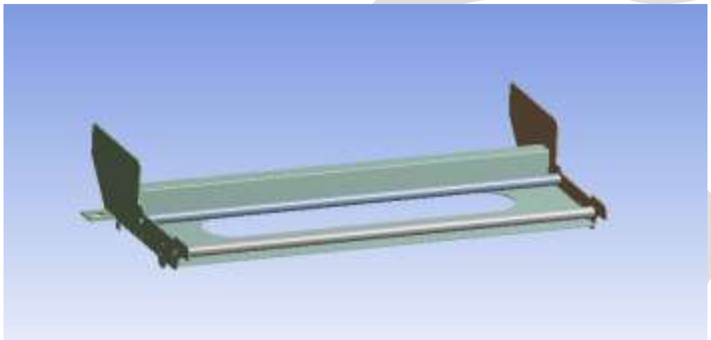

Fig.1 : CAD model of slide for Analysis

In the deflection analysis of slide, as it is fixed at both the ends, it is considered as a case of fixed supported beam and the point load is acting at the centre of the beam. The detailed analytical steps are presented here with.

Deflection of the beam when both ends are fixed and load is acting at centre is given by equation (1),

$$y_c = \frac{wl^3}{192EI} \quad \ldots\ldots(1)$$

Where,

w = half of the total weight = 6.20 N

l = length of the slide = 232 mm

D= outer diameter of the block = 12mm

d = inner diameter of the block = 4mm

E = Young's modulus for steel = 210 GPa

I = moment of inertia

y_c = 0.0095548 mm

In order to validate the deflection obtained by analytical equation, a simulation is carried out by using ANSYS Workbench.

DEFORMATION ANALYSIS BY NUMERICAL SIMULATION METHOD

ANSYS Workbench is used to carry out numerical simulation. Preprocessor, solution and postprocessor are the three steps includes in the numerical simulation procedure. The aim of the present work is carried out the static analysis of the 3-axis gantry system. As Dynamic aspect is not considered in present work, in tune with the objective and scope of the study, "Static Structural Analysis" module in ANSYS workbench is considered for analyzing the positioning slides. In static analysis, the focus is on force and displacement or deformation relationship.

a) Preprocessor:

In preprocessor step, the CAD model is developed and is imported into the ANSYS workbench. In this, Boundary conditions must require imposing for the analysis. The two slide rods are fixed at both the ends and the force is applied at the centre and top of the slide surface. The applied cutting force is varying from 1N to 10N.

b) Solution

The next step is solution for the resulting deformation. The compiler processes the model and keeps the solution ready for the further process.

c) Postprocessor in ANSYS:

This step includes the general solution report. Following Fig.2 shows the total deformation result. The maximum deformation of 0.0074433 mm is observed corresponding to a force of 6.20N.

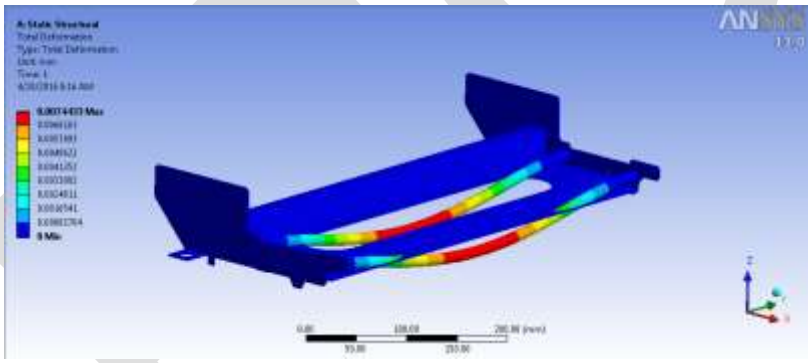

Fig.2: Total Deformation

Fig.3 shows maximum von misses stresses developed.

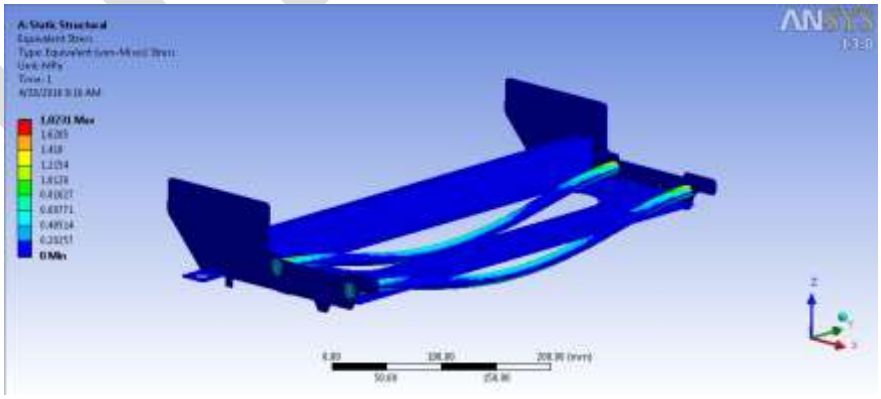

Fig.3: Von Misses Stresses

The maximum Von misses stress of 1.832 MPa is observed corresponding to a force of 6.20N.

RESULTS

The results of deformation analysis by using analytical and ANSYS method are plotted on graph as shown in Fig.4 for a range of force from 1N to 10N (1-1-10N). From the graph it is observed that the deformation curve for the forces is linear. The deflection is maximum of 0.012005mm for 10 N force.

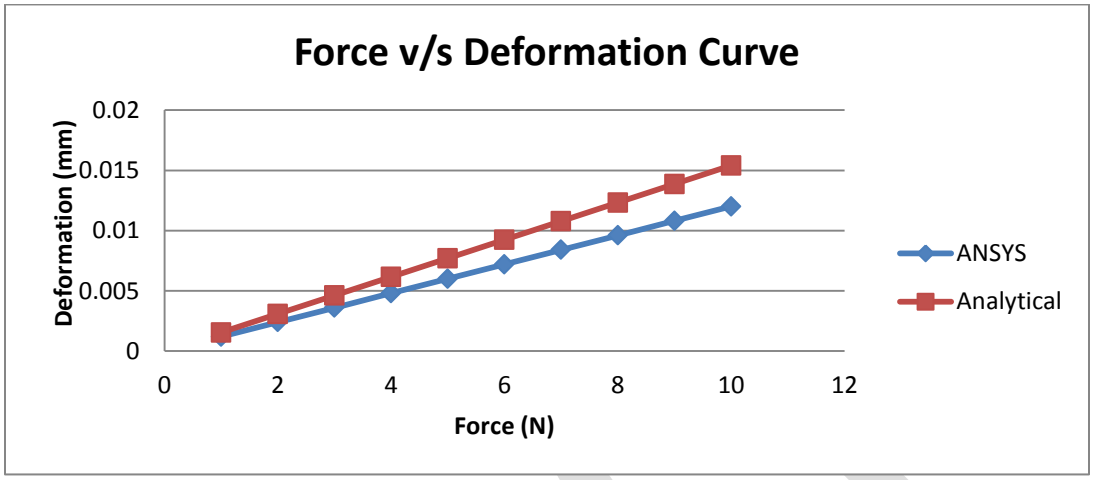

Fig.4: Force V/s Deformation Curve

The graph shows that results by analytical method and by ANSYS method have very close agreement. Hence it indicates the correctness of the analytical method adopted for deformation analysis of positioning slides.

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CONCLUSION

The results of the deformation analysis of the positioning slide by analytical method are validated by using simulation method. Hence the design is found to be satisfactory as deflection is very negligible for selected dimensions of slide. The ANSYS Workbench results proved that the simulation method is an very important tool for analysis of the complex machine parts.

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