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Simulation, Analysis and Design of Swing Massager Morning Walker Mechanism

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ABSTRACT

Traditional “build and test” design methods are now too expensive, too Time consuming, and sometimes even impossible to do. CAD-based tools help to evaluate things like interference between parts, and basic kinematic motion, but neglect the true physics-based dynamics of complex mechanical systems. Multi body system simulation is mostly used in combination with other studies as it not only provides simulation of kinetic behavior, but also shows the loads for individual components. The results from a multi body system simulation are incorporated into a stress analysis with the aid of Finite Element analysis. Swing massager morning walker mechanism was first designed in CATIA V5. Later kinematics motions were verified using CATIA Simulation Work bench and also compared using ADAMS software. By using the ADAMS, the dynamic parameters of 3-D swinging mechanism were analyzed and the simple finite element model is established on the basis of these parameters in ANSYS 14. The main focus of this paper is to analyses behavior of mechanism in different loading conditions and also results are verified by analytical equations. A good design of mechanism must be effective in least time of designing. The mechanism shall not work effectively but also be reliable in its strength and durability yet not over-design. In order to optimize analysis for swing massager mechanism, first we need to simulate the Multibody dynamics analysis for load and stress predictions. Therefore In this paper, we introduce methodology to simulate and analysis the whole contact range of exercise mechanism Multibody dynamics analysis by using ADAMS and ANSYS 14 softwares.

Keywords: CAD, Simulation, Finite Element Analysis, Swing Massager, ADAMS

Abbreviations: ADAMS-Automatic Dynamic Analysis of Mechanical Systems, CAD-Computer Aided Design

1. INTRODUCTION

Swing Massager moves the entire body, most importantly, it is moving the largest muscle group in the body i.e. your legs. It is an alternative for morning walk and it is a ergonomically designed gives relieve from various diseases. It increases oxygenation of blood and cell metabolism by giving the left & right swinging movement from toe to head like goldfish swimming. It is respiratory oxygen process for 10 to 15 minutes is equal to 10,000 s of brisk walk and 8 km in terms of benefit to improve health. The mechanism is used to convert rotary motion of d.c motor to sliding motion of the mechanism which was designed (Zhou, D., Sun, Y., Cheng, L, 2003) the 3D Model in CATIA and imported it into the Kinematics simulation software ADAMS. Due to that sliding motion of the mechanism whole body of man starts vibrating and any person doing exercise feel comfort (Alejandro E. Albanesi, 2007). The simulations of various mechanisms have been frequently designed using ADAMS since several years (Rong-Fong Fung, Chin-Lung Chiang, 2009).

1.1. Simulation

Multibody simulation evaluates the strength, stability and service life of components under mechanical or thermal boundary conditions, thus allowing precise analysis of stresses, for example, which can then be optimized in a targeted way (Shabana.A.A. 1997). During the actual working different stresses are induced in links, main body that can be analyzed by using ANSYS 14 software and basically model was designed by using CATIA V5 Software and results were verified by using ADAMS software (Retheesh Kumar, Akash Mohanty, 2013). By ADAMS software we get different forces on different joints and different links. The overall weight of the mechanism can be optimized and obtained different stresses on the mechanism using ANSYS.

1.2. Swing Masseger

Lie on your back in front of the equipment and place both your legs on to the grooved footrest of the equipment. Remember to adjust your legs in a manner that both the ankles are placed ahead of the grooved footrest. Anthropometrical data is used to determine the size, shape and/or form of equipment. The suggested time for 1st time user is between 4-6 minutes. Increase the duration gradually to suit your body requirement up to 15 minute. Once the equipment stops after the pre-set time, remain calm with your eyes closed for a period not less than 1-2 minutes.

2. COMPUTER AIDED DESIGN

The Conceptual model has designed by using CATIA V5 software .It consist of main body having an adjustment for doing exercise swing motion is applied with the help of motor and link is joined with main body by revolute joint and it has joined with base which is fixed. During the modeling in CATIA V5 we used different tools like part design, assembly design (Figure 1).

3. MATERIALS AND METHODS

The material used for this mechanism is Structural Steel. The results we get by ANSYS14 and also we are verifying by analytical equations (Table 1).

3.1. Analysis using ANSYS

In ANSYS workbench we imported ASSEMBLY file from CATIA V5 in (.STP) format for analysis of Mechanisms. Got different results by applying boundary conditions, material properties and meshing conditions for improved results. As shown in figures below. We applied 25kg load is applied on main body which having support to do exercise. We get different results like wait of mechanism, principal stresses, von misses stress, strains, and deformations (Tables 1 & 2; Figures 2 to 9).

3.2. Simulation using ADAMS

Different aspects are taken into account during a multi-body system simulation and analysis: masses, moments of inertia, active forces and moments, and the interlink and contact conditions of individual elements (Li, J., Xiao, H., Hu, 2009). The model simulation produces oscillating movements and (mass) forces. The data acquired from the simulation can be used to further optimize system components and their interaction. During the analysis this model has been imported from CATIA V5 (.stp) format to ADAMS. The Multibody dynamics analysis gives the performance parameters like displacement, velocity, acceleration, force and torque etc. at time of swinging. The motion analysis was carried out for whole mechanism assembly (Tables 4; Figures 10 to 13). The details of joints used in simulation of swing massager mechanism are listed in table 4. By the above results we will easily understand the actual behavior of efficient mechanism.

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4. RESULTS

ADAMS Multi-body dynamics software enables engineers to easily create and test virtual prototypes of mechanical systems in a fraction of the time and cost required for physical build and test. (TALABA, D., BATOG, 2011) Unlike most CAD embedded tools, Adams incorporates real physics by simultaneously solving equations for kinematics, statics, quasi-statics, and dynamics. During the normal operation under 25kg of wait the different joints carries different loads during the normal operation with time. With the variation of time joints carries different loads are as shown in figures 14 & 15; Tables 5 & 6. A moment of 2.8 Nm has been applied at joint *R1* and running the simulation for 5 seconds with time step of 0.001. The model has been verified for 100 oscillations as per ergonomics required for morning walker successfully.

4.1. Analytical dynamics modelling

Different variables and forces acting on mechanism are explained below.

Let a=angular acceleration of link,

a_{cm}=Linear accretion of link

m=mass of the link,

Fp=motor force,

Cm=moment of inertia,

T=Torque of the motor

Initially we are giving motion to left link

∑Fx=Max -- (1)

Fx-Rx=MAx

Fx=Rx+MAx-- (2)

∑Fy=MAy

Fy-Ry=MAy

Fy=Ry+May--- (3)

T+Fxr1-Fyr2+Rxr1-Ryr2=Ia- -- (4)

By solving these three equations we get matrix representation.

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ r1 & -r2 & 1 \end{bmatrix} \begin{bmatrix} Fx \\ Fy \\ T \end{bmatrix} = \begin{bmatrix} Rx+MAx \\ Ry+May \\ Ia-Rxr1+Ry \end{bmatrix}$$

In this equations Rx and Ry values we will get by external torque applied due to motor but Fx and Fy are the unknowns

Rx and Ry are the perpendicular distance we get .

For example:

Fp is the external force due to motor

Fp acts 50N @ 90° (i.e. Angle between horizontal surface and Link)

Then FX=cos0*50=50N Fy=cos90*50=0N

On this basis we can calculate all forces are acting on machine frame.

5. DISCUSSION

ANSYS gives stress contour the maximum stress developed at contact locations and corner or edge of links. The maximum Von-Misses stress value for the combined loading is 1.81 MN/mm2. Due to high Stresses, it is recommended that filleting be incorporated on the sharp region of main body link. ADAMS gives Von-Misses stress value for the combined loading is 1.79 MN/mm2which is closer to ANSYS results. Hence ADAMS gives a convenient, rapid simulation analysis and testing of mechanism (Ryan, R.R, 1989). With testing and analyzing under the work loading conditions of the swing massager mechanism, we got the kinematic, dynamics, Multibody dynamics characteristics which describe different loads acting at each joints (Dr R. P. Sharma, Chikesh Ranjan, 2013). In this graph along the y axis von-misses stresses and along the x-axis nodes. On this result we conclude that results which we obtained in ADAMS are exactly equivalent to Ansys 14 are in safe limit (Figure 16).

6. CONCLUSION

The present findings thus, indicate that Simulation and Analysis of Swing Massager morning walker mechanism was done using CATIA V-5, ANSYS14 and ADAMS12 reduces the product development period and enhances the quality of the design. The results obtained were really very useful in analyzing simulation of Multibody dynamics of the mechanism designed. In actual cases, most of the problems involve Multibody system. Using these tools, engineers can evaluate virtual prototypes of complex physical problem and optimize designs for performance, safety and comfort, without the inevitable time-scale and cost risks in building and testing physical prototypes. Therefore, based on this paper, it is recommended to use above said softwares for designing and validating innovative products. Simulation delivers its greatest benefit at early stages in product development. Starting from the pre-development and conceptual design stages, which offer reliable calculations and analyses which advance development in the right direction. Further simulations are recommended with addition of friction in analysis of swing massager mechanism.

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I express our first and foremost panamas to his Holiness Dr.Channabasava Pattadevaru and Founder President, SVE Society Dr.Bheemanna Khandre. The author acknowledge with thanks to Present dynamic President Er.Eshwar Khandre, Principal Dr.Bipin Bihari Lal who made this Endeavour possible and also express our gratitude and indebtedness to Bheemanna Khandre Institute of Technology, Bhalki for providing us an opportunity to undergo innovative work successfully.

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(i) Arms down Posture -for basic position ,relaxation ,reliving stresses

(ii) Arms under head Posture -for head ache, back pain ,joint inflammation

(iii) Arms up Posture Stretching position, more aerobic, , beauty care & slim effect

(iv) Arms spread Posture -for Strengthened spinal column, Relief in muscles fatigue.

Different desired postures for good health

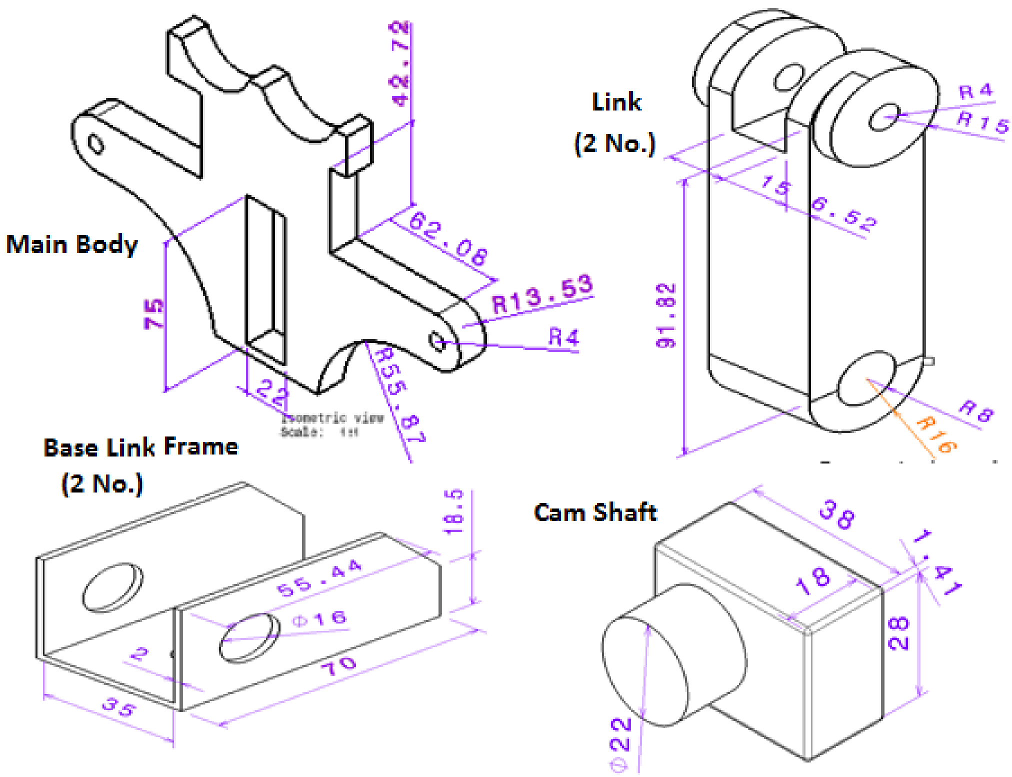

Fig -1 CATIA CAD Models of Mechanisms

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Table 1 Structural Steel Material Properties	
Tensile Yield Strength	2.5e+008 Pa
Compressive Yield Strength	2.5e+008 Pa
Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

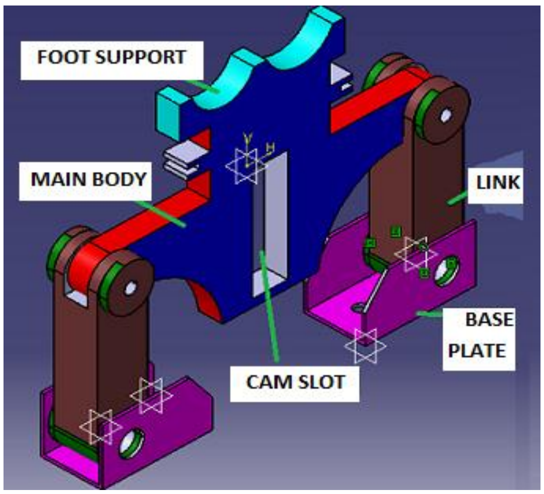

Fig -2 CATIA V5 Assembly 3D Model

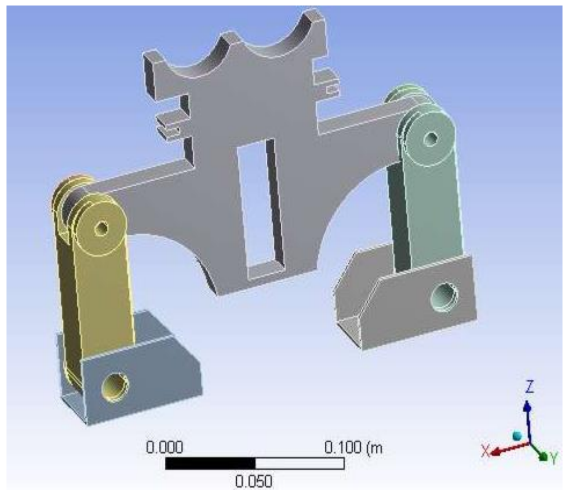

Fig -3 Imported assembly CATIA(.stp) in ANSYS

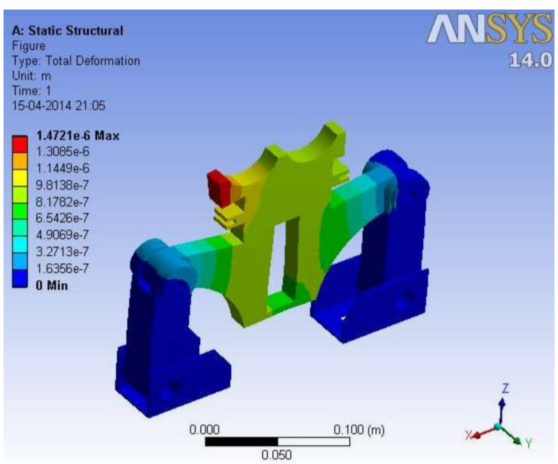

Fig-4 Total Deformation

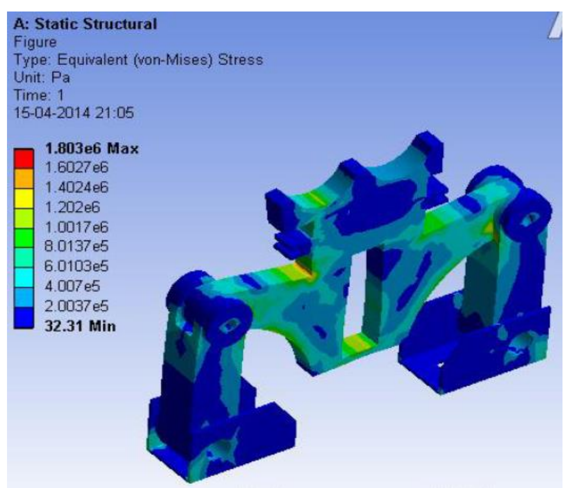

Fig-5 Equivalent (Von-misses) stresses

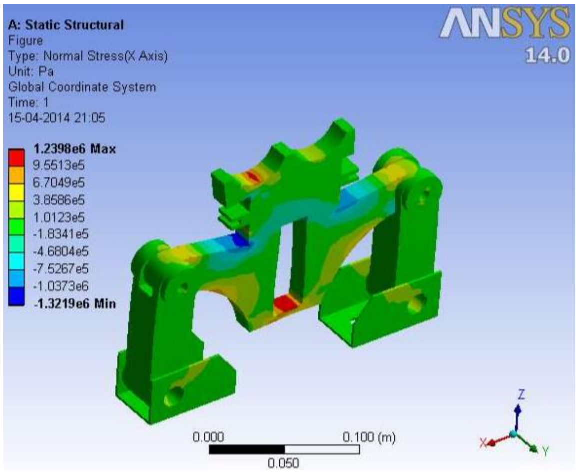

Fig-6 Normal stresses

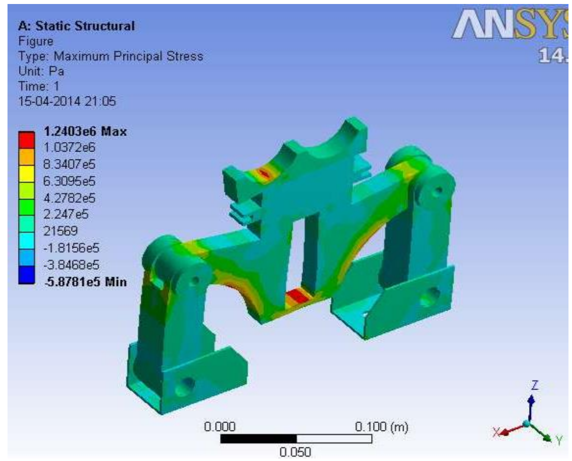

Fig-7 Maximum Principal stresses

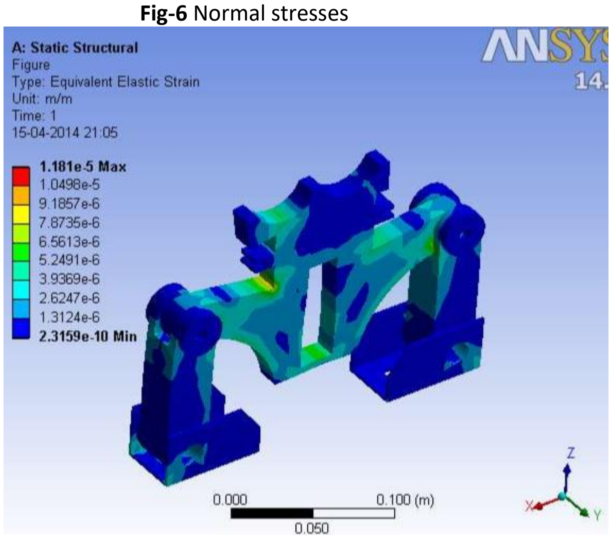

Fig-8 Equivalent Elastic strain

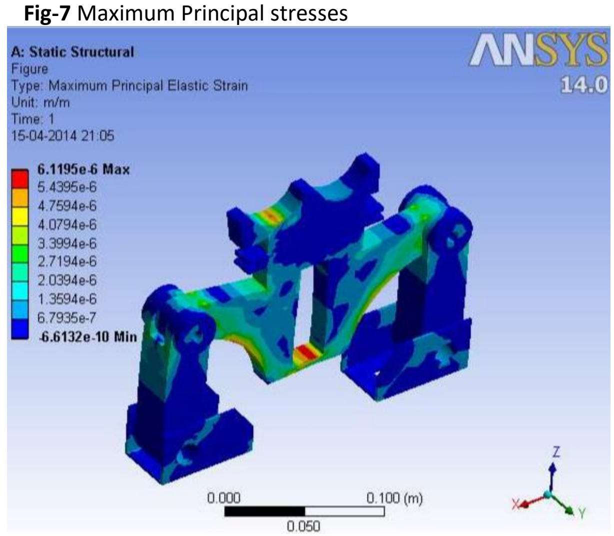

Fig-9 Maximum Principal Elastic strain

Table-2 Geometry variables

Definition	
Source	G:\ASSEMBLY FINAL .stp
Type	Step
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	0.23615 m
Length Y	3.9e-002 m
Length Z	0.18563 m
Properties	
Volume	4.1516e-004 m^3
Mass	3.259 kg

Table- 3 Real Constants for FEA

Properties		
Volume	9.1752e-005 m^3	1.9768e-004 m^3
Mass	0.72025 kg	1.5518 kg
Centroid X	5.151e-002 m	-4.7448e-002 m
Centroid Y	2.0169e-002 m	1.95e-002 m
Centroid Z	5.877e-002 m	0.1149 m
Moment of Inertia Ip1	7.6322e-004 kg·m^2	5.1991e-003 kg·m^2
Moment of Inertia Ip2	7.6336e-004 kg·m^2	1.7041e-003 kg·m^2
Moment of Inertia Ip3	1.2015e-004 kg·m^2	3.5533e-003 kg·m^2

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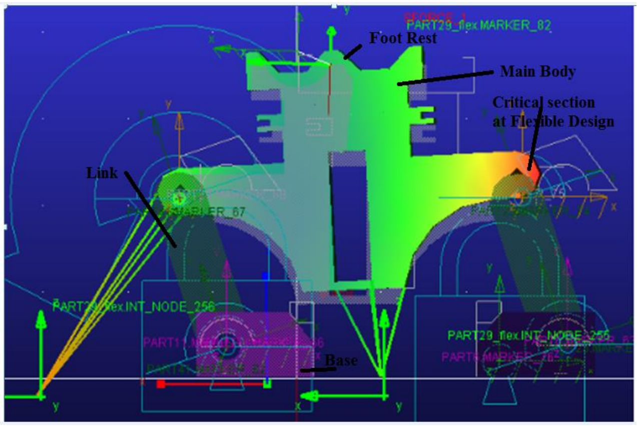

Fig -10.ADAMS Simulation Swing Massager Model.

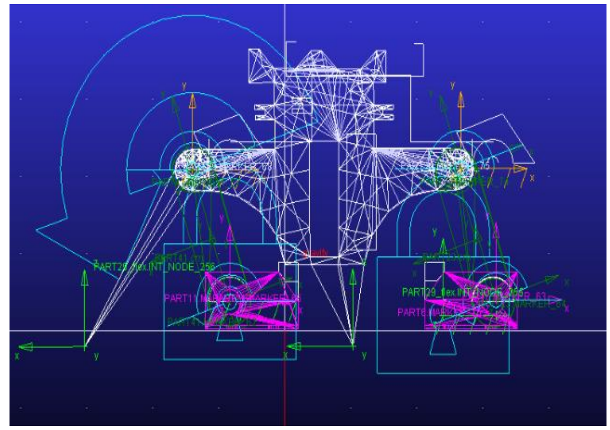

Fig -11 .ADAMS Wire Frame Model

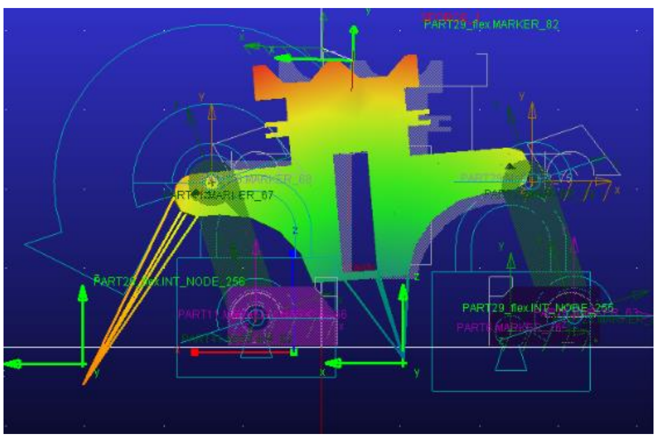

Fig -12 .ADAMS MBD Swing Massager Model

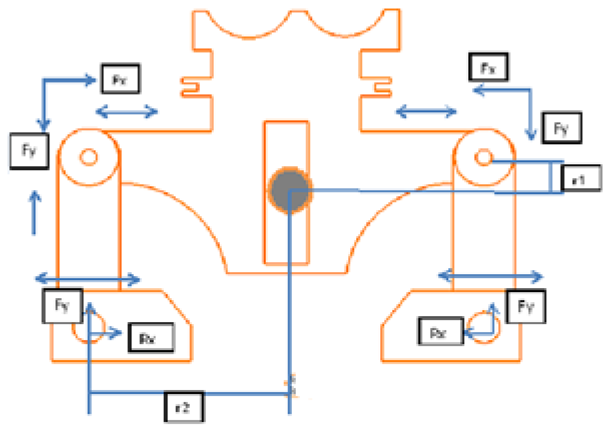

Fig-13 Forces acting on Mechanism & joints

Table- 4 Joints and Elements of Assembly	
Joints	**Elements**
Revolute joint 1	Left base and link
Revolute joint 2	Right link and base
Fixed joint 3 ,6	Left, Right base and link
Revolute joint 4	Left link and main body
Revolute joint 5	Right link and main body

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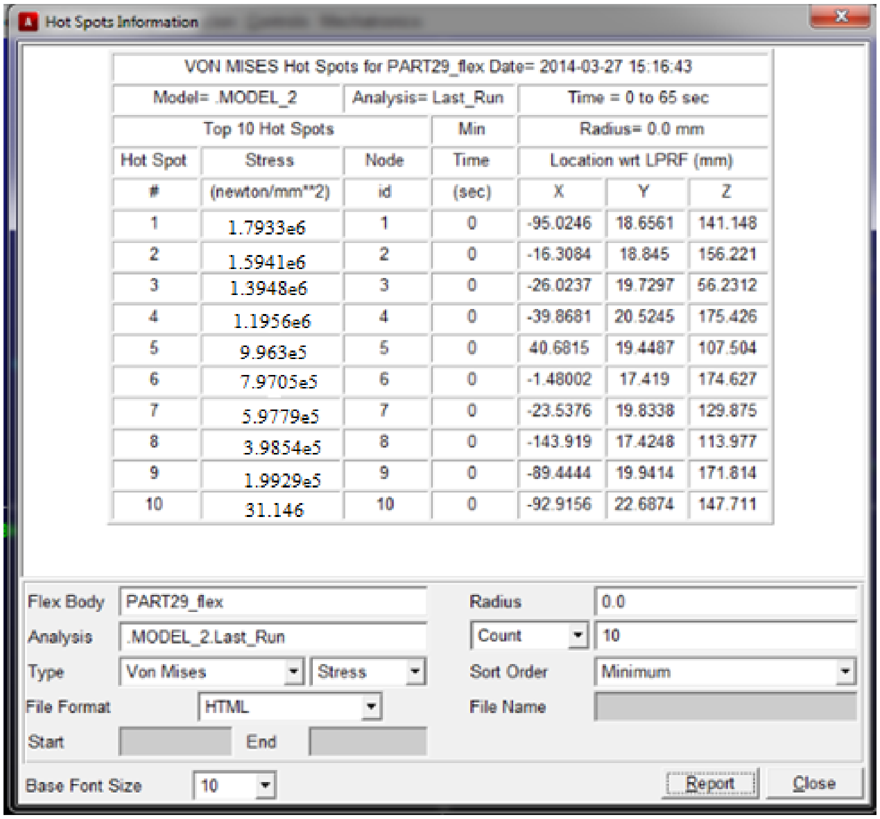
Table-5 Von-Misses Stress By ADAMS



VON MISES Hot Spots for PART29_flex Date= 2014-03-27 15:16:43						
Model= .MODEL_2		Analysis= Last_Run		Time = 0 to 65 sec		
Top 10 Hot Spots			Min	Radius= 0.0 mm		
Hot Spot	Stress	Node	Time	Location wrt LPRF (mm)		
#	(newton/mm**2)	id	(sec)	X	Y	Z
1	1.7933e6	1	0	-95.0246	18.6561	141.148
2	1.5941e6	2	0	-16.3084	18.845	156.221
3	1.3948e6	3	0	-26.0237	19.7297	56.2312
4	1.1956e6	4	0	-39.8681	20.5245	175.426
5	9.963e5	5	0	40.6815	19.4487	107.504
6	7.9705e5	6	0	-1.48002	17.419	174.627
7	5.9779e5	7	0	-23.5376	19.8338	129.875
8	3.9854e5	8	0	-143.919	17.4248	113.977
9	1.9929e5	9	0	-89.4444	19.9414	171.814
10	31.146	10	0	-92.9156	22.6874	147.711

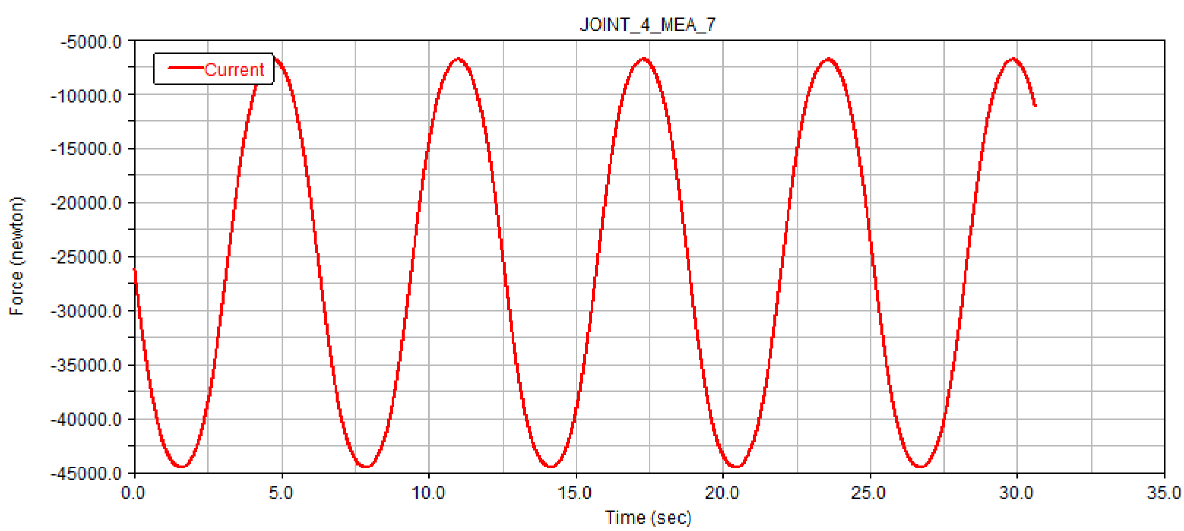


Fig-14 Forces acts on joints_4 in different time in sec.

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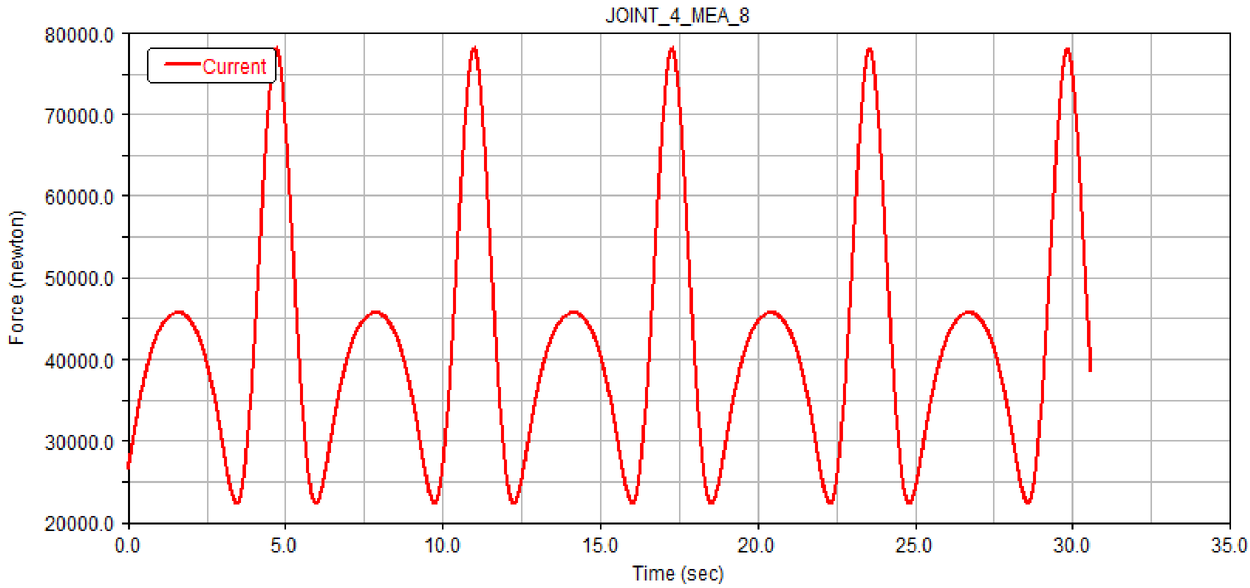

Fig-15 Forces acts on joint _4 MEA_8 in different time in sec.

Table 6 Various kinds of Forces		
Sl.No.	**Forces**	**Value**
1	Twisting Moment	2.8 Nm
2	Swing Motion	100 Oscillations
3	Gravity	9.8 m/s2

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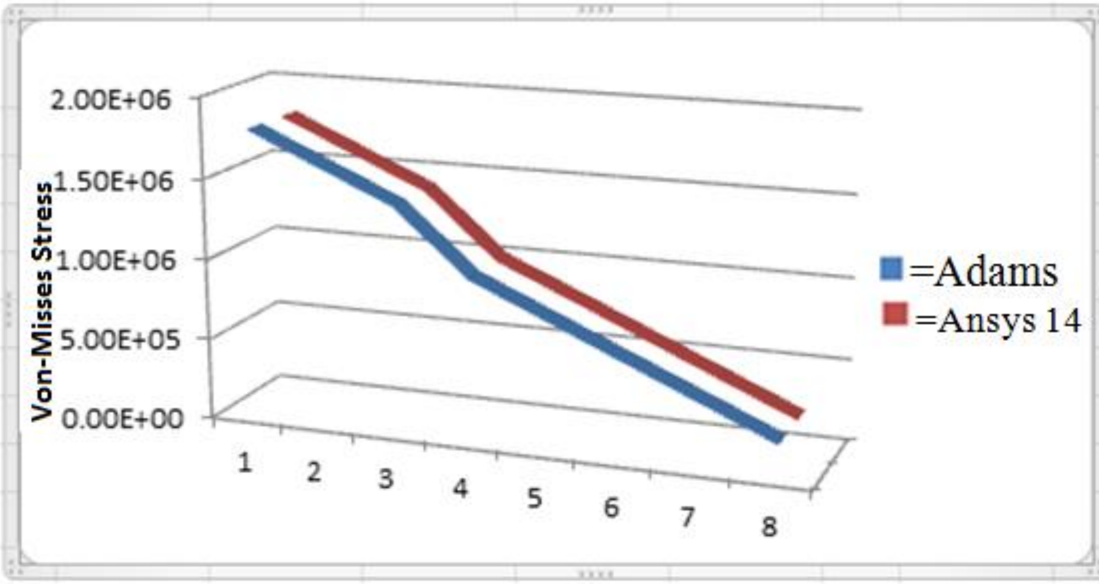

Fig-16 Comparison of Von-misses Stresses