SIMULATION and ANALYSIS of PARALLEL MANIPULATOR for MANOEUVRING LAPAROSCOPIC CAMERA - CAD BASED APPROACH

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Abstract:The inconvenience of laparoscopic operations lies mainly in the difficulties in mutual understanding between the surgeon and the camera assistant that manoeuvres the laparoscope camera according to the surgeon's instructions .Another problem arises when the operation had to be performed for many hours.[1] In these cases the camera image tends to become unsteady due to fatigue of the camera assistant. The self-camera control, give more stability of the laparoscopic image, A robotic camera Assistant(parallel manipulator) directly under surgeon's control can help the surgeon control the view better.In this paper a parallel robot is simulated for the manipulation of laparoscopic camera and Two dimentional workspace generated is indicated and velocity ,acceleration ,displacement graphs are shown and analysis is done using ANSYS.

keywords: laproscopic camera,parallel manipulator,solid works,simulation,ANSYS

I.INTRODUCTION TO ROBOTS FOR MEDICAL APPLICATIONS

In the current era of evidence based medicine enthusiasm for laparoscopic surgery is rapidly gaining momentum. There is an immense amount of literature showing advantages of minimal access surgery and acceptance by almost all the surgical speciality[1]. The advantages of laparoscopic surgery are well documented but there are significant challenges not only to the operating surgeon but also to the person who holds laparoscope.[15,16,17,18,19,20]

In laparoscopic surgery, the operating surgeon does not have direct visual control of the operative field. The surgeon depends on the camera assistant to makeover the camera for optimum visualization of laparoscopic target of dissection. In only advanced units and hospital the laparoscopic team can afford to use an experienced camera assistant. Elsewhere this is not economically feasible on a regular basis. The purpose of non-human motorized camera holders is to facilitate camera-control to the surgeon and to stabilize the visual field during minimally invasive procedures. Recently many such, active and passive camera holders have been developed everywhere in the world to offer the surgeon an alternative and better tool for control of the operating surgeon. The advantages of non-human camera operator include[2,19]:

- Elimination of the fatigue of the assistant who holds the camera.
- Elimination of fine motor tremor and little inaccurate movements..
- Delivery of a steady and tremor-free image.
- Non-dependency on camera operator.
- Reduced cost of surgery.
- Reduced number of highly skilled staff.

II.LITERATURE REVIEW

Robotic–assisted surgery is a new trend in medicine, which aims to help the surgeon by taking advantage of robots' high accuracy and accessibility[1]. Introducing a robotic assistant as an integral part of the surgical tool array provides the surgeon with several advantages. These advantages include off-loading of the routine tasks and reduction of the number of human assistants in the operating room. In addition, by using the capabilities of the robot, the surgeon can complement his own skills with the accuracy, motion steadiness, and repeatability of the robot[10]. The experimental comparison, presented in journal by Kavoussi, et al., 1996,[3] compared the performance of a human assistant and a robotic assistant in manipulating a laparoscope. The results of this comparison emphasized the superiority of the robot in terms of motion steadiness. Another work by Kazanzides, et al., 1995,[4] presented experimental results comparing the cross sections of a manually broached implant cavities and cross sections of robot milled cavities for hip replacement surgery. The comparison resulted in clear prominence of the robot in performing accurate milling of the implant cavities. Noticing these features of the robot, several researchers invested efforts in assimilating the robot in the surgical arena[12,13,14]. Another journal by Dr.R.K.Mishra compared PMAT camera holder with traditional assistant driven laproscopic camera control for laproscopic appedicectomy and ovarian cystectomy had given good practical results[1].six Possible laproscopic basic moments required are given as up,down, in ,out,to the left and to the right indicated in fig2.2,fig2.3

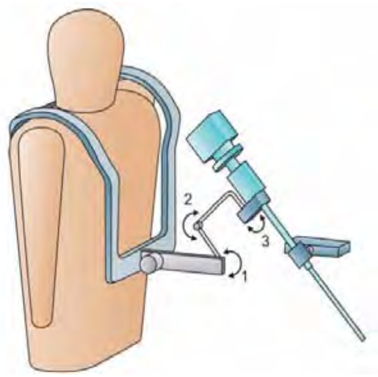


Fig:2.1(FROM[1])

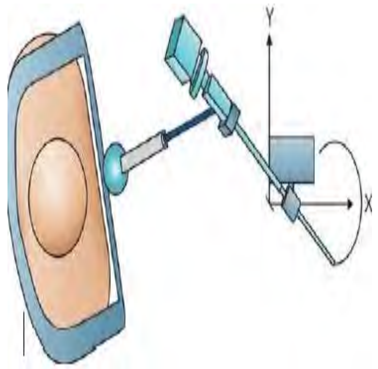


Fig:2.2

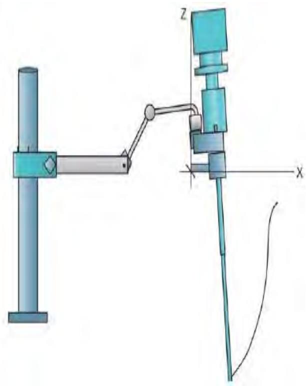


Fig: 2.3

The following pictures fig:2.1 PMAT Camera holderare developed by DR.R.K.Mishra ,laproscopic surgeon ,laproscopic hospital,new delhi,india for the purpose of camera manipulation[1] Fig:2.2 camera moment Right to left, Fig:2.3 moment in and out

III. PARALLEL AND SERIAL MANIPULATOR

From the two robot architectures, i.e., the serial and parallel ones, the one most compliant with the fundamental requirements is the parallel architecture. In contrast with the bulky serial architecture, the compact and lightweight parallel architectures simplify the relocation of the robot in the operating room, save necessary space, and allow easy sterilization by covering the robot with a closed drape. The relatively small work volume of the parallel robots, if correctly designed, can introduce an important safety feature. In addition, parallel robots behave safely near singularity. When the robot traces a path towards a singular configuration, the required forces from the actuators reach high values. Consequently, monitoring the electrical current of the actuator motors gives a reliable warning against approaching singular configurations. In serial robots, singular configurations are associated with very high values of joint velocities and this introduces a hazardous element.FIG3.1 parallel robot for spinal surgery

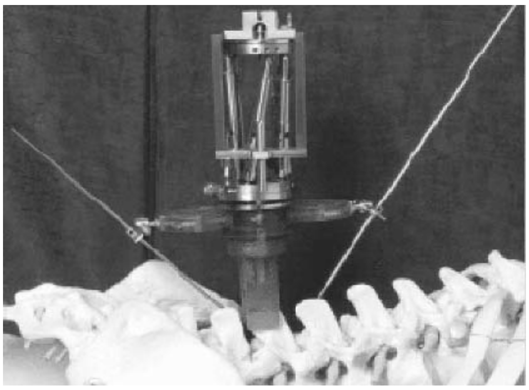


Fig. 3.1. .The MARS/Spine Assist robot for spinal surgery (courtesy of Mazor Surgical Technologies)

The parallel robots provide accuracy with lower price when compared to similar serial robots with the same accuracy level. Some accuracy levels may not be achieved with serial robots. These high levels of accuracy are important for eye surgery Based on the above arguments, we may conclude that the parallel architecture is better than the serial one for medical applications which requires minimum workspace . Robots are slowly entering the medical field with systems such as the DaVinci (Intuitive Surgical) , Zeus (Computer Motion) robots. Parallel structures also play a role in this evolution. For example in the Crigos system of Brandt [24], a parallel robot was used for orthopedic surgery operations, while the INRIA active wrist has been successfully employed for ophthalmological surgery operations on dogs [23]. In the SurgiScope system provided by ISIS Robotics ISIS, a Delta type robot is used as a microscope stand Another example addresses one difficulty for surgical robot which is to follow the patient's motion. This has motivated the development of the MARS robot which has a 6-UPS structure [25]; the robot is directly mounted on the patient's bony structure near the surgical site. This robot has been used as a surgical tool guiding spinal pedicle screws placement(figure 3.1). and is sold by Mazor , MAZ as the Spine Assist robot

IV. MODELLING OF 4 ARM PARALLEL MANIPULATOR USING SOLID WORKS

The four arm parallel manipulator consists of fixed plate/base plate and a movable plate that which are connected with drive and driven links that help to move the lower plate to a required area.[5] ,[6].when compared to delta parallel robot top plate/fixed plate is a octoganal shape it is not a triangular/circular shape and bottom plate was also varied when compared to delta parallel robot .A four arm parallel manipulator has four motors that attach to four individual driver links; these driver links then attach to four separate arms. These arms tend to be attached by ball joints or ball-and-socket joints at both ends of the driver link, meaning that for every motor there is one driver link and for every driver link there are 2 links that make up one arm.[7] The arms are then connected to the end effecter. thus, the end effector is connected to eight links but only four arms.The key difference with the Delta robot is the use of four kinematic chains instead of three

The basic concept of 4 arm Parallel manipulator is described by a simple architectural scheme as illustrated in **Fig. 4.1**,where joints are represented by lines . The manipulator is based on four independent chains between the base and the End-Effector (EE). Let R,and S represent revolute,and sperical joints, respectively,**FIG4.2**Assembeled Parallel manipulator**,FIG:4.3**Indication of link lenths (L1&L2)and R1 and R2,TABLE:4.1A Dimentions

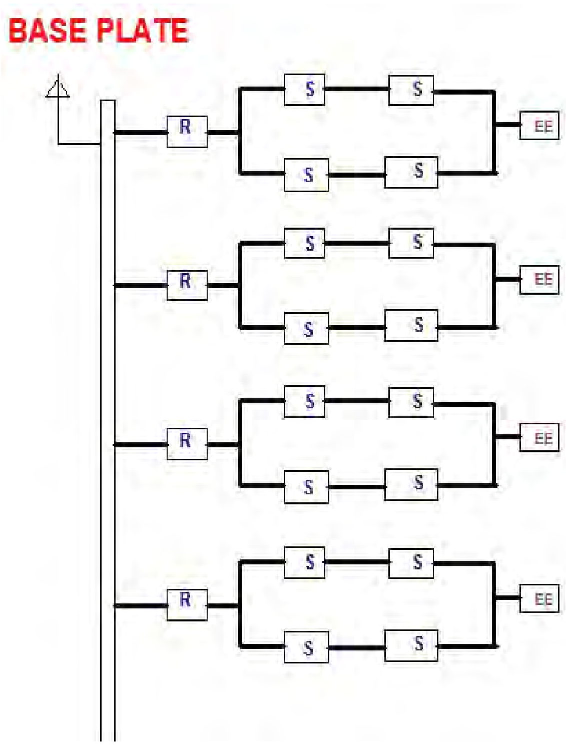


Fig :4.1, Architectural scheme of parallel manipulator

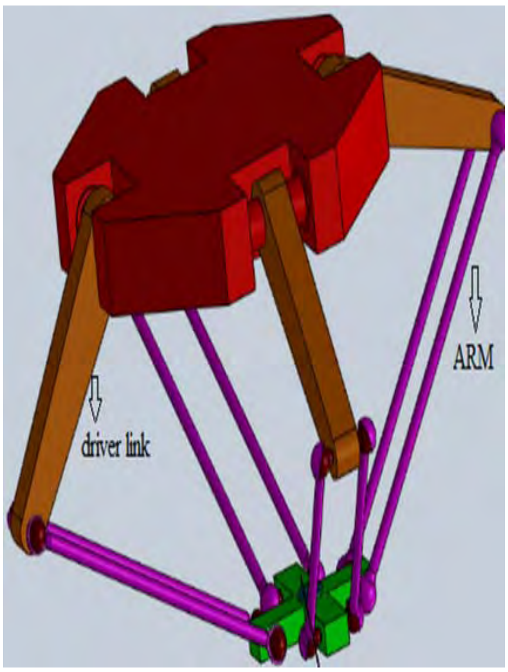


Fig:4.2.parallel manipulator

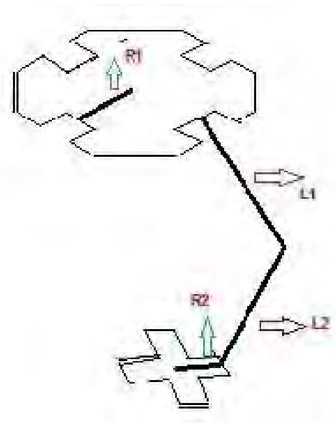


Fig:4.3

Table:4.1A

parameter	L1	L2	R1	R2
Dimensions(cm)	18	20	10	5

V.SIMULATION OF PARALLEL MANIPULATOR USING SOLID WORKS.

Simulation of parallel manipulator for different possible moments required for surgery is done in solid works,as per the literature laproscopic camera need to be manipulated in linear and curved motion in the port from where it is inserted[1]. Six basic moments required are to the left,right,up,down,in and out which are indicated in fig2.2,fig2.3 [1]workspace [9] is Generated using solidworks ,motors are assigned to driver links/Revolute joints and simulated to see the workspace generated **,[22]**workspace generated can be obtained by the option trace path in solid works motion . Movement in the cardinal directions is created by moving one motor forwards and its opposite motor backwards(indicated by red arrows in figure:5.1)**[8,11,20,21]**whether the robot is moving in the x-direction or the y-direction depends on which motors are moving. Movement along the z-axis requires coordination motion of all four joints in the same direction .The following tables shows the (degrees of rotation assianed to links(i.e motors) with respect to time in solid works. Table:5.1(Motors values assianed to driver link1&Table:5.2(motor values assianed to joint of driver link2)

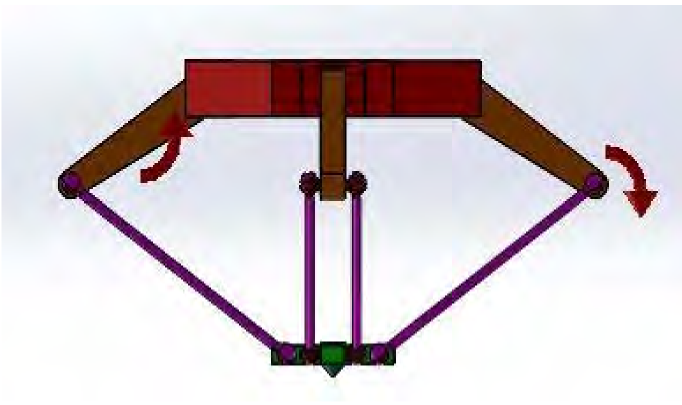


Fig5.1

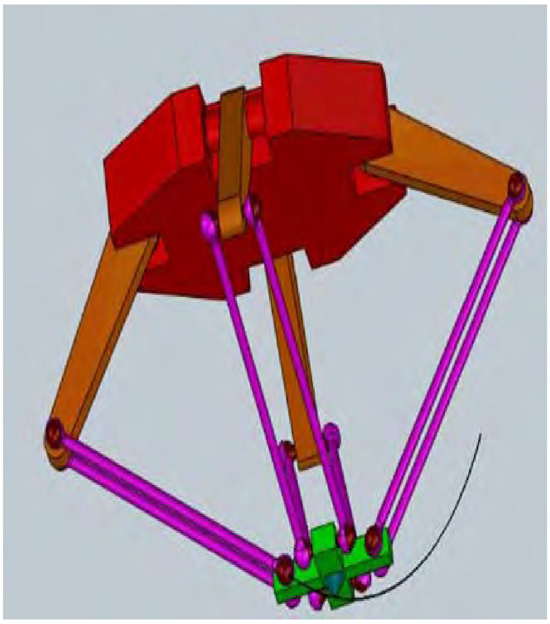
Table:5.1 Time and motor values Assianed in solid works for link1/revolute joints

TIME(SEC)	0s	2s	4s	6s	8s	10s
MOTORVALUE(DEGREES)	50	-50	50	-50	50	-50

Table 5.2Time and motor values Assianed to link2

TIME(SEC)	0s	2s	4s	6s	8s	10s
MOTORVALUE(DEGREES)	-50	50	-50	50	-50	50

Workspace generated for the motor angles is indicated by a curve which was generated by taking a point On the lower plate and by the command trace path in motion simulation of solid works, workspace is generated is indicated in fig 5.2 and 5.2A and respective velocity, acceleration and displacement are indicated in Fig 5.2b,fig:5.2c,fig:5.2d And linear displacement of driver link and arm in y and x direction are shown in fig:5.2e,fig:,5.2f



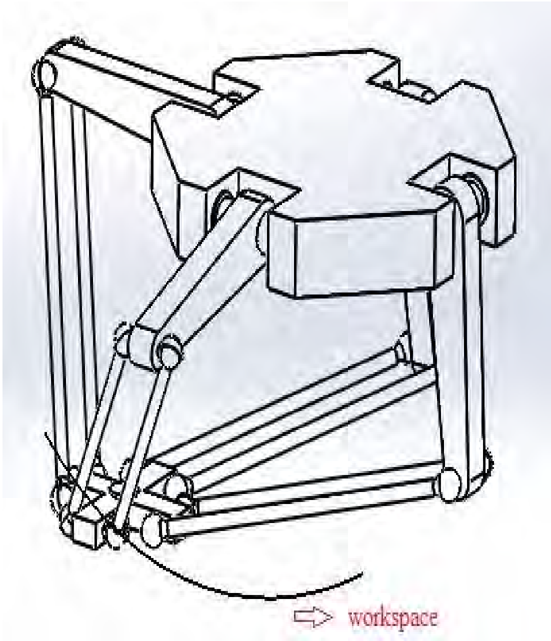
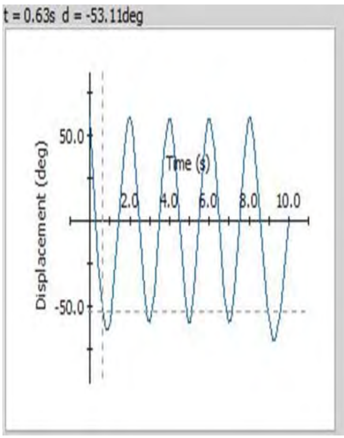
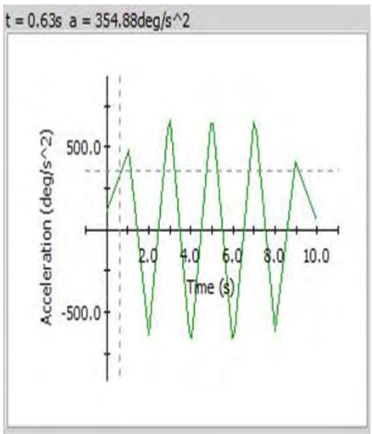


Fig:5.2 Fig :5.2A

Fig5.2&fig5.2A-:workspace of parallel manipulator is indicated by a curve/moment to the left and to the right.





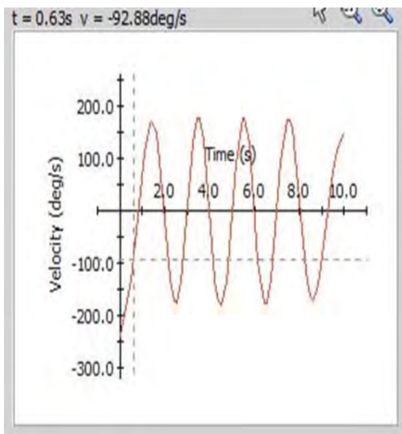


FIG:5.2B, FIG:5.2C FIG5.2D

Fig:5.2B, Fig:5.2C,Fig5.2D-Displacement,Acceleration and velocity graphs .

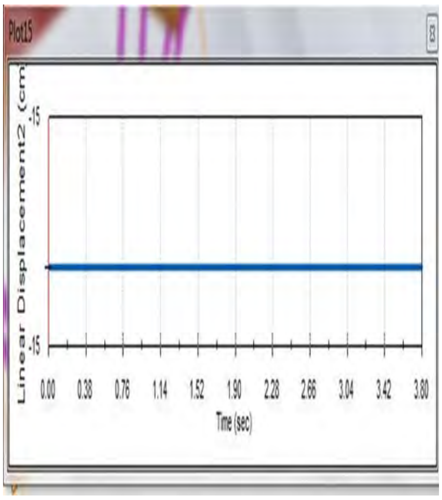


Fig:5.2E(Linear displacement of driver link1)

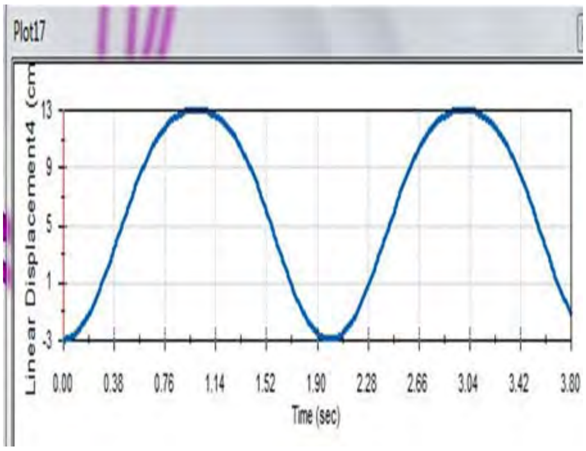
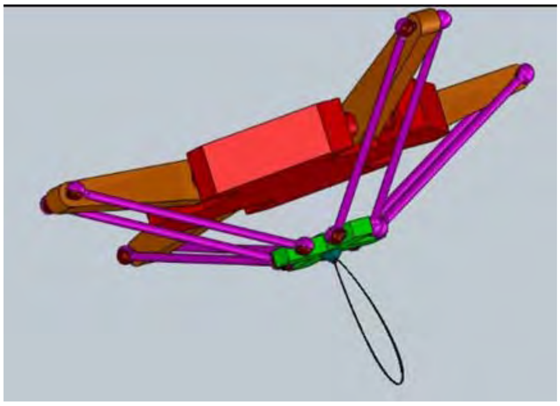


FIG5.2F linear displacement of arm in x direction

5.1:Simulation of parallel manipulator for obtaining a circular shape workspace fig6.1



Simulation Fig:6.1

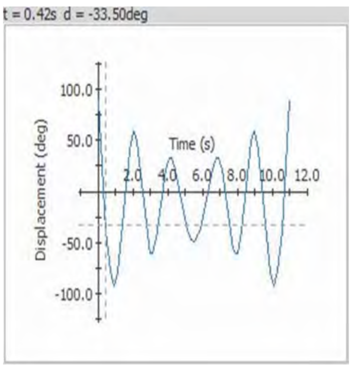


Fig 6.1A,

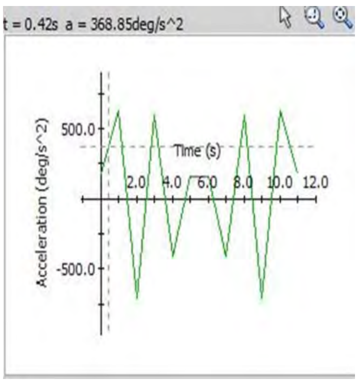


Fig:6.1B,

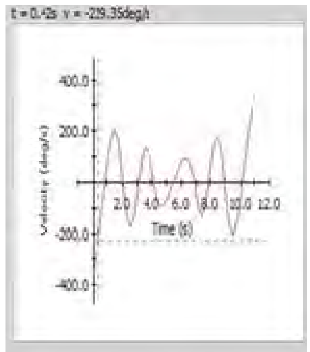


Fig:6.1C

Displacement ,velocity,acceleration graphs for simulation Fig:6.1A,Fig:6.2B,Fig:6.2C

5.2:Some trajectories generated by parallel manipulator when different angles are given to driver links/motorsfig:7.1,7.2

5.3:Workspace generated when more than one point is taken on lower plate fig:7.3

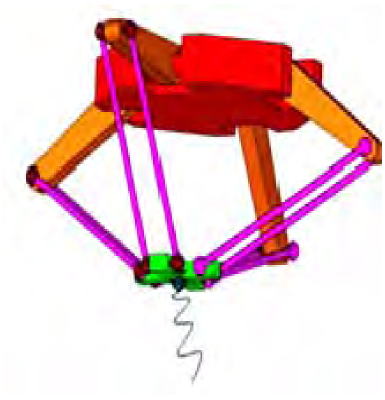


Fig:7.1

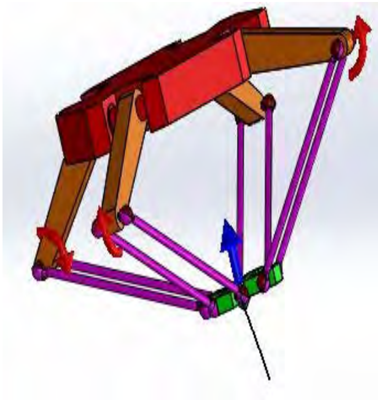


Fig:7.2

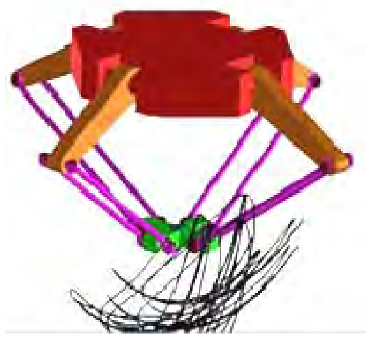


Fig:7.3

Fig:7.1parallel manipulator moment along the curve/in up,down,left and right
Fig:7.2parallel manipulator moment in linear direction indicated bystraight line/in&out moment
Fig:7.3 parallel manipulator moment in different direction

5.4 :Simulation with different motor anglesTABLE8.1&8.2 & fig8.3(parallel manipulator with workspace),fig8.4: displacement graphs

TABLE:8.1 – Motor values Assained to link 1

Time(seconds)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Value(degres)	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**40**	**30**	**20**	**10**	**0**

TABLE:8.2-Motor values and timeAassianed to link2

Time(seconds)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Value(degrees)	**0**	**10**	**20**	**30**	**40**	**50**	**-40**	**-30**	**-20**	**-10**	**0**

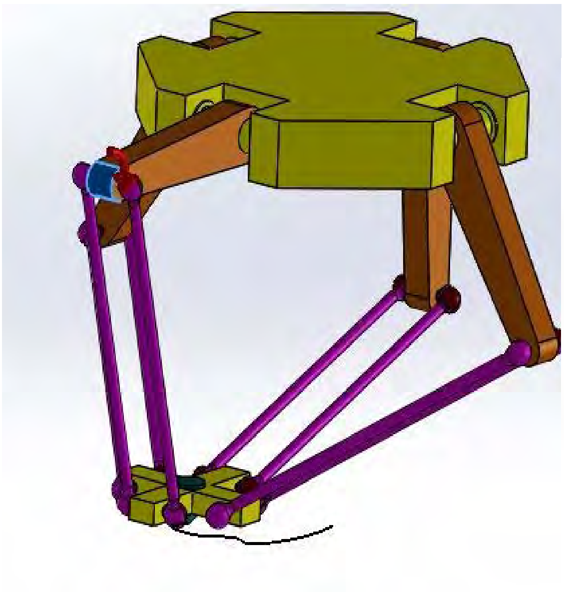


Fig. 8.3: parallel manipulator with workspace

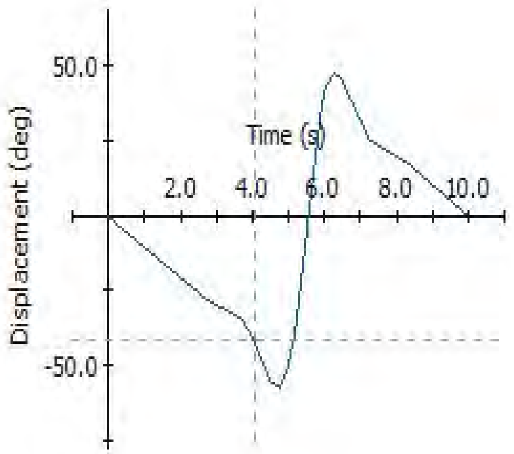


Fig.8.4 : Displacement graphs

VI.ANALYSIS OF PARALLEL MANIPULATOR

Static analysis on parallel manipulator which was designed to manipulate laparoscopic camera in the workspace of 40mmX40mmX40mm by holding the load of 5 N (camera), Displacement is found negligible. Analysis of parallel manipulator was done by constraining top plate and assigning 5N load at bottom plate FIG8.1 and FIG:8.2

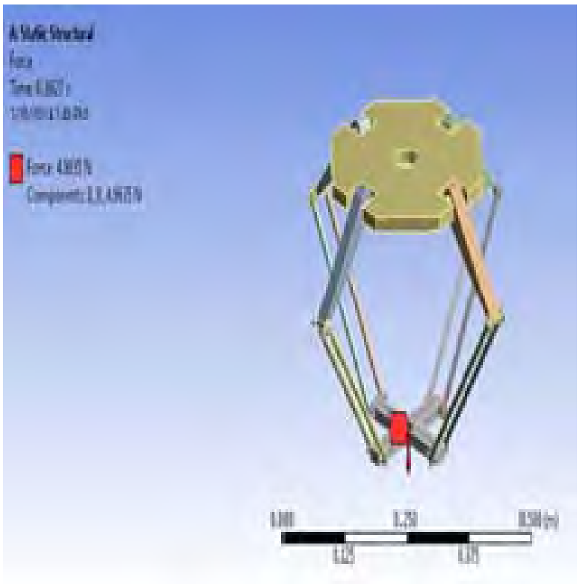


Fig:8.1

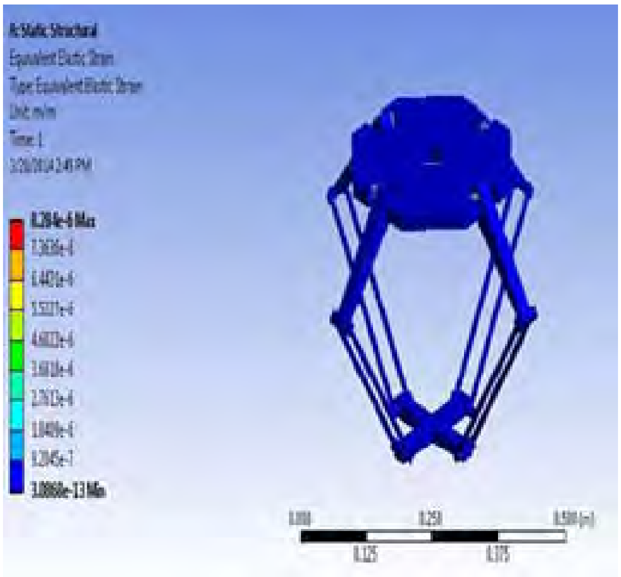


Fig.:8.2

VII.CONCLUSION

work space identification is a complicated task in parallel robot in our paper we had designed a parallel robot using solid works and workspace was identified using solid works simulation , This is a new approach for identifying the parallel robot workspace and possible moments .CAD based softwares are utilized for finding motion analysis and possible moments of the designed parallel manipulator very few papers are published in the area of parallel robot simulation using cad based approach .As minimally invasive surgery requires minimum work space this parallel manipulator is suitable for manipualing laproscopic camera . our simulation work had shown that for achieving a minimum work space we can simulate the robot links/driver within the range of 0 to 40 degrees,minimum angles can be given to links in clock wise and anticlock wise directions for achieving a minimum work space and analysis is done in ansys by considering laproscopic camera weight as 5N and we find displacement of proposed 4link parallel robot is negligibile

ACKNOWLEDGMENT

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