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Dynamic Analysis and Optimization of Delta Parallel Robot for Chest Compression Task

G.Yedukondalu, J.Suresh Kumar, A.Srinath, V. Naga Venkatesh

Abstract— Chest compression task in the process of Cardiopulmonary resuscitation (CPR) has been a very important requirement for the purpose of rescue of patients in emergency. Resuscitation (CPR) is presented in this paper. According to the requirements of CPR action from medical viewpoints, a new parallel manipulator employing the architecture of Delta parallel robot is designed, which utilizes an optimization methodology for such applications. In this paper, the dynamic analysis and optimization of Delta parallel manipulator is carried out in details. The results clearly illustrate the optimization of the delta parallel robot to assist in CPR operation.

Index Terms—Chest Compression, Medical Robot, Parallel Manipulator, Dynamic Analysis, Optimization.

I. INTRODUCTION

Chest compressions have saved the lives of countless patients in cardiac arrest since they were first introduced in 1960. Cardiac arrest is treated with cardiopulmonary resuscitation (CPR) and chest compressions are a basic component of CPR. The quality of the delivered chest compressions is a pivotal determinant of successful resuscitation.

The compression for adult CPR is at the rate of about 100-120 times per minute with the depth of 4 to 5 centimeters using two hands, and the CPR is usually performed by two rescuers with the compression-to-ventilation ratio of 15 compressions to 2 breaths. In addition, chest compressions consume a lot of energies from doctors, for instance, it needs ten doctors to work two hours to perform chest compressions to rescue a patient in a hospital.

Therefore a medical robot used for chest compressions is highly required. In view of this urgent demand, we will design and analyze an optimized medical Delta parallel robot to assist in CPR operation, and wish the robot can perform this job well instead of doctors.

II. PARALLEL ROBOT

Parallel mechanical architectures were first introduced in tire testing by Gough, and later were used by Stewart as motion simulators. A parallel manipulator typically consists of a moving platform that is connected to a fixed base by several limbs or legs in parallel.

Nowadays, parallel manipulators are applied widely since they possess many inherent advantages such as high speed, high accuracy, high stiffness, and high load carrying capacity over their serial counterparts. In particular, parallel manipulators have great potential applications in medical field due to their well performance in high structural stiffness and motion accuracy, and compact structures, etc.

The DELTA parallel robot consists of a spatial parallel structure with three degrees of freedom, and is driven by three revolute actuators. The platform is connected with drive by allowing only translational movements of the platform and keeping the platform parallel to the base plane.

III. DESIGN OF DELTA PARALLEL ROBOT

A diagram of Chest compression task is shown in Fig. 1. Owing to the merits mentioned above, parallel mechanisms are employed to design a device applicable to chest compressions in CPR operation. A CAD model of the designed medical manipulator is illustrated in Fig. 2. In practice, the rescuer usually uses two hands instead of only one hand to perform the action of chest compressions. During chest compressions action, the two arms of the rescuer construct actually a parallel mechanism.

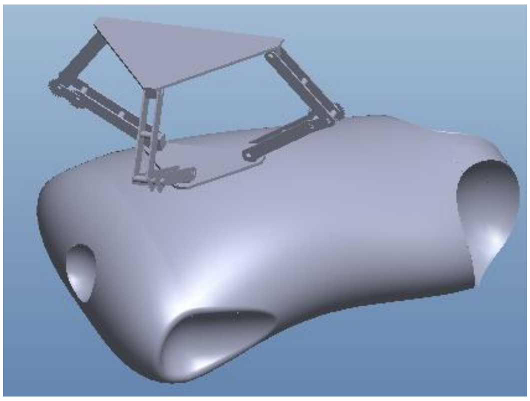

Fig. 1: Chest Compression Task

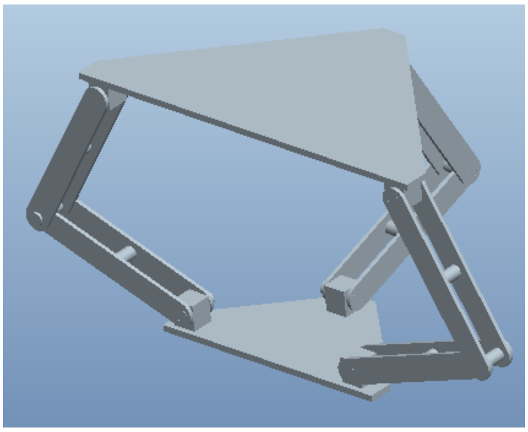

Fig. 2: The Designed Model of Delta Parallel Robot

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The reason of utilizing such kind of translational parallel manipulator (TPM) with fixed actuators lies in that in chest compressions process, the mainly used motion of the manipulator is the vertical translation. In addition to a translation in the z axis direction, the designed TPM can also provide the translations in the x and y axis directions, which enables the adjustment of the manipulator mobile platform to a suitable position for performing chest compressions. Moreover, the fixed actuators make it possible that the moving components of the manipulator do not bear the load of the actuators. This enables large powerful actuators to drive relatively small structures, and facilitates the design of a manipulator with faster, stiffer, and stronger characteristics. Furthermore, the designed TPM has a more compact structure for medical applications in CPR operation.

IV. ARCHITECTURE OF DELTA PARALLEL ROBOT

Fig. 3 represents the schematic diagram of the designed 3-RRR parallel manipulator, which consists of a mobile platform, a fixed base, and three limbs of identical RRR kinematic structure with the first and last R joint actuated by a revolute joint, where the middle R stands for the rotary actuator, respectively.

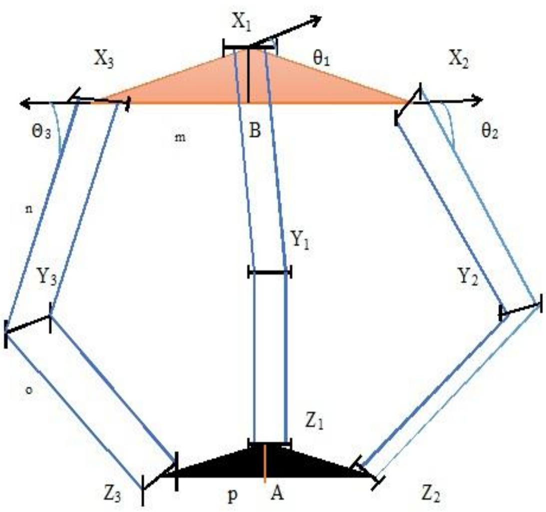

Fig. 3: Schematic representation of a 3-RRR

For the purpose of analysis, as shown in Fig. 3, we assign a fixed Cartesian frame B{*x*, *y*, *z*} at the centered point B of the fixed base platform $\Delta X_1X_2X_3$, and a moving Cartesian frame A{*u*, *v*, *w*} on the triangle mobile platform at centered point A of triangle $\Delta Z_1Z_2Z_3$, with the *z* and *w* axes perpendicular to the platform, and *x*, *y* axis parallels to *u*, *v* axis, respectively. To get a compact structure, both the base and moving platforms are designed as an isosceles right triangle described by the parameter of m and p, respectively, i.e., BX_i = m and AZ_i = p, for i =1, 2, and 3. The actuated variable of the i^{th} limb is angle θ_i. The connecting joints between the upper and lower links are denoted as Y_i, and the lengths of upper and lower links for each limb are n and o respectively, i.e., X_iY_i = n and Y_iZ_i = o. The optimized architectural parameters of the medical manipulator is described in Table-I.

TABLE I: ARCHITECTURAL PARAMETERS OF THE MEDICAL ROBOT

Parameter	Value	Unit
m	250	mm
n	160	mm
o	160	mm
p	200	mm

V. STATIC ANALYSIS

The model has been simulated using ANSYS software. For this analysis, aluminum has been considered as structural material. The tetra mesh was created to the model as shown in the Fig. 4. For adults, 30 to 50 Kg of pressure to depress the sternum 4 to 5 cm. From the static analysis, it was found that the maximum stresses of delta parallel robot as shown in the Fig. 5, which is much less compared to the yield strength of the material.

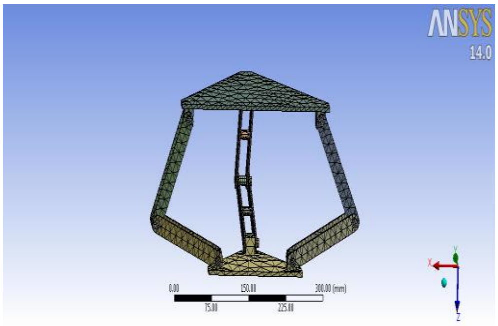

Fig. 4: Mesh model of Delta Parallel Robot

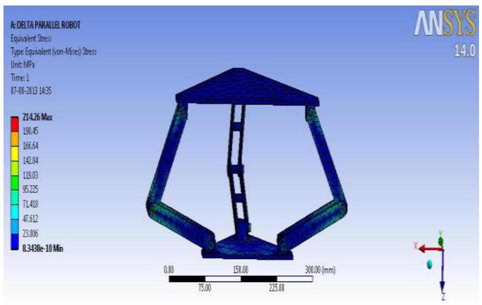

Fig. 5: Stresses developed on the Delta Parallel Robot

VI. DYNAMIC ANALYSIS

The dynamic analysis for a parallel manipulator is to establish an inverse method, then the required actuator velocity and acceleration can be computed if the motor is rotate in both clockwise and anti-clockwise direction. The data points are created in order to move the link in respective angle. Although the most important motion of the medical manipulator to assist in CPR operation is the back and forth translations in vertical direction. The dynamic model is important in designing suitable strategies for accuracy control.

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From the simulation results are shown in Fig. 6 to 8, where figures describes the time history of displacement, velocity, and acceleration, respectively, which are derived via the inverse method solutions.

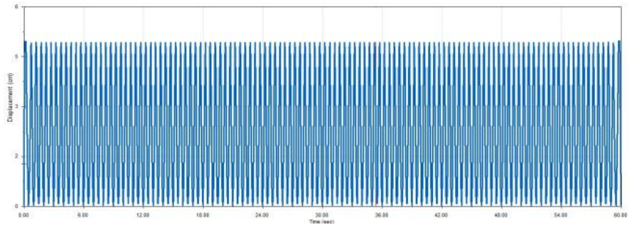

Fig. 6: Simulation results for time history of Displacement (5cm)

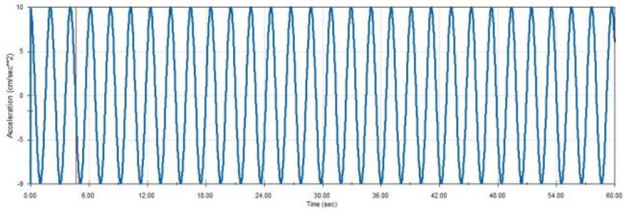

Fig. 7: Simulation results for time history of Acceleration (10cm/sec^2)

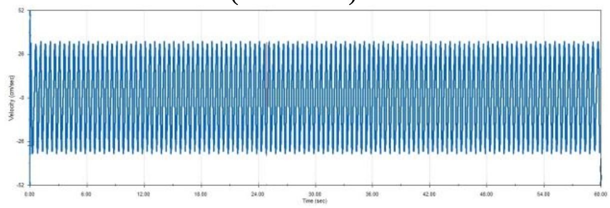

Fig. 8: Simulation results for time history of Velocity (27cm/sec)

VII. OPTIMIZATION OF DELTA PARALLEL ROBOT

Maximum stress and the safety factor are used as the evaluation criteria of the mechanical structure. The simulation model developed in Inspire solidThinking software. Optimization of mass is finding the adequate mass for a piece, taking as the design evaluation criterion the safety factor for a specific number of work cycles. This process is repeated until the design criteria is satisfied in an optimum manner. The optimization of individual parts used for assembly of Delta parallel robot is as shown in Fig. 9 to 11. The optimized model of Delta parallel robot as shown in Fig 12.

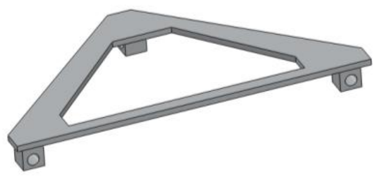

Fig. 9: Optimized part of fixed platform

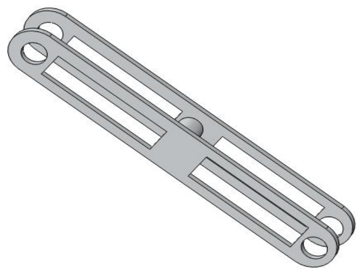

Fig. 10: Optimized part of Upper link & Lower link

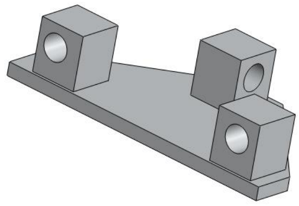

Fig. 11: Optimized part of movable platform

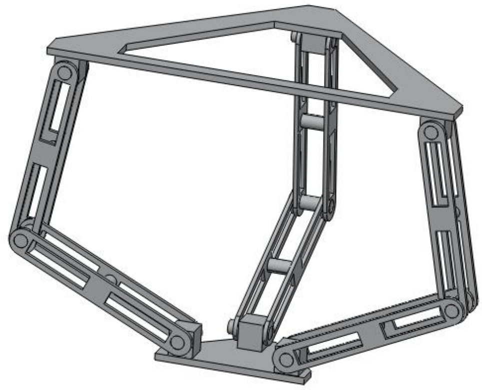

Fig. 12: Assembly of optimized Delta parallel Robot

VIII. CONCLUSIONS

In this paper, the methodology for dynamic analysis as shown in Fig. 6, it can be noted that the depth of compression is 4 to 5cms and compression rate is more than 2 compressions per second i.e. 120 compressions per minute.

The methodology allows optimization of the robot's mechanical structure in terms of weight. The weights are calculated for both initial and optimized Models, the percentage of weight reduction is 50% as shown in Fig. 12.

The study presented here provides a sound base to develop a medical robot to assist in CPR operation, which can significantly reduce the weight of the robot for CPR.

REFERENCES

[1] Kouwenhoven W, Jude J, Knickerbocker G: Closed-chest cardiac massage. JAMA 1960, 173:1064-7.
[2] Abella BS, et al: Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation 2005, 111(4):428-34.
[3] http://www.health.harvard.edu.
[4] J.-P. Merlet, Parallel Robots. London: Kluwer Academic Publishers, 2000.
[5] G. Brandt, A. Zimolong, L. Carrat, P. Merloz, H.-W. Staudte, S. Lavall´ee, K. Radermacher, and G. Rau, "CRIGOS: A compact robot for imageguided orthopedic surgery," IEEE Trans. Inform. Technol. Biomed., vol. 3, no. 4, pp. 252–260, 1999.
[6] M. Shoham, E. Zehavi, L. Joskowicz, E. Batkilin, and Y. Kunicher, "Bone-mounted miniature robot for surgical procedures: Concept and clinical applications," IEEE Trans. Robot. Automat., vol. 19, no. 5, pp. 893–901, 2003.
[7] H. Takanobu, T. Maruyama, A. Takanishi, K. Ohtsuki, and M. Ohnishi, "Mouth opening and closing training with 6-DOF parallel robot," in Proc. of IEEE Int. Conf. on Robotics and Automation, San Francisco, CA, 2000, pp. 1384–1389.

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[8] K. Homma, O. Fukuda, J. Sugawara, Y. Nagata, and M. Usuba, "A wiredriven leg rehabilitatoin system: Development of a 4-DOF experimental system," in Proc. of IEEE/ASME Int. Conf. on Advanced Intelligent Mechatronics, 2003, pp. 908–913.

[9] T. Arai, K. Takayama, K. Inoue, Y. Mae, and Y. Kosek, "Parallel mechanisms with adjustable link parameters," in Proc. of IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, 2000, pp. 671–676.

[10] Christophe A. Wyss, Julia Fox, FabianFranzeck, Marco Moccettia, AlfonsScherrer, Jens P. Hellermann,Thomas F. Lüscher, "Mechanical versus manual chest compressionduring CPR in a cardiac catherisation setting", Cardiovascular Medicine 2010;13(3):92–96.

[11] Yangmin Li and Qingsong Xu. Ha, "Dynamic Analysis of a Modified DELTA Parallel Robot for Cardiopulmonary Resuscitation", IEEE/RSJ International Conference on intelligent Robots and systems, 2005, pp. 233-238.

[12] http://www.resus.org.uk/siteindx.htm

[13] www.heart.org

[14] G.Yedukondalu, Dr. A.Srinath, and Dr. J.Suresh Kumar, "Design and Development of Different Delta Parallel Robots for Cardiopulmonary Resuscitation Application", International Journal of Advances in Science and Technology, Vol. 6, No.6, 2013.

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