Exo-Skeleton for Handheld Power Tools

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***Abstract* -The primary objective is to design and fabricate an exoskeleton that helps workers in factories to work for long hours without any physical fatigue. The exoskeleton designed shall assist the workers to hold and work with power tools like cutting and drilling machines without transferring the weight of the machine to the worker, thereby reducing occurrence of human fatigue. Instead, the setup transfers the weight of the machine directly to the ground. The power tools can be mounted on the exoskeleton rigidly and can be moved in three dimensional axes, according to the requirements of the worker. The exoskeleton designed has the same degrees of motion as that of the human knees and hip joints. A major feature of this exoskeleton is that it can be operated manually without any requirement for power source.**

Keywords – Exoskeleton, hinges, fatigue, kinematic joint, power tool

INTRODUCTION

An exoskeleton is a wearable, mobile machine that allows limb movements and also assists the user at specified tasks. Exoskeletons are placed on the user's body and act as amplifiers that augment, reinforce or restore human performance. The term "Exoskeleton" is derived from the Greek word 'exo' meaning outer and 'skeletos' meaning skeleton. The exoskeleton that has been made by us is a passive exoskeleton.

This development of exoskeleton for handheld power tools uses simple mechanism and kinematic joints. The design is environment friendly and uses just links and hinges, and it is very easy to understand.

India being a developing country, Industrial sector is improving day by day and that paves way for more skilled workers. When enquired about the difficulty, the important one was holding the heavy tool in the required position for long hours during work. This adversely affected them lately. We thereby made an exoskeleton that can hold a power tool at the required height and transfer its weight to the ground through the links. So, the workers will not get fatigued soon and can work for the required hours without overstressing their body.

It is a rectangular frame that is been cut to required lengths according to the user's height and connected using welds and hinges. And the tool is mounted on a ball joint which is mounted on a scissor jack. This exoskeleton is a passive exoskeleton. It is operated manually by rotating the scissor jack to elevate or lower the power tool.

OBJECTIVES

- To develop an exoskeleton to hold the power tools.
- To fabricate the exoskeleton at low cost and in less time.
- It should serve the purpose by transferring the weight to the ground.

COMPONENTS

1) FOOT PLATE

The foot plate acts as the base of the exoskeleton. It transfers the weight of the exoskeleton and the tool to the ground. It is fixed to the lower limb frame by welding. It also has Velcro strips for fastening around the foot of the worker. It is made of mild steel.

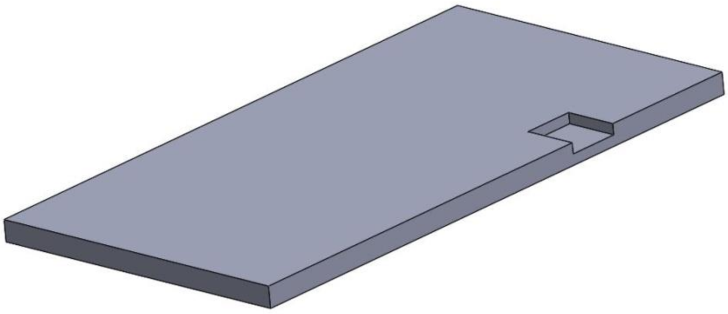

Fig 1 Foot Plate

2) LOWER LIMB MEMBER

The lower limb member is fastened around the lower limb of our legs. It is attached to the upper limb by hinges and is welded to the foot plate. It has Velcro strips for fastening around the lower limb of the worker. It is made of mild steel. It transfers the weight of the machine to the ground.

Fig 2 Lower limb member

3) UPPER LIMB MEMBER

The upper limb member is fastened around the upper limb of our legs. It is attached to the lower limb and the hip frame with hinges. It has Velcro strips for fastening around the upper limb of the worker. It is made of mild steel. It transfers the weight of the machine to the ground.

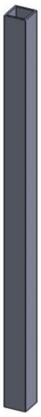

Fig 3 Upper limb member

4) HIP MEMBER

The hip member acts as the base for holding the power tool. The hip frame is in the shape of a square. The front portion of the frame can be removed and mounted easily whenever required by using bolts and nuts. On top of the front portion of the hip frame, the scissor jack is mounted. The rear part of the hip frame consists of an extension on which the counter balance weight discs are placed. This frame is attached to the upper limb members by hinges.

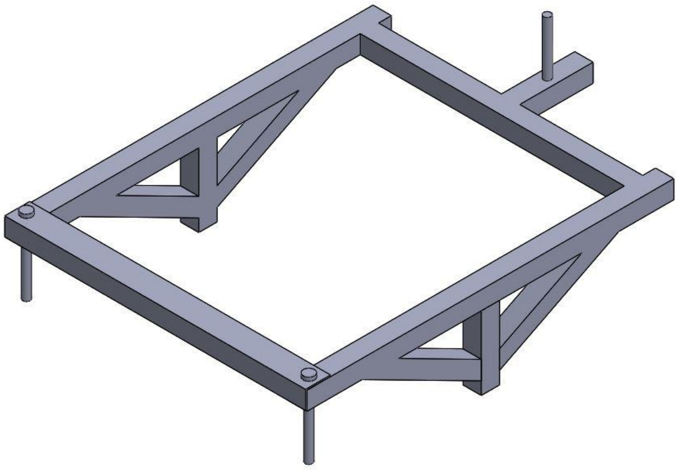

Fig 4 Hip member

5) SCISSOR JACK

The scissor jack is mounted rigidly on the front member of the hip frame. The scissor jack has four main pieces of metal and two base ends. The four metal pieces are all connected at the corners with a bolt that allows the corners to swivel. A screw thread runs across this assembly and through the corners. As the screw thread is turned, the jack arms travel across it and collapse or come together, forming a straight line when closed. Then, moving back the other way, they raise and come together. When opened, the four metal arms contract together, coming together at the middle, raising the jack. When closed, the arms spread back apart and the jack closes or flattens out again. This raising and lowering can be done manually or by using the servo motor attached to one end of the lead screw.

Fig 5 Scissor jack

6) COUNTERWEIGHT DISCS

A counterweight is a weight that is added to an unbalanced system to achieve force equilibrium. These counter weights are attached in the form of discs at the rear member of the hip frame. It helps to balance the exoskeleton when various machines are fixed on the scissor jack. The weights are added corresponding to the weight of the machine held on the scissor jack.

Fig 6 Counter weight disc

7) BALL JOINT

A ball joint is used for allowing free rotation in two planes at the same time while preventing translation in any direction, including rotating in those planes. Ball joints consist of a metal housing and stud. The stud can swing and rotate within the housing. Bearings inside the housing can be comprised of metal or plastic. The socket is filled with grease to provide lubrication, keep debris and water out of the socket, and maintain noise free operation. A rubber boot opening of the joint is used to keep debris out and grease in.

Fig 7 ball joint

8) HINGE JOINT

A hinge is a mechanical bearing that connects two solid objects, typically allowing only a limited angle of rotation between them. Two objects connected by an ideal hinge rotate relative to each other about a fixed axis of rotation: all other translations or rotations being prevented, and thus a hinge has one degree of freedom. Hinges may be made of flexible material or of moving components. Here, hinges are used to join the upper and lower limb members and to join the hip member and the upper limb members.

Fig 8 Hinge Joint

MODELLING

Front View, Top View and Side View

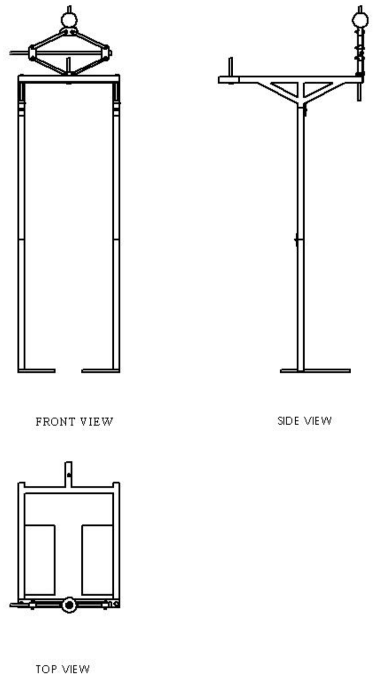

Fig 9 Front view, Top view &Side view

Isometric View

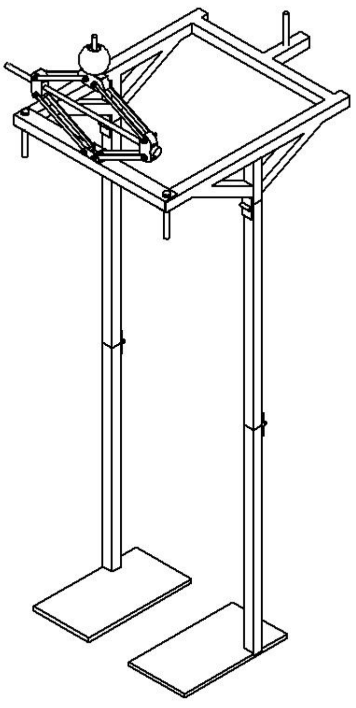

Fig 10 Isometric View

WORKING

- First, the exoskeleton is worn by the user by fastening the Velcro straps at the foot, lower limb of the leg and thighs.
- The front member of the hip frame is then mounted rigidly using bolts and nuts.
- The power tool to be used is fixed between the C clamps and is mounted on top of the ball joint assembly by using bolts and nuts.
- Then, the counter weight discs are inserted on the rear member of the hip frame.
- The weight of the counter weight discs is equal to the weight of the power tool mounted. This is done to balance the centre of gravity of the exoskeleton and transfer the weight to the ground.
- The ball joint allows complete rotational motion of the power tool in the horizontal plane.
- The power tool can also be moved up or down according to the users' requirement by using the scissor jack.
- This can be done manually or by using the servo motor.

CALCULATIONS

DEGREES OF FREEDOM:

A mechanism with l number of links connected by j number of binary joints or lower pairs (i.e. single degree of freedom pairs) and h number of higher pairs (i.e. two degree of freedom pairs), then the number of degrees of freedom of a mechanism is given by,

$n = 3 (l – 1) – 2 j – h$ ... (i)

This equation is called Kutzbach criterion for the movability of a mechanism having plane motion. If there are no higher pairs, then h = 0. Substituting h = 0 in equation (i), we have

$n = 3 (l – 1) – 2 j$ ... (ii)

Here, all the joints are lower pairs. Therefore h = 0.

a) DOF for left knee joint:

$n = 3 (l – 1) – 2 j$
$= 3 (2 – 1) – 2*1$
$n = 1$

Degree of freedom of the left knee joint (DOF) = 1

b) DOF for right knee joint:

$n = 3 (l – 1) – 2 j$
$= 3 (2 – 1) – 2*1$
$n = 1$

Degree of freedom of the right knee joint (DOF) = 1

c) DOF for left hip joint:

$n = 3 (l – 1) – 2 j$
$= 3 (2 – 1) – 2*1$
$n = 1$

Degree of freedom of the left hip joint (DOF) = 1

d) DOF for right hip joint:

$n = 3 (l – 1) – 2 j$
$= 3 (2 – 1) – 2*1$
$n = 1$

Degree of freedom of the right hip joint (DOF) = 1

DEFLECTION:

Maximum weight of the machine that can be mounted on the scissor jack = 50N (5kg)

1) Maximum deflection of scissor jack base:

Deflection = $(Wl^3)/ (48EI)$

$I = (bh^3-b_1h_1^3)/12$
$= ((25*25^3)-(21*21^3))/12$
$I = 16345.33\ mm^4$

Therefore,

Deflection = $(50*340^3)/ (48*2*10^5*16345.33)$

Deflection = 0.0125 mm.

2) Maximum deflection of counter weight holding member:

Deflection = $(Wl^4)/ (30EI)$

$I = (bh^3-b_1h_1^3)/12$
$= ((25*25^3)-(21*21^3))/12$
$I = 16345.33\ mm^4$

Therefore,

Deflection = $(50*100^4)/(30*2*10^5*16345.33)$

Deflection = 0.0509 mm

ANSYS:

Load applied: 50 N

Type of test: Total Deformation

Maximum Deformation: 0.0849 mm

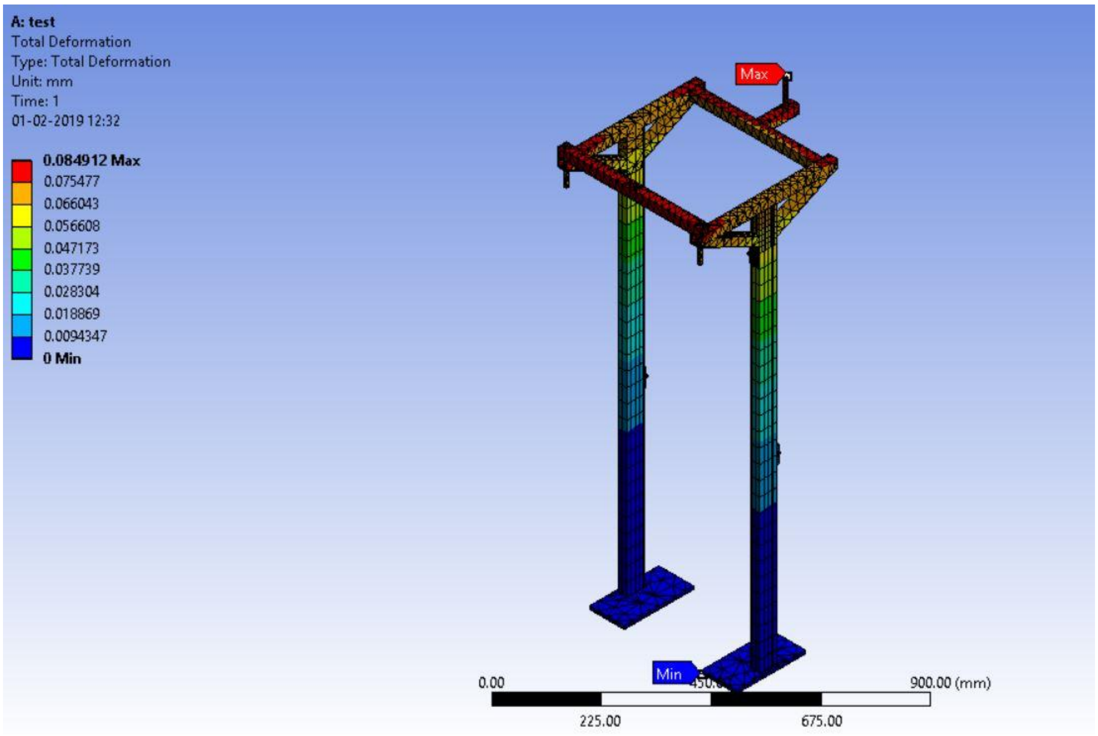

Fig 11 Total Deformation

MERITS

- Does not require power supply.
- Improves safety.
- Increases productivity of the workers.
- Increases the longevity of the workers' health.
- Helps to hold the correct posture without fatigue.

DEMERITS

- Joint contractures at the hips, knees, and ankle joints.
- Cost increases if the exoskeleton uses neurosensors and other such technologies for complete automation.

FUTURE SCOPE

- Use of lightweight alloys with good tensile strength for manufacturing can reduce the weight of the exoskeletons.
- The joints in the exoskeleton can be made in such a way that they have more degrees of freedom but maintain the rigidity to withstand the load given.
- Production in large scale can reduce the cost of the exoskeletons considerably.
- Motors and sensors can be implemented for automation of the exoskeleton.

CONCLUSION

This exoskeleton we fabricated was designed keeping the lower body of the humans in mind. It has two joints and four links with degrees of freedom similar to the human knees and hip joints. Also, these links act as a medium to transfer the weight of the power tool to the ground. The links are attached to the hip member which holds the scissor jack.

The design was then finalized and drafted and analysis was done using ANSYS for total deformation. This exoskeleton was designed primarily for the functions of holding the power tool and transferring it to the ground. This helps to reduce the fatigue caused to the workers and improves the longevity of their health.

ISSN: 2278-0181
ICONEEEA - 2k19 Conference Proceedings

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