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Stress Variation and Total Deformation Study Of 3P-2R Industrial Manipulator all through its Work Cycle

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Abstract: The structural analysis focuses on the changes occurring in the behavior of a physical structure under observation when provided with a force or in case of structures, load. Now if this load is quasi (very slow), the inertia forces from the basis of Newton's first law of motion can be neglected and the analysis becomes static. Stress analysis of manipulator is the application of various loads to various links within sustainable limits and checking stresses occurred in the links. The stress analysis is done by ANSYS workbench. Stress variation study gives results of maximum stress value that a particular material can bear for a given manipulator at different positions.
Keywords: Manipulator, Kinematics , Home position , Prismatic , Revolute , End - effector .

I. INTRODUCTION

Robots and manipulators are complicated mechanical systems with highly non linear dynamic behavior. Kinematics deals with the basic geometry of the linkages. If we consider an articulated manipulator as a device for generating position and orientation, we need to know the relationships between these quantities and the joint variables, since it is the latter that we can easily measure and control. Structure analysis is carried out in both static and dynamic condition. Joint limits, material for links can be determined using stress analysis. We define whole body postural control as the property of being able to control the angle of all links of the robot (including the base) relative to the ground. Under these conditions, we determine what forces at the end effector. The orientation of the base of one robot is fixed so that it is perpendicular to the ground. The dynamically stable robot is free to orient its base with respect to the ground. The difference in the range of forces that each of these robots can apply at their end effectors is then determined. The robot model we choose for static analysis is 5 DOF manipulator (3P-2R manipulator)which has 3 prismatic joints and 2 rotary joints. Stress variation along link length is finding out under particular load at different positions using ANSYS. Stress variation analysis gives maximum stress value a given manipulator can bear under applied load. For given stress value we can determine joints limits and suitable material for given manipulator.

II. METHODOLOGY

For the static analysis we choose 5 DOF manipulator having 3 prismatic joints and 2 rotary joints. Stress analysis is done in ansys. Manipulator has base frame (20mm*20mm) and 5 links (100mm*20mm/kl). We calculated the maximum stress value for a given manipulator at different five positions.1)Homeposition 2)End position 3) 3 intermediate position. For given manipulator we selected stainless steel as a base frame and for links. Following fig shows the equivalent stress analysis and strain analysis along link length when load is app ,l lied at end of end effector. For analysis of various links we have used Ansys Workbench 14.0 version.
Material selected – Stainless Steel

SR.NO	PROPERTY	VALUE	UNIt
1.	Density	7750	Kg/m^3

2.	Poissions ratio	0.31	
3.	Tensile yield strength	2.07e^8	Pa
4.	Compressive yield strength	2.07e^8	Pa

Catia model PPPRR Manipulator using Catia V2R20 is shown below :

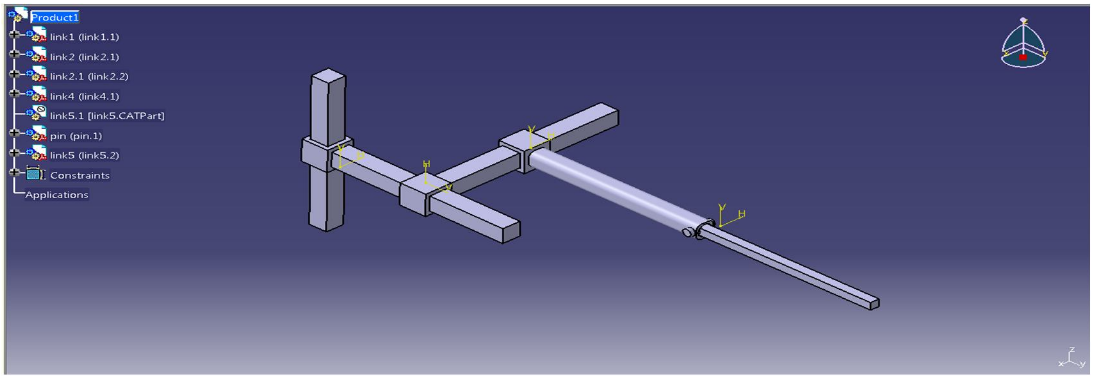


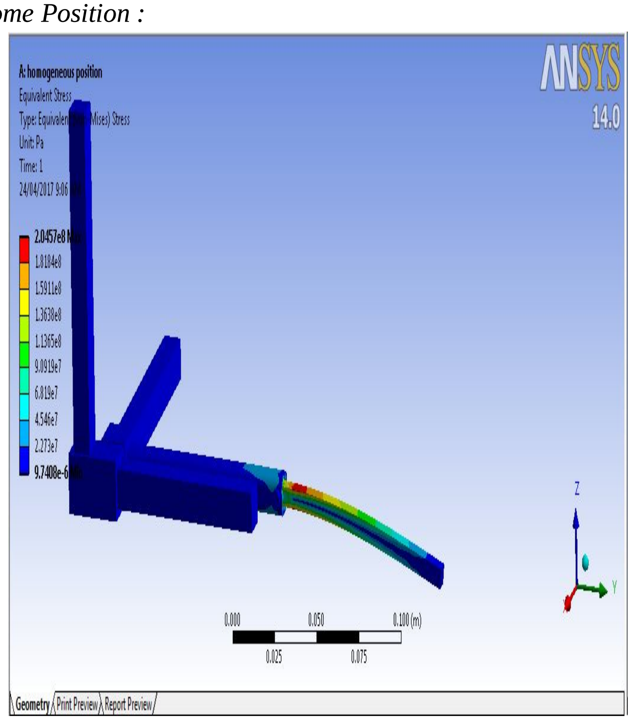
Figure 1. PPPRR Catia Model.

A. Different Distances of various Links from Home Position are as follows

SR.NO	POSITION	DISTANCE FROM HOMOGENEOUS POSITION
1	Homogeneous Position	0.00 mm
2	Intermediate Position 1	25.00 mm
3	Central Position	50.00 mm
4	Intermediate Position 2	75.00 mm
5	End Position	100.00 mm

B. Results Evaluated from Analysis in Ansys Workbench 14.0 are as Follows

1) Home Position :



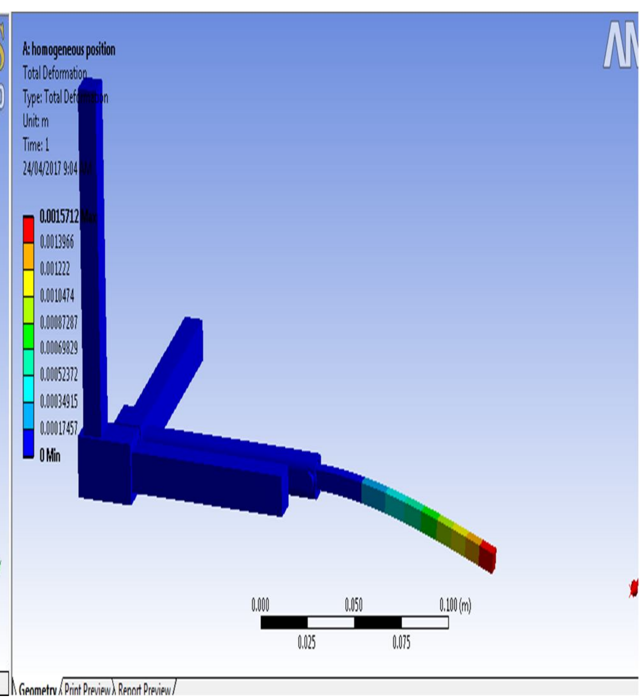


Figure 2. Equivalent Stress

Figure 3. Total Deformation

2) Intermediate position 1:

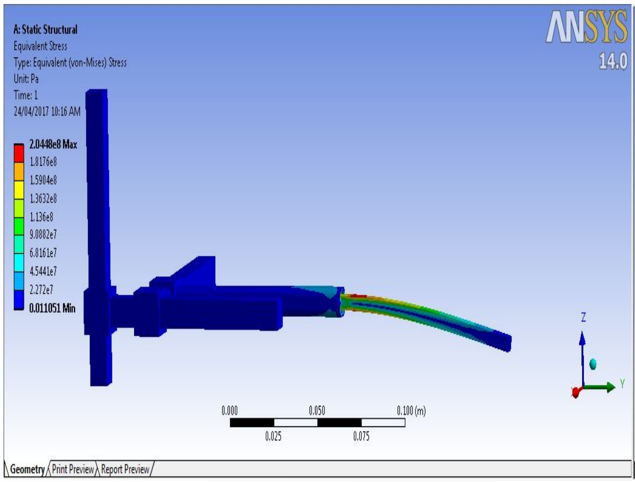


Figure 4. Equivalent stress

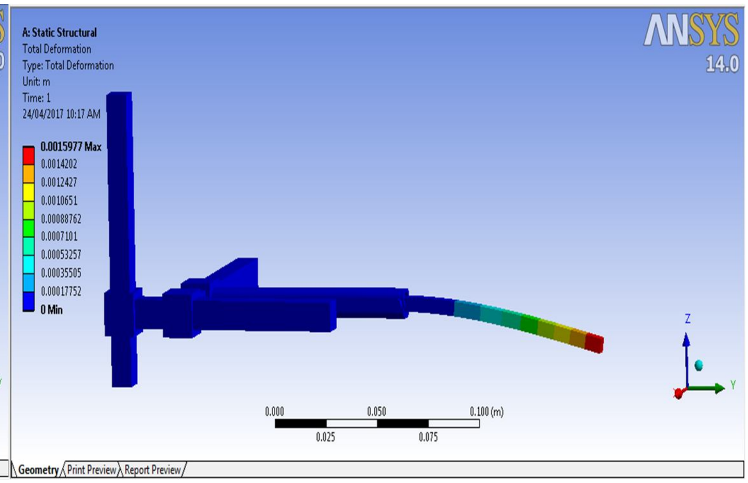


Figure 5. Total Deformation

3) Central Position:

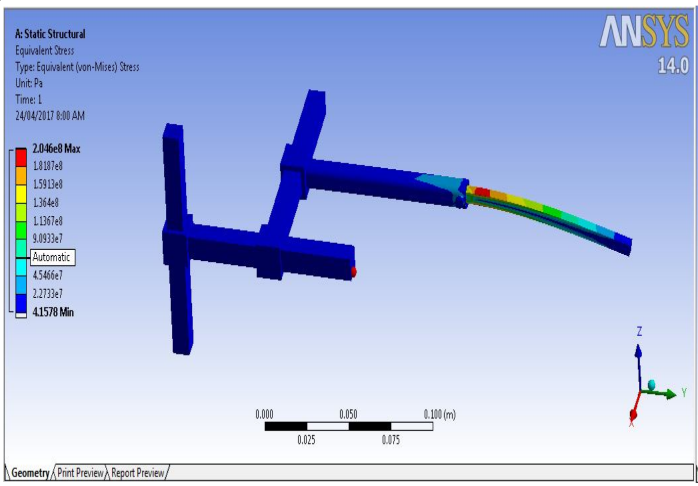


Figure 5. Equivalent Stress

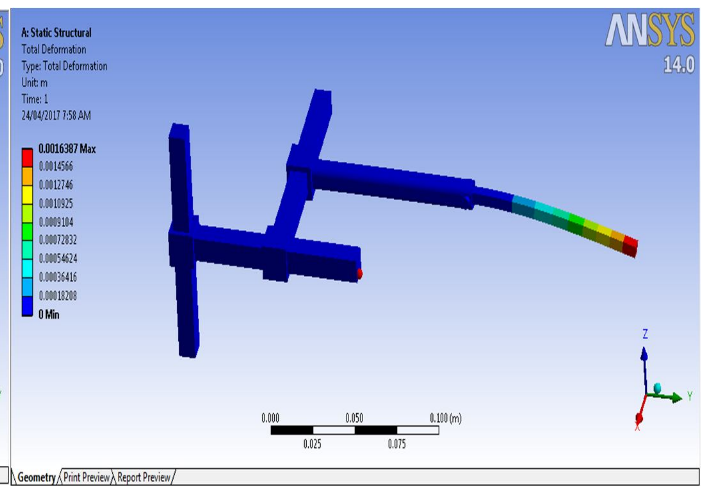


Figure 6. Total Deformation

4) Intermediate Position 2:

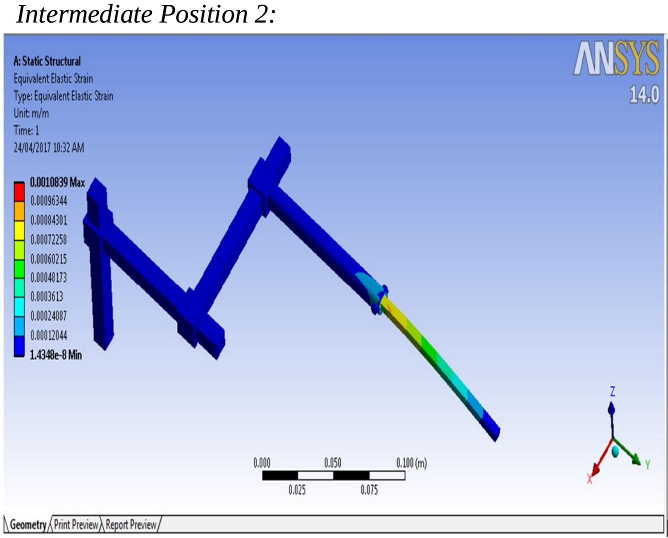


Figure 7. Equivalent Stress

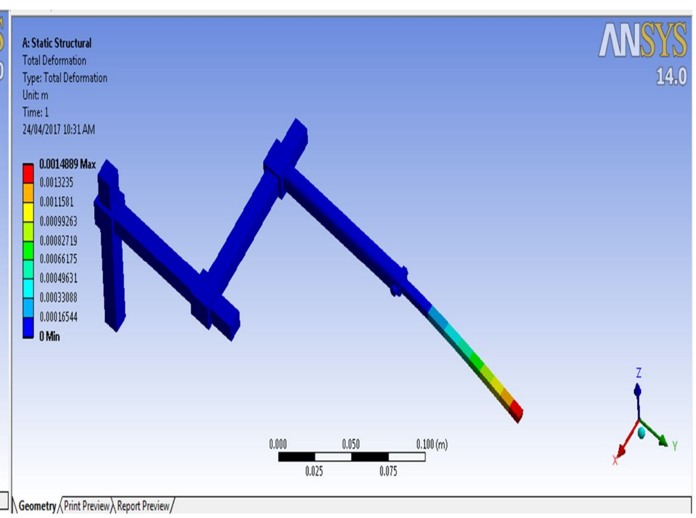


Figure 8. Total Deformation

5) End Position:

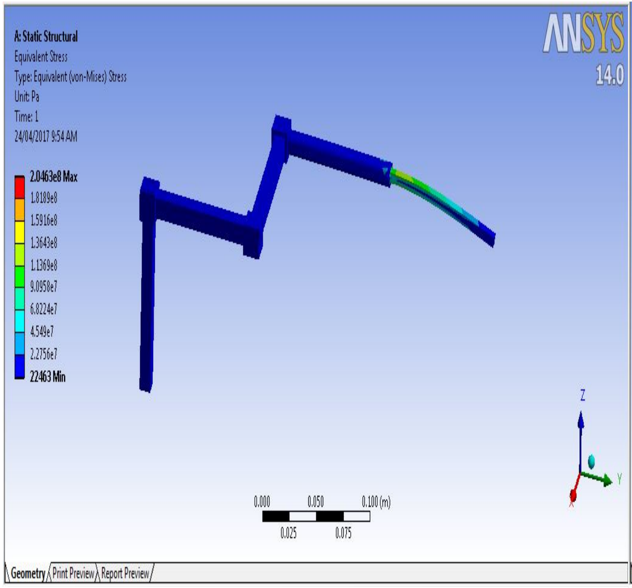


Figure 9. Equivalent Stress

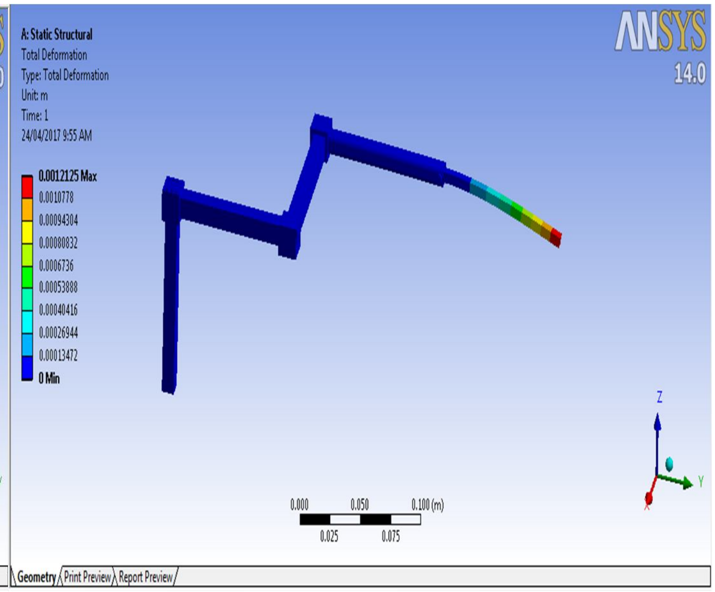


Figure 10. Total Deformation

III. RESULT TABLE

Following table gives the value for equivalent stress analysis and strain analysis and maximum stress that a given manipulator can sustain at different five positions.

SR.NO	Manipulator positions	Equivalent stress analysis (Pa)	Elastic Strain analysis (m/m)	Total deformation (m)	Max. Load manipulator can sustain (N)
1.	Home position	2.0457e8	0.00102	0.0015712	44
2.	Intermediate position 1	2.0448e8	0.0010259	0.0015977	44
3.	Mean position	2.046e8	0.0010266	0.0016387	44
4.	Intermediate position 2	2.0461e8	0.0010839	0.0014889	38
5.	End position	2.0463e8	0.0010822	0.0012125	30

IV. SUMMARY

Variation of stress value at different position and maximum value of stress that a given manipulator can sustain at different five positions is carried out. After plotting a table we find out that up to mean position manipulator can sustain maximum 40 N load. At 4^{th} position maximum stress value a manipulator can sustain is 38N. And at end position a manipulator can sustain maximum 30N load. That means as we go upward along the link length the stress value that a manipulator can sustain is constant up to mean position. As we go above mean position maximum stress value that a manipulator can sustain goes on decreasing.

V. CONCLUSION

In this way, from stress variation study we can find out variation of stress along link length at different positions. Also from this analysis we can find out joint limits for given manipulator. We can select a suitable material for particular stress under particular load depending on applications. Hence maximum load can be sustained by PPPRR robotic manipulator is 30 N with safe design.

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