

# Design and Optimization of Robot Support Structure for Inverted Operation



Santosh H.Pawar, G.R.Selokar

**Abstract:** In this paper we present a new method for optimization of robot structure for inverted operations, as rapid development is seen in the fields of robotics, robots are being designed for different operations. Robots move with higher speeds & create inertia loads, & during emergency operation there is sudden spike in load & the robot support structure needs to accommodate these loads. In this project we analyze the robot support structure. Robot support structure means the main supportive member which is the base of the robot and it gives support as well as stabilization to the robot. 3D geometry of robot support structure is designed as per dimension in the workbench by using ANSYS 16.0. Upon applying boundary conditions such as robot weight, forces applied to his body and moments applied to the structure of the robot support. Following this, stress analysis, von-mises stress, total deformation of the structure of the robot support.

**Keywords :** Finite Element Analysis, Vibration analysis, Material classification for vibration properties, Non Linear FEA, Robot Pedestal design.

## I. INTRODUCTION

Automation has been rising in the industry for a few days now. Automation is a combination of technologies that result in process and computer operation with no significant human intervention and achieve superior performance than manual operation. Robots are used in many industrial automation projects to develop solutions such as machining, pick & position, etc. Robot word the Czech novelist pronounced in 1920. The word robot comes from the Czech word robota, the meaning of which is to do work or compulsory duty aggressively. Robot can be reprogram, multifunctional manipulator designed to move material, pieces, & tools & accomplish a variety of tasks. In simpler words, it means performing a variety of tasks in less time as a human being and faster in work. To keep the work piece during service, it requires a specialized frame. Precision made robot table and robot platform are standard equipment of capital and are needed in the manufacturing companies of high technology today. Robots are designed to perform complicated tasks for specific functions in a custom environment. Typically, each robot requires its own custom-made robot pedestal, custom-made to size and strength to ensure immobility while supporting the robot firmly.

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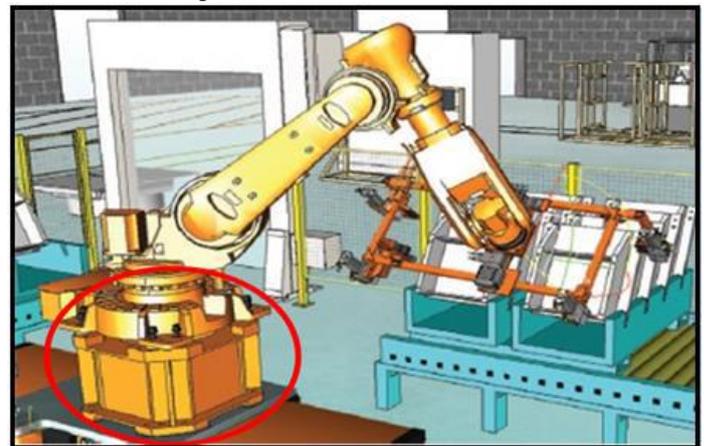
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The robot base is the substructure of any robot that should maintain the robot's motion stable under each type of load. Due to the importance of the structural base frame, the structural base frame design must be optimized using structural optimization methods in terms of stability, strength, weight and material utilization.

From figure given below we can see the location or the structure of robot pedestal.



**Fig. 1: Robot Pedestal**

Robot includes a complex supporting system to carry the work piece correctly during the operations. Precision made robot table and robot platform are standard capital equipment and are needed in today's manufacturing companies with high technology. Most robots are designed to perform high-level tasks for specific functions within a custom environment. Due to dynamic forces, robotic construction is difficult. The force amplifies itself during the process of an emergency stop. The robotic structure should not fail to withstand during stops, so it should be properly designed to take transport load into consideration. The project's aim is to design and analyze the robotic pedestal and optimize the pedestal's structural aspect.

## II. LITERATURE SURVEY

X. Liao (2010)[1] works on the basis of the welding robot in this project. By using ANSYS-10.0, the natural frequencies, robot welding base mode shapes and robot dynamic analysis were discovered. Model analysis findings are, the base's upper edge & tail edge has a greater vibration that can be tired and harmed. At the 7th natural frequency, they find a peak amplitude of 39,249 Hz. The results are fast and reliable by using ANSYS -10.0 code

G. Chung et al. (2010)[2] This work is based on heavy duty industrial robot design. After checking or figuring out the static & dynamic analysis of heavy duty applications, i.e. at a weight of 600kg(max).

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Finally, they compare the results of both the experimental and the FEM. We were studied the elastic rigid dynamics of the body to measure the robustness of the parts of the robots during robot movement. Results show that the frequency of multi-body research reaction forces is 6.67Hz and 18 Hz was the normal frequency.

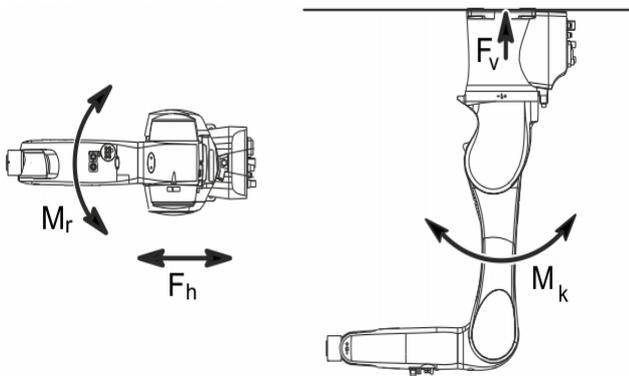
In this research, M.H.F.Dado et al. (2000)[6] are investigating the dynamic response of a 2-R planer robot with flexible joints. They are the drive system's template servo stiffness & surface damping. This study concludes that servo damping plays a significant role through machine dynamic behaviour. W. Shijun et al. (2002)[7] are focusing on the optimum robot structure model. Optimal design I d does not automatically change it requires automatic modification and repeated calculation. To this end, they used ANSYS software's APDL language to generate an optical control program that is used to optimize the automatic running process and improve the optimum efficiency.

J.H.Varma et al. (2015)[8] work on the robot weapon support structure for light vehicle door frame welding purposes. First, with their features & implementations, they model and evaluate the welding subsystem. They design a welding gun support structure that can move quickly to multiple locations, even causing 1.5-fold gravity force in tunes.

### III. ROBOT SPECIFICATION & DISCUSSION

#### A. Specification

We are designing support structure for kuka KR 6 R700 six robot for with following load condition.



**Fig2. Load Condition**

Below table depicts the force/torque/mass of our proposed specification.

**Table- I: Load Condition for Force/torque/mass**

Type of load	Force/torque/mass	
	Normal operation	Maximum load
FV = vertical force	FV normal = 967 N	FV max = 1297 N
FH = horizontal force	FH normal = 1223 N	FH max = 1362 N
Mk = tilting moment	Mk normal = 788 Nm	Mk max = 1152 Nm

Mr = torque	Mr normal = 367 Nm	Mr max = 880 Nm
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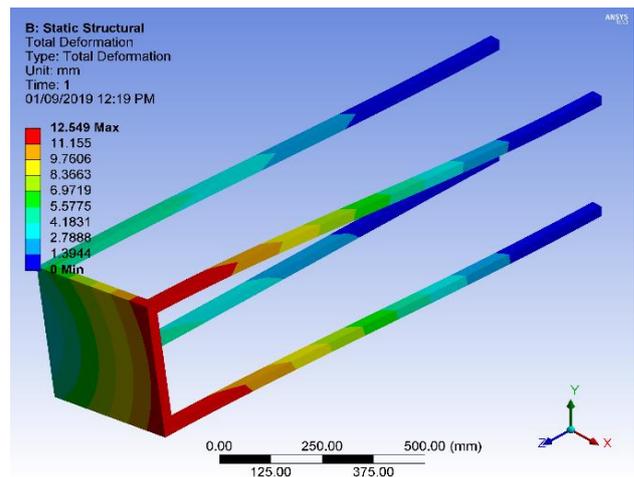
**Table- II: HEX Dominant Meshing**

Element Size	Node	Total Deformation (mm)	Stress MPa
15	19941	12.548	142.63
14.4	31500	12.548	163.54
10	40000	12.549	169.72
9.95	62477	12.554	172.71
9	68237	12.554	174.88
7.5	80000	12.555	176.39
7.49	115000	12.556	186.13

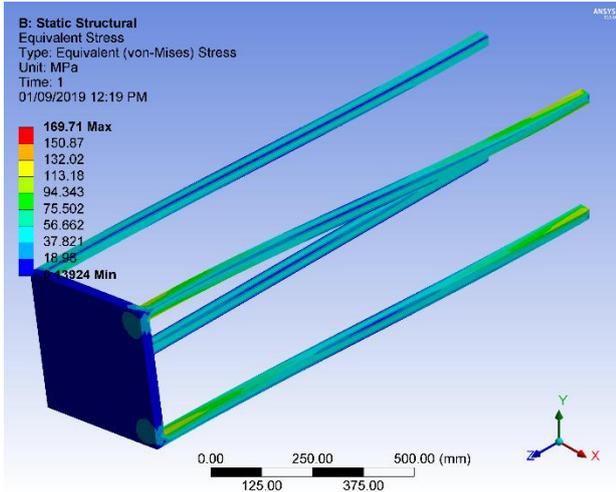
**Table- III: Tet Element Meshing**

Element Size	Node	Total Deformation mm	Stress MPa
30	24000	12.38	124.06
25	31326	12.371	133.26
17	40105	12.408	131.25
12.5	62000	12.748	157.63
11.5	72000	12.489	169.570
11.35	78000	12.513	160.74
9.5	109000	12.526	169.28

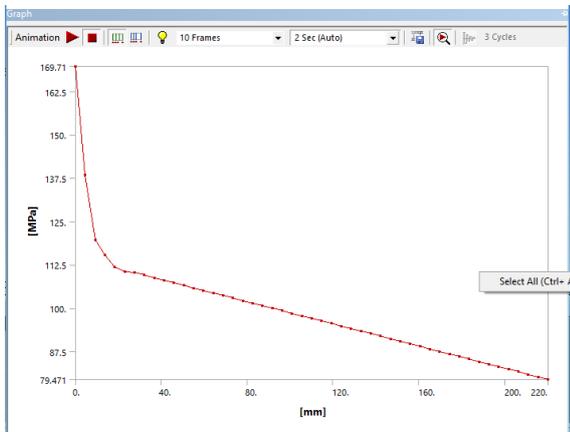
Table II and Table III shows the value of stress obtained based on the element size. we have observed that the convergence point at 40,000 node in Hex Dominant, there is stress riser at 40,000 Nodes. By using Path operations we have to find that the actual stress is 125 MPa, so we have to select 10 mm Element size and hex Dominant meshing.



**Figure 3: hex dominant meshing 10 mm element size (deformation)**

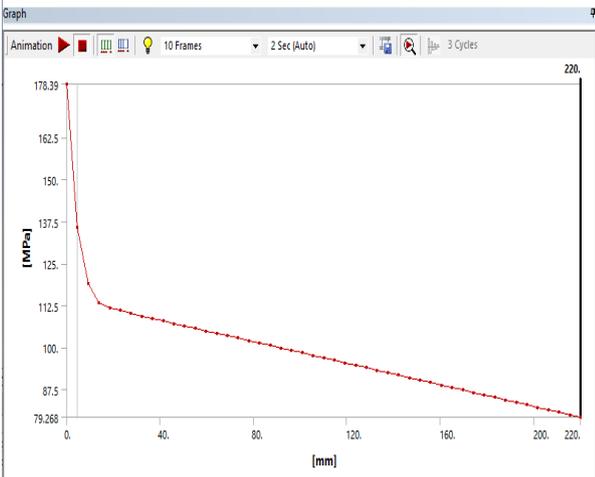


**Figure 4: hex dominant meshing 10 mm element size (stress)**



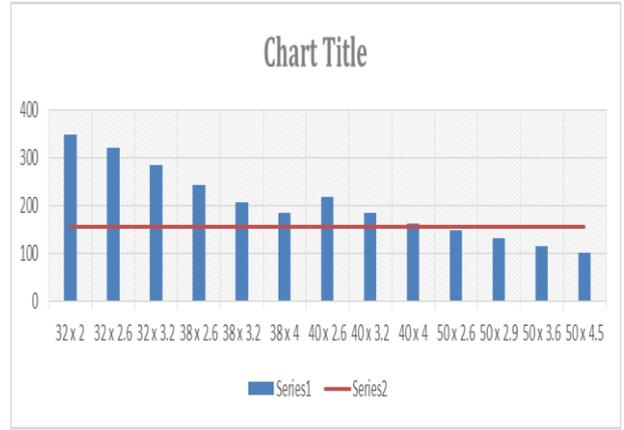
**Figure 5: Path operation for 10mm hex dominant**

**B Non linearity**



**Figure 6: non linearity checking path operation with substepping 10**

For checking the Geometric Non-Linearity we have set the 10 sub stepping's by opting large deflection, and we are getting same stress around 125 MPa. Figure 3,4,5,6 depicts the demonstration.



**Figure 7: Graph of stress vs Leg size**

Chart title in figure 7 shows us that the Yield strength of selected material is 310 MPa, by considering FOS 2, we have to select leg size depending upon the stress values, and the model with stress below 155MPa is selected. As we can see from the chart 50X2.60, 50X2.90, 50X3.6, 50X4.50. is perfect so we are selecting this.

For finalization of load position and type of structure two cases are considered as follow.

Case-I:  $F_x = 1362N$ ,  $F_z = -1297N$ ,  $M_y = 1152 NM$ ,  $M_z = 880NM$

Case-II  $F_y = 1362N$ ,  $F_z = -1297N$ ,  $M_x = 1152 NM$ ,  $M_z = 880NM$

LEG SIZE	A TYPE			
	CASE 1		CASE2	
	STRESS	deformation	STRESS	deformation
50X2.60	59.283	0.40947	41.247	0.25339
50X2.90	44.765	0.37017	30.914	0.22917
50X3.6	38.282	0.30356	27.17	0.18839
50X4.50	31.292	0.24847	22.404	0.15464

LEG SIZE	V TYPE			
	CASE 1		CASE2	
	STRESS	deformation	STRESS	deformation
50X2.60	58.577	0.36352	38.143	0.20752
50X2.90	44.327	0.32819	29.936	0.18688
50X3.6	37.759	0.26867	26.076	0.15331
50X4.50	32.103	0.2193	22.308	0.12517

For further testing we select case I and analysis is done as shown in figure 8 and figure 9.

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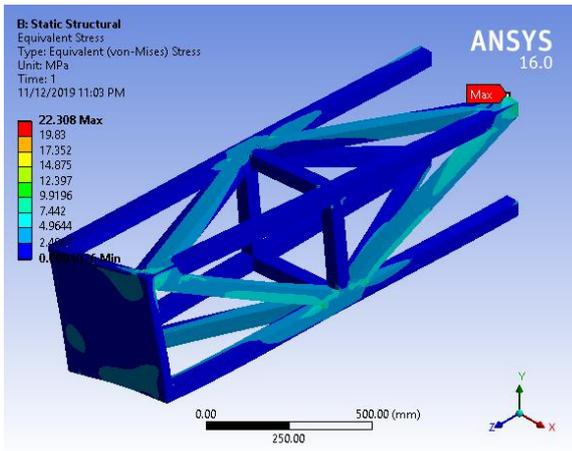


Figure 8: v type structure

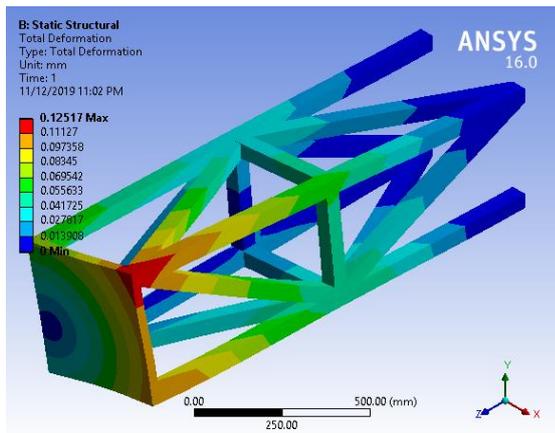


Figure 9: v type structure

After analysis we select V type structure and its comparison is done with stress graph.

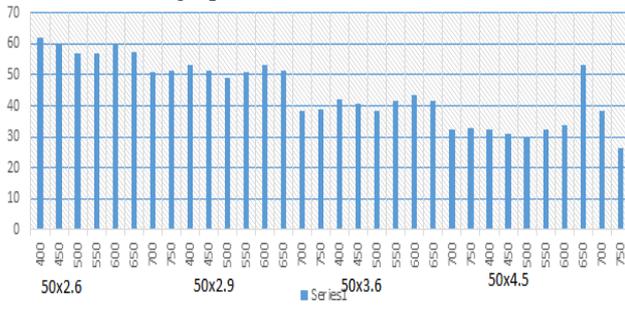


Figure 10: V type structure lenth of horizontal srtructure vs stress graph

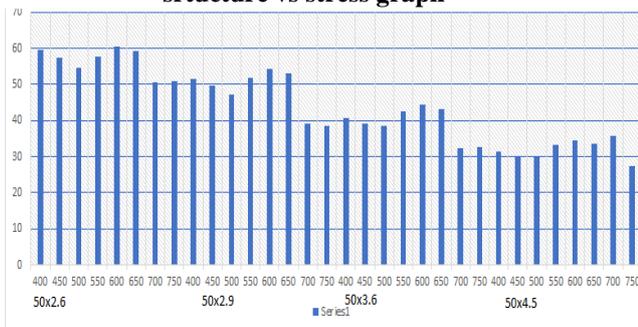


Figure 11: Graph A type structure lenth of horizontal srtructure vs stress graph

The results obtained are shown in graphs in above figure 10 and figure 11 which helps for Selection of Horizontal A type & V type Stress deformation.

From above chart, we are selecting the optimized stress and deformation structure selected, among those V type is selected with leg size 50 X 4.5.

Horizontal V and A type stress is done as shown in figure 12 and figure 14, and deformation in figure 13 and figure 15.

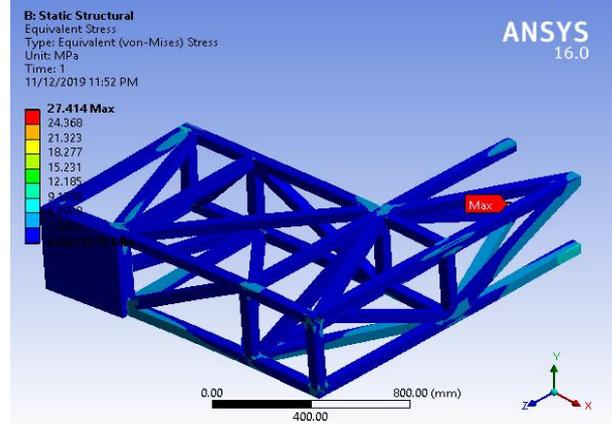


Figure 12: Horizontal A type Stress

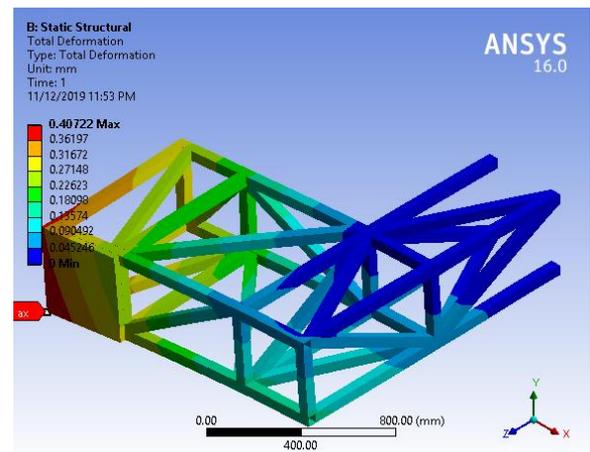


Figure 13: Horizontal A type deformation

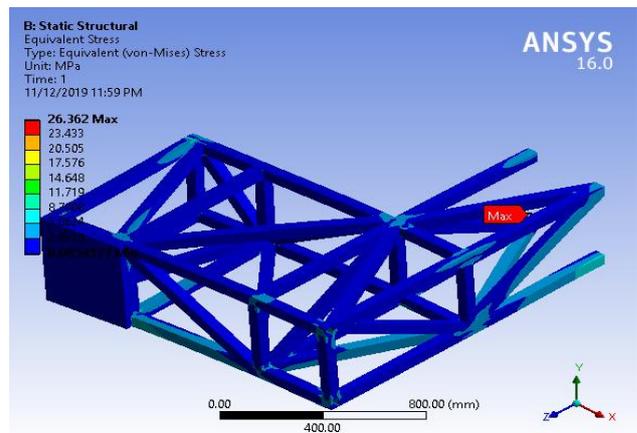


Figure 14: Horizontal V type Stress

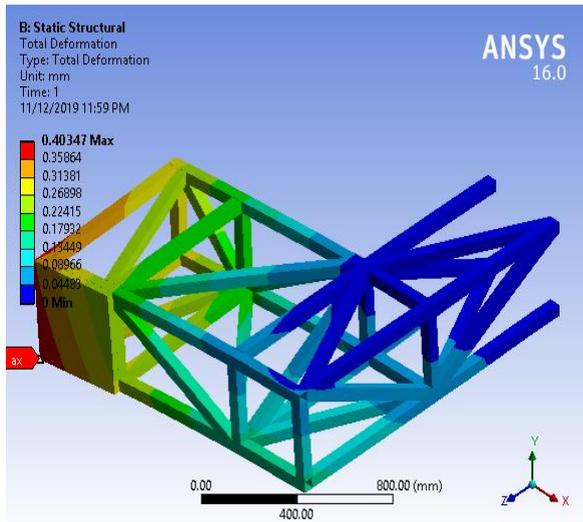


Figure 15: Horizontal V type deformation

#### IV. CONCLUSION

For robot mounting An effort is taken for the Design and Analysis of the Structural base frame for robot mounting. Initially Design of structural base frame is optimized by using sizing method of structural optimization method. New optimized structural base frame CAD Model is developed in ANSYS workbench. Static and dynamic analysis results are carried out by Ansys 16 Software and Developed optimized design of structural base frame for robot mounting. The results obtained are showing that the the V type supporting structure is optimized.

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