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Analysis on the Load Carrying Mechanism Integrated as Heterogeneous Co-operative Manipulator in a Walking Wheelchair

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Abstract:

After industrial robots came into existence during 1960, the technology of robotics with the design and analysis of robots in various forms in industries as well as in domestic applications were developed. Nowadays, along with the automotive sector the robots are producing a great impact in the form of quality and production rate to register their existence reliable in various other sectors also. Robotic technology has undergone various phase translations from being tortured as humanoids to the present day manipulators. Depending upon the various forms of its existence, robot manipulators are designed as serial manipulators and parallel manipulators. Individually both types can be proved effective though both have various drawbacks in design and the kinematic analysis. The versatility of robots can be increased by making them work in an environment where the same work volume is shared by more than one manipulator. This work volume can be identified as co-operative work volume of those manipulators. Here the interference of manipulators in the work volume of other manipulators is possible and is made obstacle free. The main advantage of co-operative manipulators is that when a number of independent manipulators are put together in a cooperative work envelope the efficiency and ability to perform tasks is greatly enhanced. The main disadvantage of the co-operative manipulators lies in the complication of its design even for a simple application, in almost all fields.

In this paper, a cooperative design of robot manipulators to work in co-operative work environment is done and analysed for its efficacy. In the industrial applications when robotic manipulators are put together in more numbers, the trajectory planning becomes the tough task in the work cell. Proper design can remove the design defects of the cooperative manipulators and can be utilized in a more efficient way. In the proposed research paper an analysis is made on such a type of cooperative manipulator used for climbing stairs with three leg design and anlaysis were also done on the mechanism integrated to the system. Kinematics of the legs are analysed separately and the legs are designed to carry a maximum of 175kgs, which is sustained by the center leg and shared by the dual wing legs equally during the walking phase. In the proposed design, screwjack mechanism is used as the central leg to share the load and thus the analysis on the load sharing capability of the whole system is analysed and concluded in terms of failure modes.

1.Introduction:

Designing a wheelchair to get integrated with walking mechanism is possible only in the form of co-operative manipulators. In co-operative manipulators the load is shared uniformly to almost all the components involved in the motion while the other components will be sharing the function in a passive way, like a counter balance. Designing this needs a thorough knowledge of both the serial and parallel manipulators.

After the design of the wheel chair and the legs are done separately, they are integrated to work in the cooperative environment to follow the trajectory planned. The proposed wheelchair is made up of three slots provided with V-grooves. The middle slot is assigned for the telescopic screw jack mechanism and the two other slots are provided for the wing legs as described in Figure 1.

All the three legs are interfaced with the base of the wheelchair by hip joints. The wing legs are composed of three components, the hip joint and two serial links. And the screw jack leg is composed of the normal screw jack components joined to the base of the wheelchair by the hip joint.

The slots provided are of 230mm length and 45mm breadth with V-grooves. These details are provided in the wireframe and solid model specified below. Analysis on the wing legs are separately done applying the maximum load that is going to act on it during the walking and stair climbing phase. Also the screw jack leg is subjected to the same form of analysis allowing the load acting on it to be a uniformly distributed load. Special attention is made towards the screw jack leg to understand the angle it can make with the floor during walking and stair climbing. Since the angle of inclination of the screw jack leg in the walking phase is maximum, it is designed in such a way that the frictional forces at the foot of the screw jack leg should not allow it to slip. And the angle is restricted to 68° from various analysis made. The stress and strain created during the analysis beyond 68° show abnormal features which may support failure of the screw jack mechanism or any component of the screw jack leg. Slip is another factor when the angle is increased beyond 68°. A lead screw link is provided on the wing leg slots to drive the wing legs horizontally on the base of the wheelchair. During this motion only the weight of the legs are carried along the slots, which is easier than carrying the whole load and moving forward. The screw jack leg is fixed at the middle and the slot of the screw jack leg is only to reduce the weight of the base of the wheelchair. Thus pulling the screw jack leg forward will make the base of the wheelchair to move forward and this makes the whole mechanism move forward and the mass transfer form screw jack leg to the wing legs. This has been explained in the simulation of the mechanism and has been animated.

Two triangular components are provided on both sides of the base of the wheelchair facing upwards. They are the base level of the seating arrangement. On the top of these triangular components the seat is mounted. With all the components discussed here and mentioned above the exact model of the proposed walking wheelchair is shown in the figure 1.

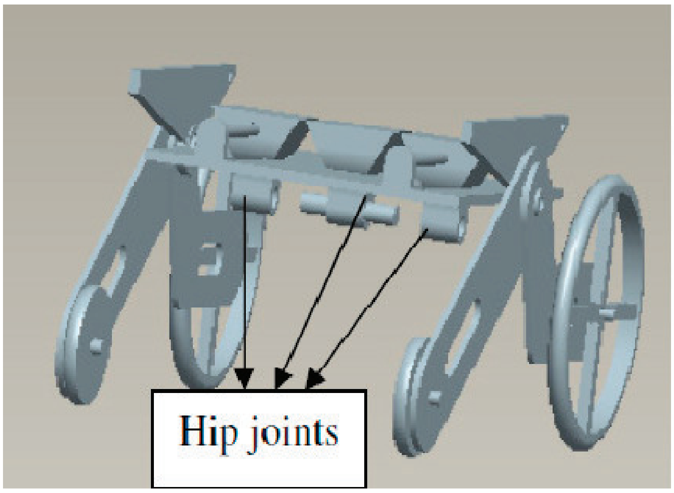

Fig.1. Wheelchair base interfaced with hip joints.

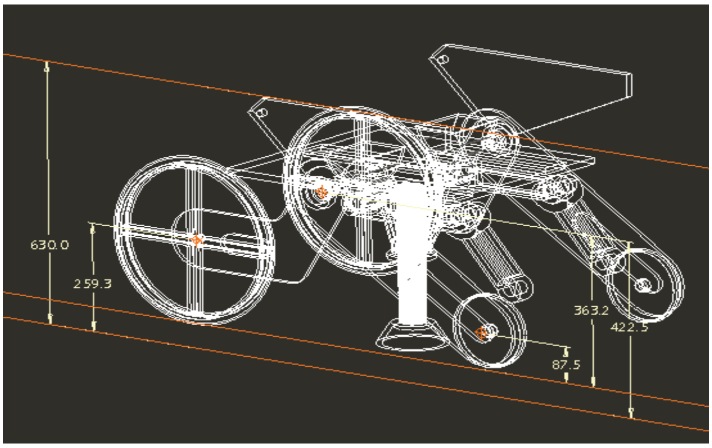

Fig.2. Wire frame model of the wheel chair and leg assembly.

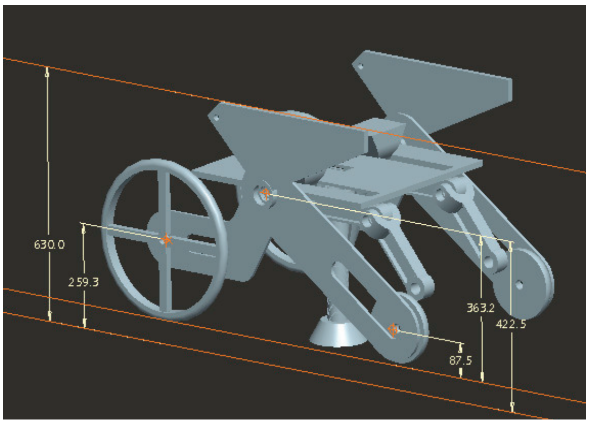

Fig.3. Solid model of the wheel chair and leg assembly with dimensions

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In the co-operative environment, interference of manipulators are possible and are designed productive instead of destructive. This is done by the proper trajectory planning. In walking, the transfer of potential energy and kinetic energy is utilized in the walking wheelchair mechanism.

In the stair climbing process an ultrasonic sensor is used to analyse the dimensions of stairs in the form of raise and plinth. Then the controller used decides the position of wing legs when the whole mechanism is being lifted by the screw jack. During the first raise the stress and strain intensities are analysed to be high than the following steps. The length and size of the legs are designed in such a way that the next stair will not hinder the stair climbing process and similiarly the previous stair will not hinder the process of stair climbing down process. In all the cases the platform of the wheelchair is kept horizontal and the wheels are lifted above the platform of wheelchair level to act as a counterbalance to support the walking/stairclimbing process.

Figure explaining the wireframe model of the integrated mechanism identifies the intensity of co-operative manipulators to take and share the load among the mechanism. Any interference of the components into the work envelope of the other component can be easily identified by the wire frame model. Figure showing the solid model of the integrated mechanism and some isometric views of the walking wheelchair is shown in above figures. The triangular elements facing upwards fixed on the base of the wheelchair provides the base of the wheelchair seating arrangement. This is explained in the isometric views of the mechanism.

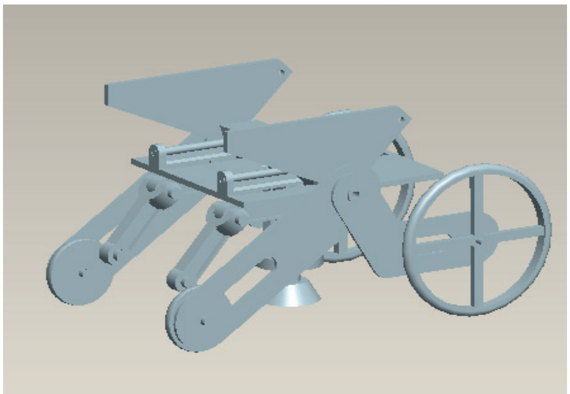

Fig.4.1 Isometric RHS view of the proposed mechanism

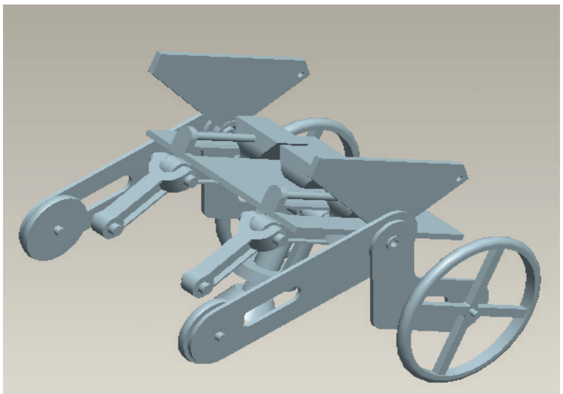

Fig.4.2 Isometric tilted top view of the proposed mechanism

Figures shown above infers the walking wheelchair designed with less weight and simple components to assemble the legs through the hip joints provided on the slots of the base of the wheelchair . This can be used as a normal wheel chair which can move with very less energy consumption. Either manually or propelled wheelchair, this can perform its task in a reliable manner. Figure salso infers the assembly of the legs. Wheels and the wheel connecting links are removed for clear visibility. The screw jack leg will be over hanging when the wheel are grounded. The height of the base of the wheelchair is 363.2mm and the height of the screw jack at fully retracted condition is 351.2mm. This provides a minute 12mm clearence of the screw jack leg touching the ground and the weight of the screw jack leg also will be carried by the wheelchair during wheeling process. The reason for the clearance given to the screw jack leg given is to reduce the jerkless operation of the lifting of the whole system. If the clearance in more, when the walking command is given the screw jack will extend to touch the ground. This may produce a impact load on the screw jack leg, if the clearnance is more and will be ultimately transferred to the whole mechanism. The wing legs will kept in the retracted condition.

From the base of the wheelchair to the seat arrangement base there will a space of 120mm. This space can be used to keep the electrical and electronics components like battries or motors as explained before. The whole system weighs roughly about 65kgs and can accomadate an average load of 80kgs and just above on it during both wheeling and walking mechanism. Since the results are oriented purely on the mechanism of the skeleton of mechanical components, any inclusion of components both electrical and electronics oreinted should be considered accordingly as per the individual properties of included components. And these components should be placed syemmtrically within the golden ratio of the wheelchair discussed before. Care should be taken in placing the components, since the major concept of this walking mechanism is based on center of gravity.

2.Analysis:

In the analysis phase the vital areas are identified on the basis of maximum load bearing position, maximum load bearing time and maximum failure zone. Depending upon the movement it differs. Like for stair climbing all the legs will be active parts where as wheels are passive parts. Wheels acts as counter balance to support walking.

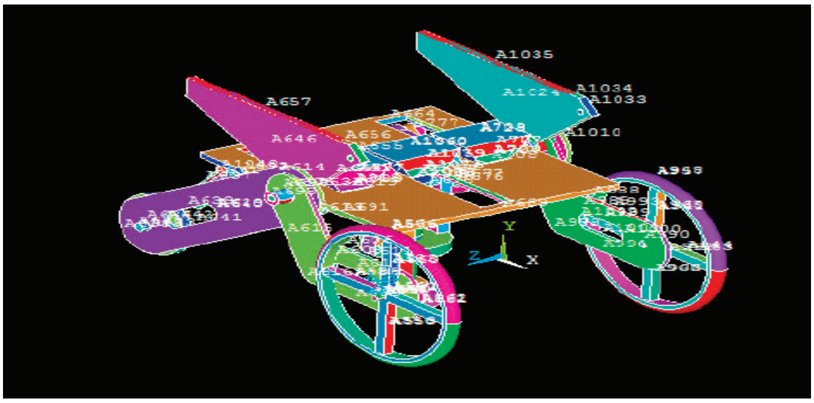

Fig.5. Identification of stress concentrating areas

Then the wheelchair is meshed with triangualar components for nodal analysis. In this analysis a thorough checkup is done on the elements of the wheelchair to avoid failure in any mode during the walking or stair climbing process. Since the wheels and most of the components connected with the platform is being lifted above the stress/strain intensity to cause failure is very minimal.

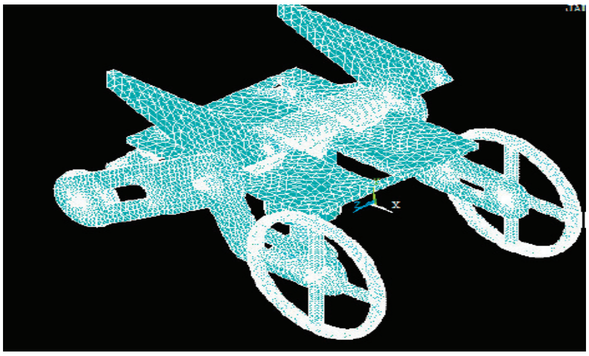

Fig.6. Meshed sequence of wheelchair

The mechanism integrated with the co-operative manipulators are then analysed separately and some of the results are tabulated below:

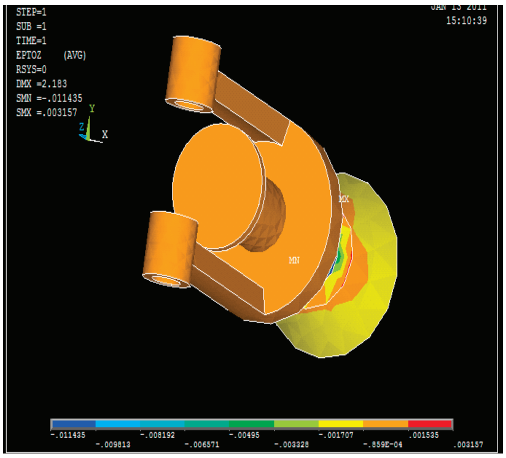

Fig.7. Elastic stress intensity on the screwjack mechanism

From figure.7, it can be inferred that the elastic stress intensity is concentrated much towards the stem region of the screwjack mechanism than the other areas. As the load carrying capacity of screwjack is well known, it can be justified that the whole system can be lifted and moved by the screwjack mechanism without failure. It is also analysed that the failure at joints are highly restricted during even eccentric loads, jerks and abnormal vibrations.

The hub of the screwjack mechanism is separately tested for the maximum load carrying capacity and its found to be more than the maximum load of the system with eccentricity caused by it. Diagram below shows the distribution of stress intensity during the working phaseof the whole system. It is understood that the connecting region pays a less failure intensity and thus provides the ability of the system in load carrying capability as co-operative manipulator.

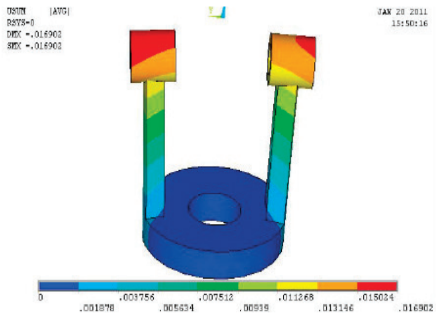

Fig.8. Mechanical stress intensity on the hub of screwjack mechanism

Finally the whole active co-operative manipulators components are analysed for the failure rate after elemental analysis the following figure shows the result:

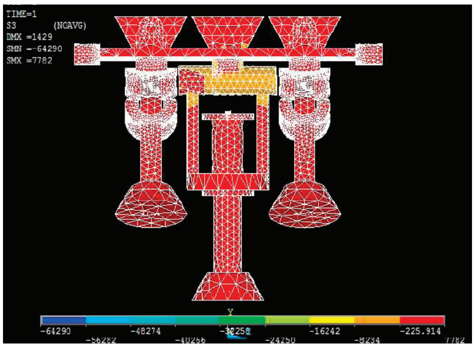

Fig.9. Nodal analysis of stress concentration on the screwjack mechanism during raise

It is analysed that the stem and joint region of the whole leg mechanism is subjected to the maximum deformation range. Though the deformation range is maximum it is much less than the failure range for the functional phase of the whole system.

3.Conclusions:

During the various functional phases the cooperative manipulators are subjected to follow various kinematics of serial and parallel manipulators. The results are obtained after subjecting each component of the cooperative manipulators and were tabulated. The efficiency of the proposed mechanism is thus proved by the results that have been produced. It is found in through the results that the components that work individually are subjected to more stress and deformations for the same load and constraints made than that of the components which are cooperatively performing the same task. Even the ability of the components that are jointly doing the task has been proven good. Thus the designed co-operative manipulators integrated wheelchair mechanism can be applied for walking and stair climbing process with a normal person of 80Kgs with out any jerk or vibrations. Further the whole system can be enhanced by proving more sensors to obtain feed back from the walking/stair climbing phase and can be real time based working co-operative environment. But more care should be taken in the tracjectory planning and other functions related to walking of the mechanism than the wheeling process of the mechanism. Study for providing the angles for various staircase heights and velocity needed for the foot to reach the target as inputs and applying artificial neural networks the stair climbing process can be made autonomous within the limits of the wheelchair leg dimensions.

References:

1. Hassan. S., Anwer. N., Khattak. Z. and Yoon. J. ,2010, 'Open architecture dynamic manipulator design philosophy', *Robotics and Computer-Integrated Manufacturing*, **Vol. 26**, pp.156–161.
2. Derek C. Schuurman and David W. Capson, Robust Direct Visual Servo Using Network-Synchronized Cameras, *IEEE Transaction on Robotics and Automation*, **Vol. 20**, NO. 2, pp.319-334.
3. Lawn M.J. and Ishimatsu T. 2003, 'Modeling of a stair-climbing wheelchair mechanism with high single-step capability', *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, Vol. 11, No. 3, pp.323–332.
4. Gaetano Paviglianiti, Francesco Pierri, Fabrizio Caccavale and Massimiliano Mattei, 2010, Robust fault detection and isolation for proprioceptive sensors of robot manipulators, *Mechatronics* **Vol.20**, pp.162–170.
5. Jay Lee, 1987, Computer-Aided Robot Modelling, Programming and Simulation, *Elsevier Science Publishers, Robotic*s **Vol.3**, pp.399-408.
6. Gao.Z., Zhang. D and Ge.Y, 2010, 'Design optimization of a spatial six degree-of-freedom parallel manipulator based on artificial intelligence approaches', *Robotics and Computer - Integrated Manufacturing*, **Vol. 26**, pp.180–189.
7. J. Angeles and O. Ma, "Performance evaluation of four-bar linkages for rigid-body guidance based on generalized coupler curves," *ASME J. Mech. Des.,* **vol. 113**, no. 1, pp. 17–24, 1991.
8. J. Angeles, "The design of isotropic manipulator architectures in the presence of redundancies," *Int. J. Robot. Res*., **vol. 11**, no. 3, pp. 196–201, 1992.
9. M. Jamshidi, H. Seraji and Y.T. Kim, 1987, Decentralized Control of Nonlinear Robot Manipulators, *Elsevier Science Publishers, Robotics* **Vol.3**, pp. 361-370.
10. Renato Tinos and Marco Henrique Terra, 2002, Control of Cooperative Manipulators with Passive Joints, *Proceedings of the American Control Conference*, pp 1129-1134.
11. Nilanjan Chakraborty and Ashitava Ghosal, 2004, Kinematics of wheeled mobile robots on uneven terrain, *Mechanism and Machine Theory* **Vol.39**, pp.1273–1287.
12. Vitiello N, Lenzi T, De Rossi, S.M.M, Roccella S. and Carrozza M.C., 2010, 'A sensorless torque control for antagonistic driven compliant joints', *Mechatronics*, **Vol. 20**, No. 3, pp.355–367.
13. L. J. Stocco, S. E. Salcudean, and F. Sassani, "On the use of scaling matrices for task-specific robot design," *IEEE Transactions on Robotics and Automation*, **vol. 15**, no. 5, pp. 958–965, Oct. 1999.