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Structural Analysis & Optimization of EDM Machine Table

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Abstract

The Machine Tool industry aims for high precision and repeatability while it is in operation. The quality of the machine tool, in fact, is determined on this count. The structural components in the machine tool play a vital role in helping to achieve consistent performance. The damping for the vibrations, load-bearing capacity for the over-hung members, the stable alignment between the mating parts forming links and for the components experiencing dynamic/ rotation movement in the given pair.

This report briefs the opportunity to optimize the machine tool structure of an EDM machine whose structure needs to be improved. The given reports are discussed the objectives and methodology for EDM machine.

Keywords

FEA, EDM Machine Structure, CATIA V5 R17, Die Sinking Machine, VMC, Mega Float.

I. Introduction

The Machine Tool industry aims for high precision and repeatability while it is in operation. The quality of the machine tool, in fact, is determined on this count. The structural components in the machine tool play a vital role in helping to achieve consistent performance. The damping for the vibrations, load-bearing capacity for the over-hung members, the stable alignment between the mating parts forming links and for the components experiencing dynamic/ rotation movement in the given pair [3].

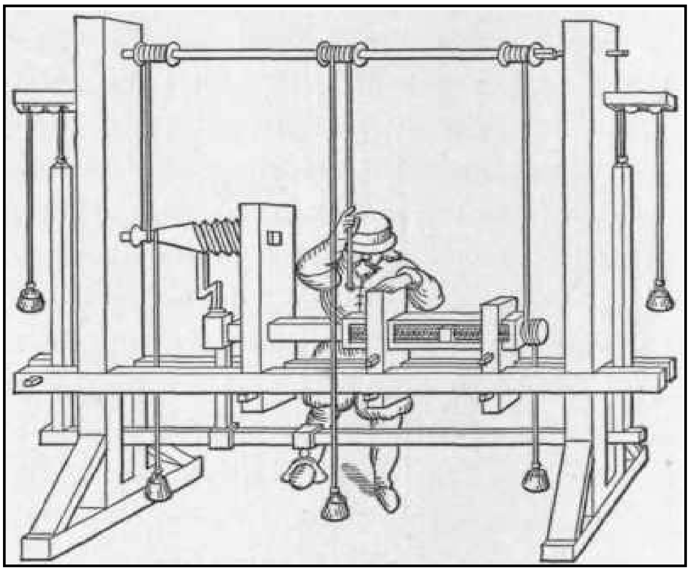

Fig. 1: Structure of Machine

The model of any machine under review is now undergoing changes to the structure. The new design needs to be reviewed in the light of structural strength while subjecting the components/ sub-assembly to Analysis using CAE. The geometry of the machine frame/ structure is amenable to the usage of 3D modeling. The design of the structure would necessitate knowledge of the fundamentals for Machine Design. The information like weight of the structure and the relative position with respect to other elements of the machine tool can be readily offered by the three dimensional CAD interface [3].

A. Different Types of Structure

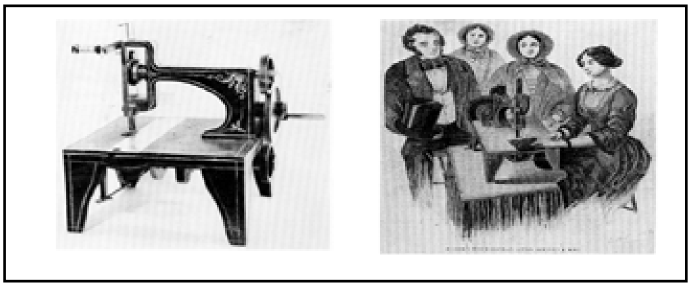

Fig. 2: Structure of the Sewing Machine

Sewing machine consists of two major parts - the frame, which holds the material, and the stitching mechanism, called the hand. The Frame is the prominent structure in the Sewing Machine.

1. Structure of Electro-chemical Die Sinking Machine

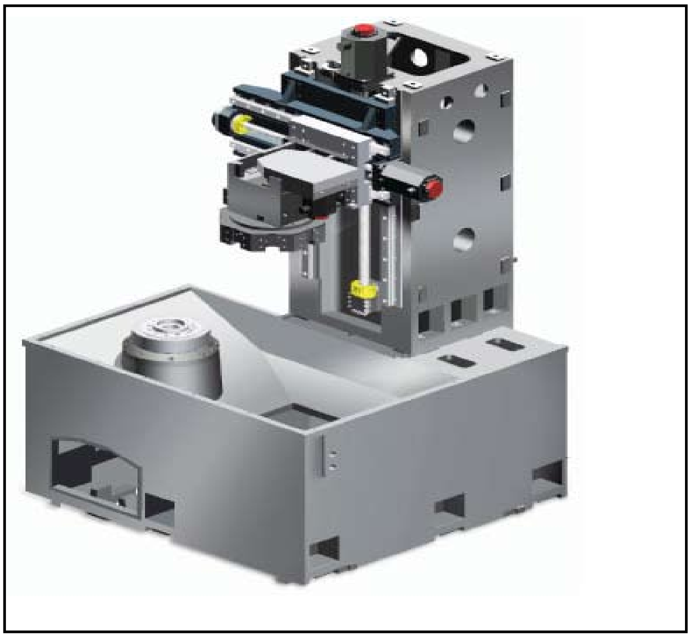

Fig. 3: Electro-chemical Die Sinking Machine

The above Fig. shows a structure of electro chemical die sinking machine.tis machine is used for removing the metal by an electrochemical process. The desired structure is built up to allow for successful electrochemical machining. This structure consists of column and table. Table is used for to hold the work piece and column is used for processing in Y direction.

3. Basic Structure of a Single bar Knitting Machine

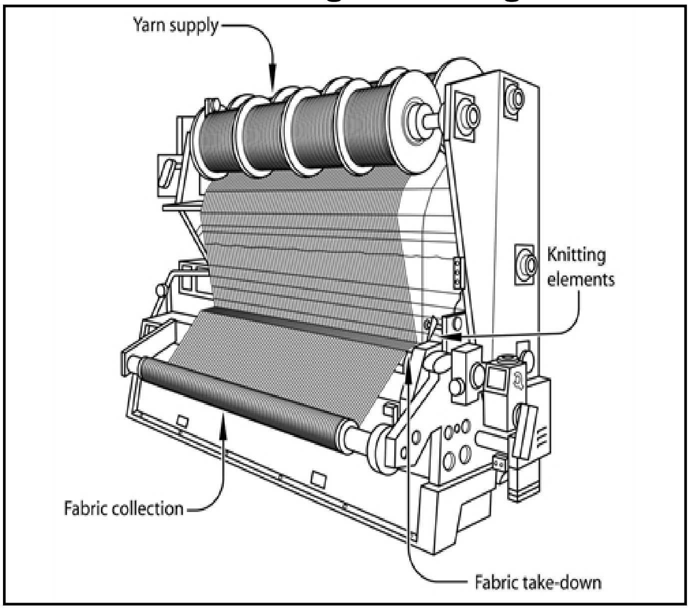

Fig. 4: Basic Structure of a Single bar Knitting Machine

The main machine frame is constructed from sturdy cast steel or welded vertical side frames held together and stabilized by a large welded steel box section transverse girder. The needle bar and the yarn guides are mounted transversely above the box section girder in the middle of the machine and run virtually the full width of the machine. Machine widths range from 1 meter to 5 or 6 meters depending on the type and end use of the fabric.

4. Elements of a Modular Structure

Fig. 5: Elements of a Modular Structure Made From Aluminium Channels

The given figure shows an element of modular structure of channels which is use at corner for joint purpose.

5. Sturdy Base Structure for a Vertical Machining Centre - VMC

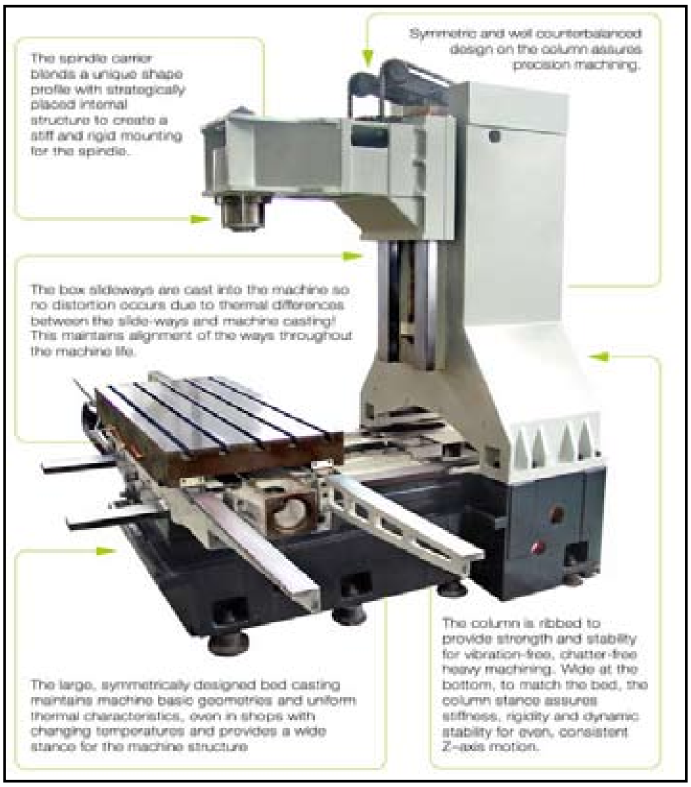

Fig. 6: Structure for a Vertical Machining Centre - VMC

Vertical machining center are often used for high precision application such as mold making and graphite machining. The above structure shows the various parts like column, bed, box sideway and spindle. This structure is capable of withstanding the much better stress without deforming and provides the maximum vibration damping. The column is ribbed to provide the strength and stability for vibration free, chatter free heavy machining. Wide at the bottom, to match the bed, the column stance assures the stiffness, rigidity and dynamic stability. The large symmetrically designed bed casting maintains machine basics geometric and uniform thermal characteristics.

6. Parallel Structured Milling Machine with Long X Travel

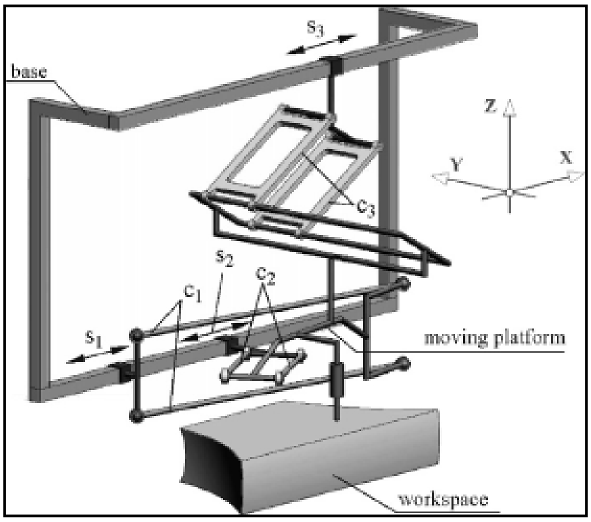

Fig. 7: Parallel Structured Milling Machine with Long X Travel

As in above Fig, shows the mechanism consists of the mobile platform, three joint parallelograms c1, c2 and c3, and a stationary base with two parallel guide-ways. Two crossed parallelograms c1 and c2, with spherical and/or universal, joints, are connected with one of their ends to the mobile platform, and with their other ends to the independent sliders s1 and s2 which, with a common guide way, make two powered and controlled translatory joints. The third joint parallelogram c3 is connected with one of its ends through passive translator rotating joints with 2- DOF, to the mobile platform. Its other end is connected with rotating joints to the slider s3, which makes, with the second guide-way, the third powered and controlled translatory joint. The actuation of sliders s1, s2 and s3 offers three degrees of freedom to the mobile platform.

7. Very Large Floating Structure (VLFS)

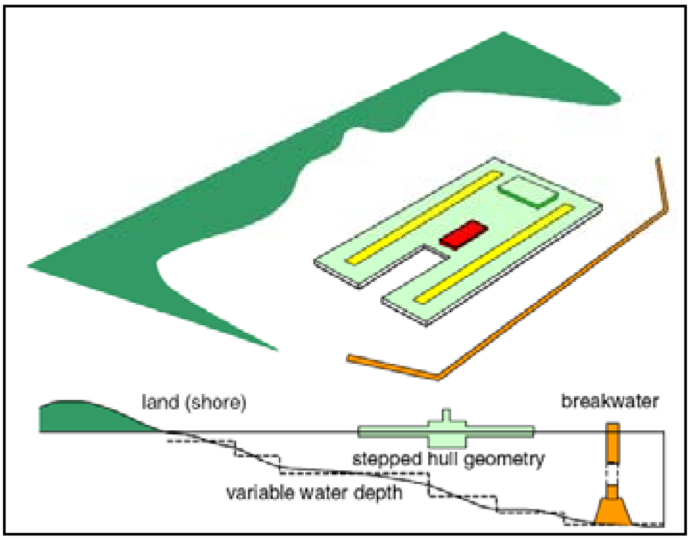

Fig. 8: Structural Unit of a Mega-Float

Mega-Float is to have stepped hull geometry as an assembly of box-shaped, shallow-draft floating units, stationed in a water area and protected by both breakwaters shore as well as stepped bottom topography, as shown in fig. The Mega-Float is not a uniform rectangular plate. Mega-Float, assumed to be up to about 5 km long and 2 km wide, is a huge assembly of box-shaped, shallow-draft, floating units with inner structures. The hydro elastic response of Mega-Float to water waves has been one of its major issues.

B. Need for Design and Optimization

Structure design is a continuous challenge towards the best for strength, minimum weight, and shock absorption due to vibration, low energy consumption, low structural stiffness, and load carrying capacity. So there is lots of issues are available is need to improve all above factors are mentions.

The demand for machine tools is growing relative to conventional machine tools because of the need to save space, and because of the need for low energy consumption when the overall size of a manufacturing components are a few millimeters with micro-scale machining precision, such as a camera lens for mobile phones. Machines have other advantages as well: rapid and precise motion controls are possible due to low structural inertia, and they produce low levels of vibration and heat during machining. One of the weak points of miniaturized machines is their low structural stiffness caused by low bearing capacity and their inadequate structural robustness, which affects machining precision in products. Many efforts have been made to address these limitations such as raising the spindle speed with a low level of run out (below 0.1 lm). Improvements in structural damping and stiffness using new materials. We can increase structural stiffness and damping capacity, thereby improving the load-carrying capacity of a stage driven by air bearings.

A machine tool is often composed of several structural parts. The need of the concept design of a machine tool is to select the appropriate principal dimensions of each of the structural parts so the total weight of the assembled structure is minimized while sufficient stiffness is maintained. To achieve the goal, optimization methods can be used to help to determine the best values of the principal dimensions.

II. Literature Review

A. Use of Finite Element Structural Models in Analyzing Machine Tool Chatter

Baker et al. (2002)

The objective of the research done by author is that a reasonable assumption is that any structural modification that enhances chatter resistance for a cutting process characterized by the model in would likely also enhance the chatter resistance for the structural system if the cutting process model were somewhat different. A different cutting model could easily be used with the structural matrices in the stability analysis, as long as the force components are based on linear combinations of terms involving the relative tool work piece motion normal to the cutting surface. Future verification work on this method of stability analysis is desirable. This could be performed by developing a suitable FE model of an existing machine tool structure, estimating the cutting parameters necessary for representation of the cutting process using the cutting force equations in, or some other similar dynamic cutting process model, and predicting the stability borderline curve. The predicted borderline curve could be compared to experimental results found by varying widths of cut until chatter is induced across a range of spindle speeds [1].

B. Isogeometric Analysis of Structural Vibrations

Cottrell et al. (2006)

The main objective that the newly developed concept of is geometric analysis to structural vibration problems. After reviewing some fundamentals of isogeometric analysis, application is made to several structural models; including rods, thin beams, membranes, and thin plates. Rotation less beam and plate models is utilized as well as three-dimensional solid models. The concept of k-refinement is explored and shown to produce more accurate and robust results than corresponding finite elements. He introduced the concept of isogeometric analysis, which may be viewed as a logical extension of finite element analysis. The objectives of the isogeometric approach were to develop an analysis framework based on functions employed in computer aided design (CAD) systems, capable of representing many engineering geometries exactly; to employ one, and only one, geometric description for all meshes and all orders of approximation; and to vastly simplify mesh refinement procedures. The method is used by author that of NURBS-based isogeometric analysis Non-uniform rational B-Splines (NURBS) are a standard tool for describing and modeling curves and surfaces in computer aided design and computer graphics [2].

C. Parallel Structured Milling Machines with Long X Travel

Milos et al. (2008)

The describe mechanism's structure, modeling approach and the development of vertical milling machine experimental prototype. The developed and preliminary investigated vertical milling machine experimental prototype indicates that such commercial machines may be superior to the comparable serial and parallel machine designs, both in respect of the price and the dynamics and accuracy, which justifies further research in this direction. The development of the 5-axis hybrid parallel-serial milling machine with added 2-DOF serial mechanism is also under way. It has several advantages such as: rather regular shape of the workspace similar to serial machines, greater stiffness by nature of strut arrangement and good force and speed ratio through the entire machine's workspace [3].

D. Electromagnetic Modeling and Subsequent Structural Analysis for ITER Core CXRS Upper Port Plug Diagnostic Structure

Anatoly et al. (2011)

EM forces on main plug components have been calculated and main integral mechanical moments are represented. Two external contracts on independent global EM models were launched and are being successfully benchmarked against the FZJ model. In support of the CXRS design its components are structurally analyzed under EM loading. Four different approaches to calculate EM loads for detailed structural models have been used and are described. One of them, called an "express" analysis, allows a prompt choice between different design solutions. They were concluded that the "express" approach has been used for a rather detailed EM stress analysis of the fast shutter. The shutter design changes were proposed and implemented. The "air" elements, which should fill gaps between assembled conducting parts in the electromagnetic FE models, are neglected in this approach. This may save up to 90% of time for building and calculating complex EM models [4].

E. The Application of Polymer Composites to the Table-Top Machine Tool Components for Higher Stiffness and Reduced Weight

Sung-Kyum Cho et al. 2011)

Small machine tools have the inevitable drawback of low structural stiffness caused by a low load-carrying capacity of bearing components. Therefore, mass reduction of the components is advantageous to ensure high performance of the machine tools. In this study, a small table-top machine tool structure was designed and fabricated by using carbon/epoxy composites and resin concrete to reduce the weight of the structure, and enhance the structural stiffness and damping capacity. The types of composites and stacking sequences for fibrous composites were determined by finite element analyses with respect to structural stiffness and damping capacity. The newly fabricated hybrid structure showed a 36.8% weight reduction and the structural stiffness was increased by up to 16% based on our modal analysis results with higher damping capacity [5].

F. Structural Analysis and Optimization of Press Brakes

Pedro Coelh, et al. (2005)

The bending process in Press Brakes is established using Timoshenko beam theory. Expressions for the work piece bending error are derived that explicitly consider the influence of shape, dimensions and initial deformation of the machine structural components on its bending accuracy. The minimization of the bending error is formulated in terms of optimization problems that are solved numerically using a genetic algorithm It is studied the introduction of an optimized initial deflection for each bending length and load value is essential in a conventional Press Brake, where the bed and ram supports are located in the machine columns. This is an interesting solution if it can be computed and introduced in an automatic way each time the bending conditions are changed. The methodology presented in this paper proved well suited to analyze the structural behavior and bending precision of existent Press Brakes. The methodology presented in given paper proved well suited to analyze the structural behavior and bending precision of existent Press Brakes and should be useful to optimize their performance and assist in the design of new solutions [6].

G. Analytical Models for High Performance Milling. Part I: Cutting Forces, Structural Deformations and Tolerance Integrity

E. Budak (2006)

The analytical milling force, part and tool deflection, and form error models are presented, and their application in improving the performance of the process is demonstrated. The milling process is considered due to its complex geometry and mechanics; however similar modeling methodology can be applied to other machining processes such as turning. On the other hand, the models can be extended to more complex milling processes such as ball end and five-axis milling. These models provide general information about the relations between the process performance and the process parameters [7].

H. Application of a Two-Level Optimization Process to Conceptual Structural Design of a Machine Tool

Bi-Chu Wu et al. (2000)

The objective of the research done by author is that the principal dimensions of all the structural parts can be determined, minimizing the weight of the machine while maintaining sufficient stiffness. Propose a modified two-level optimization approach for the concept design of a machine tool. The lower level of optimization is applied to each structural part of the tool and the upper level to the machine tool as an integrated system. When frequent modification of design specifications is required and re-use of previous design experience is preferred, the proposed approach is efficient because of the approximation functions used [8].

I. Integrated Hydrodynamic–Structural Analysis of Very Large Floating Structures (VLFS)

Hideyuki Seto et al. (2005)

The Integrated and well-balanced approaches to hydrodynamic and structural analyses are indispensable for the detailed design of actual VLFS. We have developed a 3D hydro elastic, response analysis method, based on a modal approach, which incorporates NASTRAN and a new hybrid, finite/infinite element domain decomposition method for water waves. It has been successfully applied to realistic Mega-Float models both in open sea or protected by breakwaters and shore, and with variable bottom topography [9].

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J. Structural Bionic Design and Experimental Verification of a Machine Tool Column

Ling Zhao et al. (2008)

The machine tool column with stiffening ribs inside was designed using structural bionic method. After the lightening effect was verified by finite element simulation, scale-down models of a conventional column and a bionic column were fabricated and tested. Results indicate that the bionic column can reduce the maximum static displacement by 45.9% with 6.13% mass reduction and its dynamic performances is also better with increases in the first two natural frequencies. Structural bionics offers a new method to improve the conventional design of machine structure. Based on mimicking biological structure and rib parameter [10].

IV. Existing Design Structure of the EDM Machine

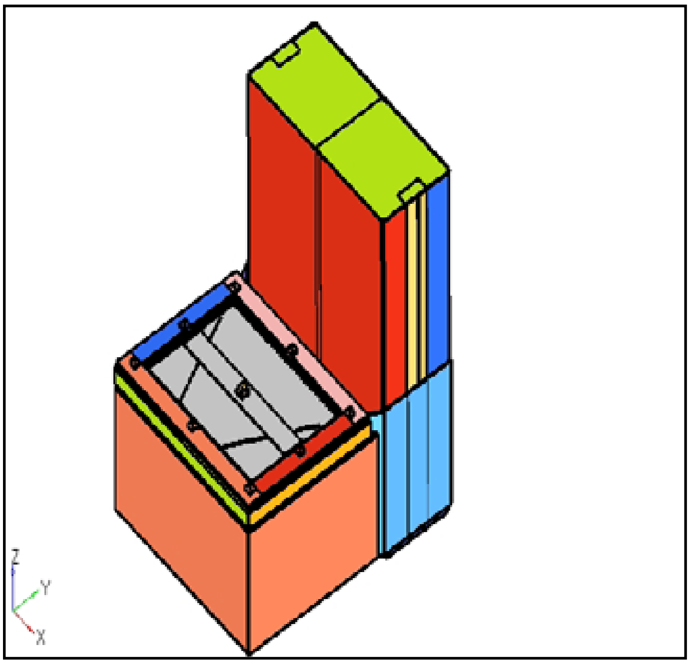

Fig. 9: Structure of EDM Machine

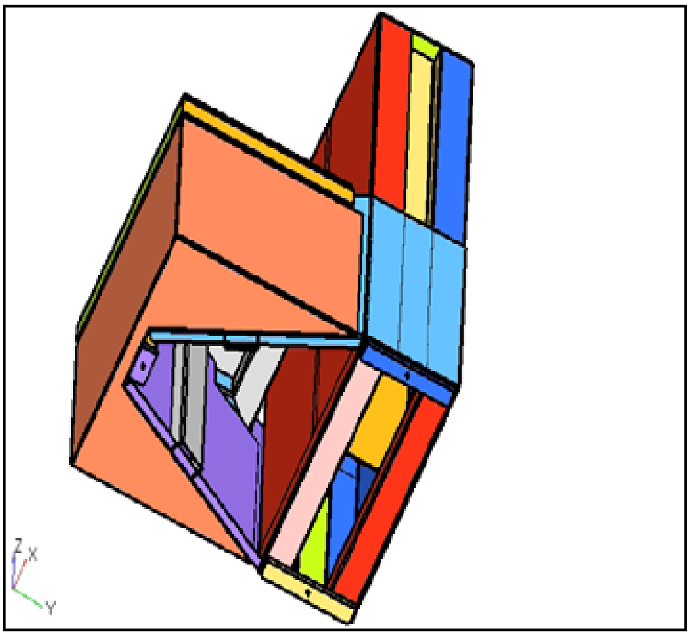

Fig. 10: View From the Bottom

V. Problem Associate With Existing Structure

Existing structure having adequate strength as per requirement but that structure will be modified by considering reducing the material ultimately cost of structure by using modified design and CAE technique. The new design needs to be reviewed in the light of structure strength while subjecting the components.

A. Objectives

The main Aim of project work is to "Simplification of the Engineering Design of the frame (structure) while offering scope for modularity over the upcoming versions".

1. Evaluate the existing design for strength while keeping in view the function of the frame
2. Modeling and analysis of existing EDM structure.
3. Develop the new structure by changing geometry that is size and shape.
4. Analyze the new design using CAE tools.
5. Compare the new design structure with existing structure for evaluating the result.
6. Proposing the optimized EDM machine structure.

VI. Approaches, Techniques and Methodology

Analytical approach using Empirical formulae and relations:-

This is typically a traditional method of addressing the given problem while considering the effects of unbalanced forces on the structural member whose construction is manifested or represented by any of the standard types of load carrying members for which the empirical formulae has been established. This forms the basis of `Machine Design' with principles of Applied Mechanics at the core of the subject matter.

A. Analysis using CAE tools :-

This is a modern approach and is fast becoming the standard or de-facto method with the advent and penetration of software in the CAE domain. The assembly consisting of individual parts is modeled in the software environment and the requisite material properties, boundary conditions and constraints are applied. The software is then allowed to `solve' the structure for strength for the load test parameters of interest.

B. Experimentation :-

This refers to physical experimentation. This involves generating prototypes and testing the same after `setting up' the test conditions. The `in-process' parameters, variables are typically monitored using mechatronics interfaces. The data so collected is later interpreted and the problem diagnosed.

For the subject project work, the techniques would engage software tools like CATIA V5 (for Machine Design) – with output in IGES format & NASTRAN or ANSYS (For Structural Analysis)

VII. Methodology

1. Identifying and documenting the constraints for the existing Machine Design (space, physical properties of materials, etc)
2. Conceptualizing and generating a geometry using CAD for the structure using existing design for reference data
3. Exporting the geometry in the form of IGES or STEP file
4. Importing the geometry for the assembly in the pre-processing environment for applying boundary conditions and constraints.
5. Solving for the model using Nastran or Ansys for Modal Analysis to identify the resonating natural frequencies (up to 4 modes)
6. Solving the structure in the linear static analysis mode
7. Viewing the results with the `graphs' and `animation' (during

post-processing)
8. Review and modification for the Design while pursuing the objectives
9. Analysis for the modified Design.
10. Interpretation of the results.
11. Revising the geometry for feasible number of iterations while anticipating improved results.
12. Comparing the new Design with the existing structure.
13. Recommendations upon consolidation of the Project Work.

VIII. Details of Machine Structure

A. The Specifications for the Machine are as Follows:
1. Nearly all the parts in the machine either have material as grey cast iron for castings and Mild steel for sheets and plates.
2. The maximum job weight on the t-slot worktable is 3500 kg.
3. The X, Y & Z travel of the machine is 650x550x250 respectively.
4. The empty volume of the work tank which holds dielectric material is 1250 liters.
5. The machine is supported on ground with the help of 8 nos. of mounting pads as shown in the model.
6. The job is stationery while the machine head moves.

B. Loading Conditions:
Mass = 542.58 Kg

Table Assembly has been analyzed for the following loading conditions:
1. Static Load of 3500 Kg of the Job on it and the weight of T-Slot 224 kg, This is equally distributed on each 8 pads.
2. Remote Load of the Tool Machine which is assumes to be 800 kg.

C. Material Properties

Structural Steel > Constants	
Density	7.85e-006 kg mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

D. Assumptions:
1. There is bonded face connection between all bodies.
2. Various positions of Tool machine is not consider.
3. Material of all the parts in main assembly, including the tool machine and machining part is assume to be Structural Steel

IX. Possible Outcomes From the Work
It will perform structural analysis of table assembly. Stress analysis will carry out to evaluate structural integrity of the Table Assembly under given loading conditions. The model of this EDM machine under review is now undergoing changes to the structure. The new design needs to be reviewed in the light of structural strength while subjecting the components/ sub-assembly to Analysis using CAE. Simplification of the Engineering design of the frame (structure) while offering scope for modularity over the upcoming versions.

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