

# MASTER-SLAVE MANIPULATOR GUN

Sanket Gorade<sup>1</sup>, Atul Dighe<sup>2</sup>, Rutuparna Kale<sup>3</sup>, Ameya Bhase<sup>4</sup>, Dr. A. S. Bhongade<sup>5</sup>

<sup>1-4</sup>Student, Dept. of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, India

<sup>5</sup>Professor, Dept. of Mechanical Engineering, Bharati Vidyapeeth College of Engineering, Navi Mumbai, India

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**Abstract** - Mechanical manipulators are being used for various applications related to radio-activities, medical research, manufacturing industries, safety measures, etc. Our project demonstrates on how a gun can be controlled by using mechanical master-slave manipulator separated by a defensive shield. This technology can be used in defense sector to aid soldiers by avoiding their exposure from the danger of getting shot by the enemy. This paper explores the above concept in detail and the review of the various applications of a MASTER-SLAVE MANIPULATOR.

**Key Words:** extended reach manipulator, master slave manipulator, gun, mechanical manipulator, degrees of freedom.

## 1. INTRODUCTION

The project is based on remote handling, where the remote handling is the operation, in which manual tasks are performed without human intervention at the work site. The use of remote handling equipment enables the people, to maintain a safe distance in hazardous work environments. The remote handling strategy depends on the risk and the complexities associated with task. The basic mode of remote handling devices are using tools which extend throughout the length of the standard tools. It helps to provide a safe distance between the dangerous environment on the remote site and the operator. A remote handling tong consist of an assembly of following basic tools: gripper, a handle and a connecting rod. It can be installed in a shielding wall or hung on a carrying system. Depending upon source of power or electricity used to actuate the mechanism, the MSMs are classified into Mechanical MSMs and Electrical MSMs (Servo Manipulators). The same technique can be implemented in a war-fare situation with the weapon on the battlefield and the soldier behind the shield. This paper explains the above idea in brief.

### 1.1 Motivation

Until recent times, the border of Indian territories are secured by the Indian Army by building bunkers for surveilling the area covered by the bunker and protecting the villages near the borders. These bunkers have open blocks for the soldiers to survey the border and aim the enemies, but while peeping through the narrow space they possess the danger of coming under the range of the enemies as their upper portion of the body gets exposed. To avoid such danger due to the exposure, we have come up with an alternative

solution of Master Slave Manipulator Gun in which the soldier controls the Gun and perform the motion through Master Arm inside the bunker and these motions are transmitted through mechanical system to the Slave Arm where the Gun is fitted externally to the bunker.

### 1.2 Why mechanical manipulator instead of electrical one?

The first fundamental question comes here that why to use Mechanical Manipulators instead of Electrical Manipulators for the operation of Master and Slave Arms. The Electrical Manipulators works on Servomotors, Sensors and many electrical parts which requires a good source of electricity. But in the remote areas of the borders it is sometimes not possible to supply constant electricity to the bunkers. The usage of servomotors and various sensors also add up to the initial costs as well as maintenance and replacement costs. On the other hand, Mechanical Manipulators do not require any electricity supply for the transmission of the motions and the lifespan of the Mechanical Manipulators are much greater than Electrical Manipulators because of the use of long-durable and corrosion, wear & temperature resistant materials for its construction.

## 2. MECHANICAL MASTER SLAVE MANIPULATOR

In master slave manipulation process, the human i.e. the user, while being within the process; his manipulative, interactive and decision-making capabilities are extended to the remote site.

### 2.1 Construction

The MSM tool has two arms, a master arm in the operating area and a slave arm in the remote site. The master arm is provided with a handgrip and the slave arm with a gripper at their respective free ends. Like a human arm or a robot manipulator, the slave arm of an MSM consists of a series of links connected together through joints. Usually, the arms would have minimum six motions for arbitrarily positioning the gripper. For specifying the configuration of an object in space, 6 Degrees of Freedoms are needed: 3 for position and 3 for orientation.

### 2.2 Working

When the operator(user) holds the master-gripper provided on the handgrip and moves it along the desired path, the slave gripper on the slave arm reproduces the exact motion

on the remote site. Extended Reach Master Slave Manipulator has six independently controlled joints (six Degrees Of Freedom) for arbitrary positioning, actuating and orientating the object. Power is transmitted from the master arm to the slave arm through an assembly of stainless steel wire ropes, stainless steel tapes and a parallelogram mechanism. The force and torque applied by the operator also gets reproduced on the slave gripper. The operator can get visual feedback of the hot cell, through the viewing window and camera to aim at the target.

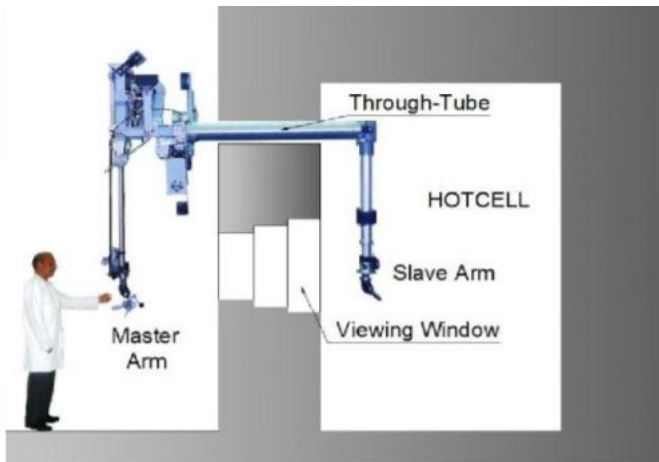


Fig-1: Master Slave Manipulator

## 2.3 Degrees of Freedom

### 2.3.1 X-Motion ( $\pm 45^\circ$ ):

It is the movement of the manipulator in a side-to-side plane across the front of the viewing window. The motion is transmitted by side-to-side movement of the handle to the master arm and through tube.

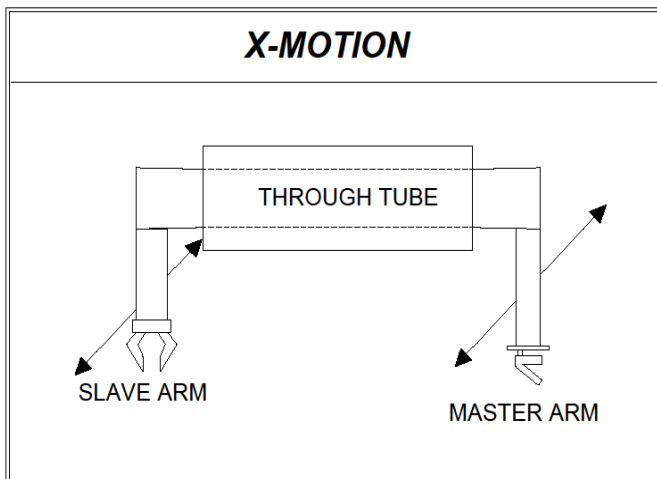


Fig-2: X-motion of MSM

### 2.3.2 Y-Motion ( $+28^\circ$ & $-20^\circ$ ):

It is the movement of the manipulator in a plane perpendicular to the wall and viewing window. The mechanical connection between the arms is through parallel tie rods within the through tube.

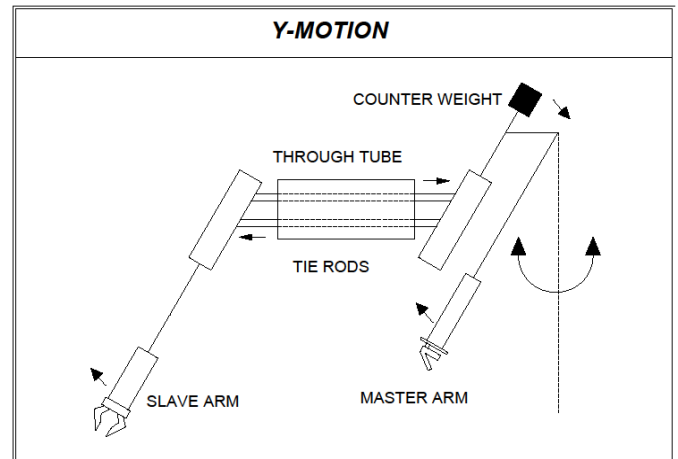


Fig-3: T-motion of MSM

### 2.3.3 Azimuth ( $\pm 170^\circ$ ):

Azimuth rotation is the simultaneous movement of each boom tube about its own axis to cause rotation of wrists, handle and tongs.

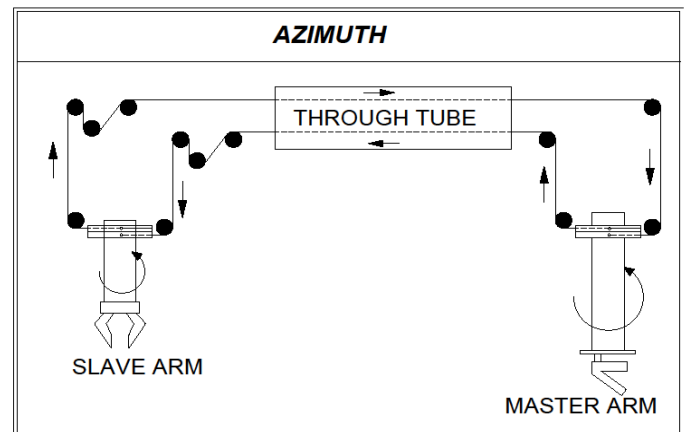


Fig-4: Azimuth motion of MSM

### 2.3.4 Wrist Elevation (EL):

It is up and down angular displacement of the handle and tongs in the plane of the boom tubes.

### 2.3.5 Wrist Rotation:

It is the rotary motion of the handle and tongs about the axis of the differential pinion. The master and slave wrists are taped so that handle rotation will cause differential pinion rotation.

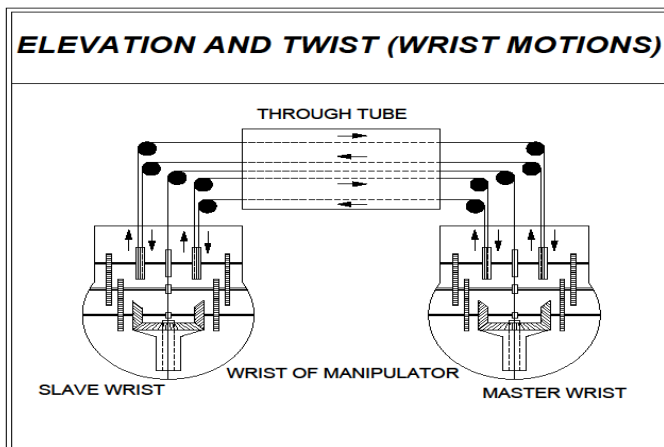


Fig-5: Elevation and twist motions of MSM

### 2.3.6 Triggering Motion:

A gripper is attached at the end of slave arm to which a gun is attached. To trigger the gun, a handle is given on the master arm which is connected through rope and pulley mechanism.

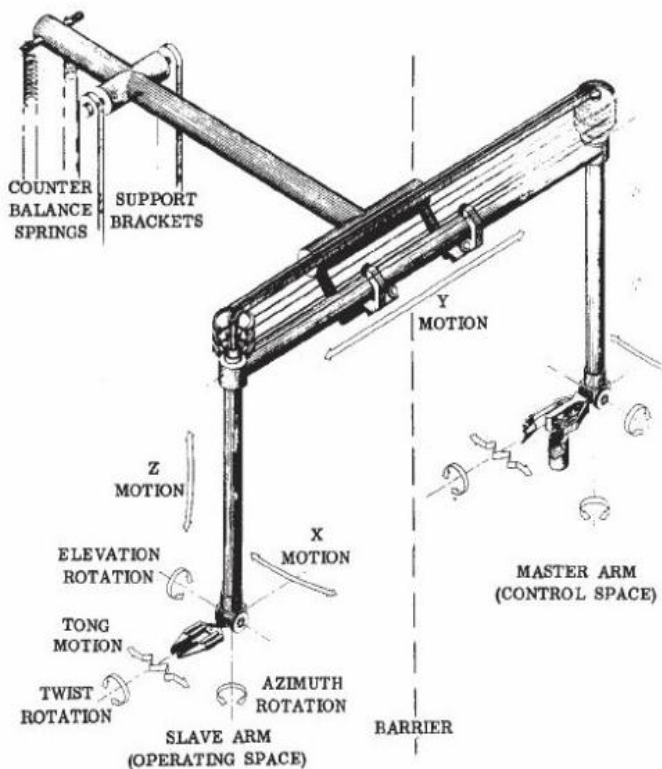


Fig-6: Types of Motions

## 3. LITERATURE REVIEW

### Hot cell applications:

[A] A. Palanivel and et.al.[1] made development of **EXTENDED REACH MANIPULATOR FOR HOT CELL APPLICATIONS.**

Extended manipulators (ERM) are specialized master type manipulators to cover more work space. They put human hand in place instead of using radioactive material after extensive protection in the hot cells of nuclear machines to protect the personal environment and harmful radiation. ERM is applied to hot concrete cells, which assist in the remote operation of metal detectors, chemical process management, operation and maintenance of radioactive chemical equipment in hot cells. The master's arm is in the workplace and the slave's arm is inside a hot cell connected to a network of equipment, pulleys, taps and wires. The slave side is provided with a boot so that radiochemical arm contamination is avoided. Movement is transferred to the arm of the slave with a gain of 1: 1.

[B] **MASTER SLAVE MANIPULATOR developed by Kosuke Kishi[2]**

A large-scale tool works including a remote decoy tool, manipulator, and control unit. The remote control device like a master provides a command of operation that corresponds to a number of levels of freedom. The manipulator of slaves involves the multiplicity of interactions that correspond to the levels of freedom. The slave manipulator involves a joint assembly between the members. The control unit regulates member operations in accordance with the operating command. The control unit calculates the flexibility of the graphical device that is farther away from the operating command at set intervals over a period of time and selects and pulls one of the joints to a positive re-relationship between the members in the dance integration by alternating rotation.

### Medical field applications:

[A] **Development of DUAL-ARMED SURGICAL MASTER-SLAVE MANIPULATOR SYSTEM WITH MR COMPATIBILITY is done by Kosuke Kishi and et.al.[3]**

We suggest that the manipulator surgical system support surgical treatment and diagnosis for intraoperative disease. Manipulators equal to vertical-magnetic-field open-set-magnetic resonance (MR) images, and surgical instruments at the end of the manipulator arm are interchangeable. We explored how we could work out slave labor using an input device equipped with a pair of instruments and a console. We have done basic cleaning jobs in training materials that mimic human tissues and small blood vessels.

#### **[B] DEVELOPMENT OF A PNEUMATIC SURGICAL MANIPULATOR IBIS IV is done by Kotaro Tadano and et.al.[4]**

In non-wireless, non-invasive surgical systems, the balance and transmission of operator power is problematic. In order to perform safer and more efficient operations using robot manipulators, power measurement and response of the controller are the most important factors. We have previously proposed a pneumatic surgical manipulator that can measure external force without the use of Force sensors. However, the army equation had a sensitivity of only 3 N due to the effects and effects of the collision. In this paper, we create a new and improved model of pneumatic surgical manipulator, IBIS IV. It also operates its operations according to mandatory measurements. Test results show that IBIS IV estimates foreign forces with a sensitivity of 1,0 N. We also perform in-vivo tests and confirm the operation and optimization of the control machine.

#### **[C] THE MECHANICAL MASTER-SLAVE MANIPULATOR: AN INSTRUMENT IMPROVING THE PERFORMANCE IN STANDARDIZED TASKS FOR ENDOSCOPIC SURGERY developed by J. Diks and et.al.[5]**

Background: This study aims to evaluate the feasibility and effectiveness of non-invasive endoscopic surgical instruments. Contrary to the current practice of motor-servant manipulators, these machines have two mechanical, hand-operated arms that strengthen seven freedom members (DOF). Methods: In this study, 30 medical students performed four different tasks in a pelvic trainer's box using two standard needle presses or a set of mechanical players. The exercises involved four different activities: repositioning coins, passing ropes, passing fences with rings and tying a surgical knot. The entire survey was recorded on videotape (S-VHS), and the data were subsequently analyzed by an independent observer using time-based analysis. Results: Significant differences in the number of total actions (including failures) liking the mechanical mehndi group were largely shown in the exercise. Significant differences in failure to perform each task have been shown to be appreciated by the mechanic manipulator team. No significant differences were observed in the total duration of each exercise. Conclusions: The works have clearly demonstrated the effectiveness of the mehndi it uses, even though some technical errors have been incurred during the test. Considering the fact that the first type of man-made machine has been tested, the following model will be modified.

## **4. DESIGN AND DEVELOPMENT**

### **4.1 Problem Statement:**

Soldiers are constantly at a risk of getting attacked if they are exposed in the range of the enemy. By implementing Master Slave Manipulator Gun, they can be protected and the risk of getting attacked by the enemy can be gradually reduced.

### **4.2 Methodology:**

To solve the above given problem, using the MSM (Master-Slave Manipulator) mechanism is an alternative, that is currently used in the hot cells of nuclear reactors.

The Master-Slave Manipulator Gun is made up with components such as master arm, slave arm, through tube, a rope-pulley mechanism, a trigger mechanism and a gun holder, as shown in fig 3.1. The handgrip is replaced by a trigger mechanism and the gripper with a gun holder. The entire layout was sketched on paper, gave the best estimate of dimensions required to proceed further. After getting the layout ready on paper, 2D sketches of essential components were made on AutoCAD. Inferences from the 2D sketches helped lead to creating 3D modelled parts on SolidWorks. After that all the parts were assembled along with the shield. Post-assembly, whether the master arm reciprocates well with the slave arm was checked. After setting the constraints properly, the mechanism worked exactly according to our expectations. All the prior steps ensured that the fabrication was up to the mark.

In this way remote handling by manipulating the movements of Slave arm through Master arm of the MSM can be achieved, alongside the safety of the soldier.

### **4.3 Material Selection:**

The proper selection of materials for the different part of a machine is the main objective in the fabrication of machine. For a design engineer it is must that he/she be familiar with the effect, which the manufacturing process and machining have on the properties of material. The selection of material for engineering purpose depends upon the following factors;

1. Availability of the materials.
2. Suitability of materials for the working condition in services.
3. The cost of materials.
4. Physical and mechanical properties of material.
5. Mechanical properties of material.

The mechanical properties of the metal are those, which are associated with the ability of the material to withstand mechanical loads and forces. These properties as follows:

1. Strength.
2. Stress
3. Weight.

The selection of the material depends upon the various types of stresses that are set up during operation. The material selected should withstand it. Other criteria for selection of metal depends upon the type of load because a machine part resist more easily than a live load and live load more easily than shock load.

Selection of the properties depends upon factor of safety, which in turn depends upon the following factors;



1. Reliabilities of properties.
2. Reliability of applied load
3. The certainty as to exact modes of failure
4. The extent of initial stresses set up during manufacturing
5. The extent loss of life if failure occurs
6. The extent of loss of properties if failure occurs

#### 4.3.1 Materials Selected in Equipment

##### Body material used:

- Aluminum

##### Reasons:

1. Aluminum is readily available in market.
2. It is economical to use.
3. It is available in standard sizes.
4. It is light in weight.
5. It has corrosion resistance
6. It is recyclable.

##### Properties of Aluminum:

Aluminum is a light metal, about the third of the density of copper, steel, and brass. Aluminum exhibits good corrosion resistance to common atmospheric and marine atmospheres. Its corrosion resistance and scratch resistance can be improved by anodizing. Aluminum can be severely deformed without failure. As it allows Aluminum to be formed by extruding, rolling, drawing, machining and other mechanical processes. Whereas it can also be cast to a high tolerance. cold working, alloying and heat-treating can all be utilized to tailor the properties of Aluminum. The tensile strength of pure Aluminum is approximate 90 MPa but this could be improved to over 690 MPa for heat treatable alloys. The incredible strength of material makes it possible to create light and exceptionally stable structures.

##### Material used for Gears, Pulleys and Cables:

- Stainless Steel

##### Reasons:

1. Stainless steel is low maintenance and durable material.
2. It can be cut, formed, machined and fabricated easily.
3. It has high resistance to corrosion.
4. It is used to make high strength components.
5. It has high quality and pleasing appearance.

##### Material used for Shielding wall

- Ballistic steel

##### Reasons

Ballistic steel provides the protection against armour piercing ammunitions.

#### 4.3.2 Materials of Construction:

SR. NO	Description	Material
1	Hand grip	Al- 6061- T6
2	Body	Al- 6061- T6
3	Through Tube	Al- 6061- T6
4	Differential housing(wrist)	Al- 6061- T6
5	Differential gear	SS 304
6	Pulleys	SS 304
7	Cable	SS 304
8	Wall	Ballistic Steel

Table -1: Raw Material & Standard Material

#### 4.4 Design Specification

##### 4.4.1 Design

The design of Master Slave Manipulator Gun essentially consists of a master arm connected to the slave arm through tie rods and through pipes. The master arm and slave arm consist of two eccentric pipes of varying diameter connected by a bearing to perform azimuth motion on both the ends. The handle is connected to the master arm through master wrist and the gun is connected to the slave arm through slave wrist. The wall is provided with the handle opening to facilitate in the Y-motion while reloading the gun magazine. The design of the manipulator helps in proper functioning of various motions that are performed on the Master Slave Manipulator Gun.

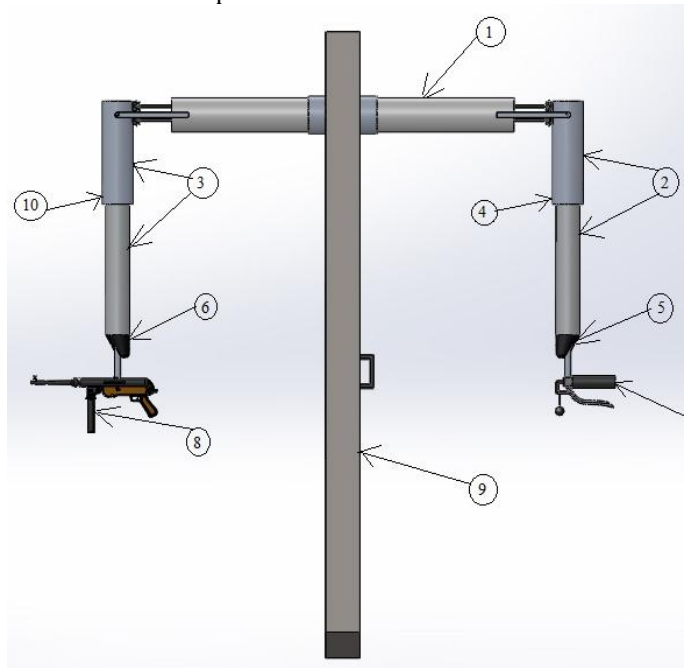


Fig -7: Master Slave Manipulator Gun SolidWorks Model

1.	Through tube
2.	Master arm
3.	Slave arm
4.	Master arm bearing
5.	Master wrist
6.	Slave wrist
7.	Handle
8.	Gun
9.	Wall
10.	Slave arm bearing

**Table -2:** Annotations of parts in Master Slave Manipulator Gun

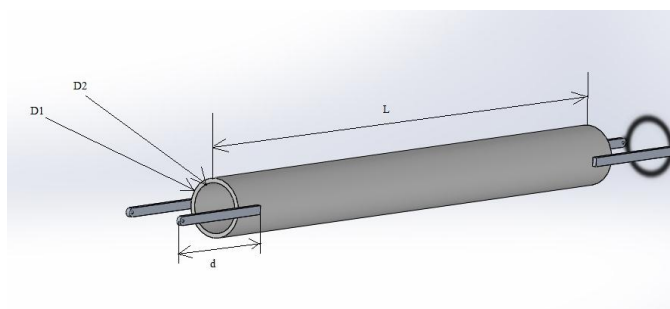
**4.4.2 Dimensions:**

1. Central distance between master and slave arm  
 $= A + 2C + 2D$   
 $= 121.92 + 2*10 + 2*6.655$   
 $= 155.23 \text{ cm.}$
2. Length of slave arm = 140 cm.
3. Length of master arm = 140 cm.
4. Wall thickness = 12.5 cm.
5. Diameter of first half of slave arm = 6.35 cm.
6. Diameter of second half of slave arm = 3.2 cm.
7. Diameter of first half of master arm = 6.35 cm.
8. Diameter of second half of master arm = 3.2 cm.
9. Diameter of through tube = 10.2 cm.

**4.4.3 Essential Parts:**

**1. Through Tube: -**

The through tube is responsible for the X and Y motion of the master and slave arm. It acts as the horizontal supporting structure for the entire assembly.



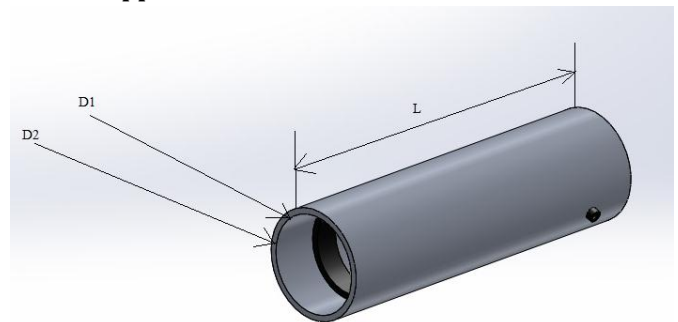
**Fig -8:** Through Tube

- Outer diameter, D1 = 7.62 cm
- Inner diameter, D2 = 7.41 cm
- Length of through tube, L = 122 cm
- Length of strips, d = 15 cm
- Width of strips, t = 2.5 cm.

**2. Master / Slave Arm: -**

The master arm and slave arm have two half arms connected to each other by roller bearings for transmitting the Azimuth rotation mechanism. Both the master arm and slave arm have similar structure and dimensions and performs motions identically.

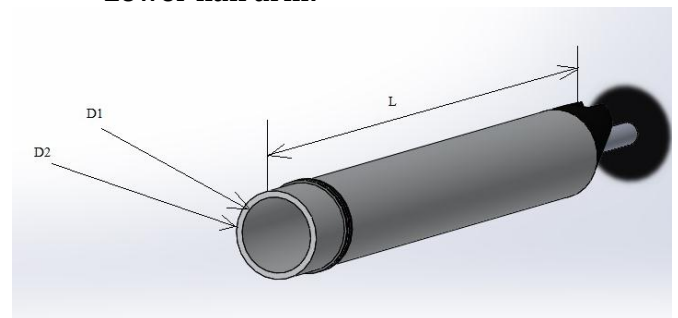
**Upper half arm:**



**Fig -9:** Upper half arm

- Inner diameter, D1 = 6.35 cm
- Outer diameter, D2 = 6.65 cm
- Length, L = 46 cm

**Lower half arm:**

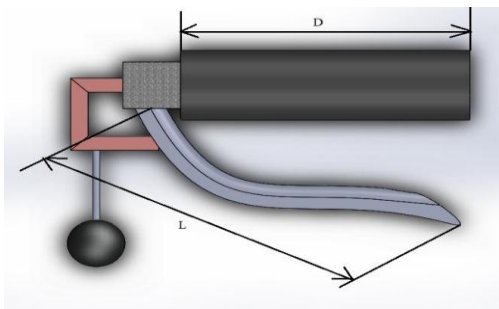


**Fig -10:** Lower half arm

- Inner diameter, D1 = 3.06 cm
- Outer diameter, D2 = 3.18 cm
- Length, L = 61 cm
- Total length of Master and Slave Arm=91.44 cm.

**3. Handle: -**

The handle is provided on the Master Arm to perform various motions and operation on the Gun. The handle should imitate the same motion with high accuracy and precision.



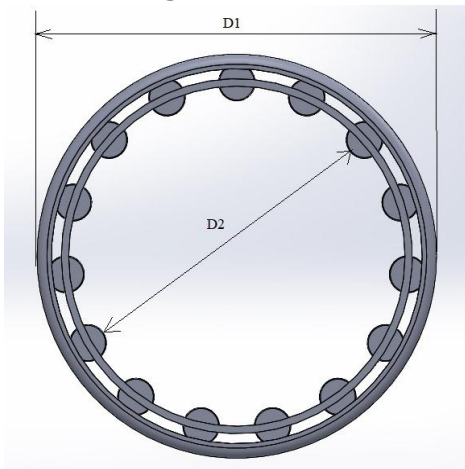
**Fig -11: Handle**

Length of handle,  $D = 12$  cm  
 Length of triggering lever,  $L = 15$  cm

**4. Bearings: -**

The bearings are fitted inside the master arm and slave arm and also inside the through tube and wall connection. The bearings facilitate the Azimuth rotation of the both the arms and X-motion of the through tube. Ball bearing is fitted in the master and slave arm while Roller bearing is fitted in the through tube and wall connection.

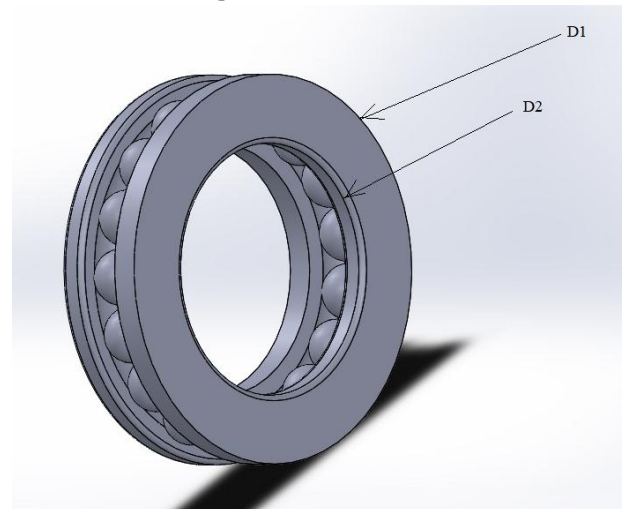
**Roller Bearing:**



**Fig -12: Roller Bearing**

Outer Diameter,  $D1 = 10.5$  cm  
 Inner Diameter,  $D2 = 9.51$  cm  
 Roller Diameter =  $0.45$  cm

**Ball Bearing:**



**Fig -13: Ball Bearing**

Bearing 6008,  
 Outer Diameter,  $D1 = 6.8$  cm  
 Inner Diameter,  $D2 = 4$  cm  
 Ball Diameter =  $1.05$  cm

**5. Wrist: -**

To hold the handle on the Mater Arm and the Gun on the Slave Arm.



**Fig -14: Wrist**

**6. Ropes and pulleys: -**

The ropes and pulleys are provided to perform the mechanical transmission of various motions in the manipulator.



**Fig -15: Rope and pulley**

**7. Bevel Gear: -**

In the bevel gears, axes of the two shafts intersect each other and their faces are conically shaped. Bevel gears are mounted on the shafts that are perpendicular to each other, and can be designed to any other angles.



**Fig -16:** Bevel Gear

**8. Spur Gear:-**

Spur gears are cylindrical gears with shafts that are always parallel & lies in the same plane. Their teeth are straight and oriented parallel to the shafts. They are used to increase or decrease the torque or power of an object and transmit motion from on shaft to another shaft.



**Fig -17:** Spur Gear

**9. Tie-Rod: -**

Tie-Rod is used to connect one end to the Master Arm and another end to the Slave Arm. The tie-rods works on the principle of parallelogram mechanism.



**Fig -18:** Tie Rod

**10. Gun: -**

The Gun is attached to the Slave Arm and its motion are controlled by the handle on the Master Arm through ropes and pulley mechanism. A separate motion has to be added for the triggering of the Gun.



**Fig -19:** Gun

**5. RESULTS**

The through tube connected to both the arms, provides right/left movement of the gun. The ropes and pulleys provide the rotation of the arms. The tie rods pivoted on both the arms, provide a parallelogram motion that enables the operator to move the gun to and fro in case there is a height adjustment required. Throughout the study, it is seen that the arms can carry weight up to 20 kg. It is also seen that if we increase the thickness of all the components, the bulking capacity will increase.



## 6. FUTURE SCOPE

Mechanically driven systems are of lower cost than hydraulic and electromechanical systems and perform well in carrying out arduous work where modicum of electrical energy arises. Basically, as the technology progresses there would be various enhancements developed for the device. So future scope of this report will be much higher. The MSM gun is inspired from devices that are already existing where human intervention is highly undesirable. The MSM will be of great use in handling of heavy guns (up to 20 kg). Its use can be extended and by few difficult and complex modifications to design that can be easily patched by the developers with sufficient resources and data. In future technological adaptation with the help of advance materials (bulletproof materials) and surveillance system can be used to make the whole mechanism much more resistant to constant attacks.

## 7. CONCLUSION

As seen in the above section, the master slave manipulator, can be used to manipulate the gun with high precision and accuracy. It can reproduce the natural motions of human in 1:1 ratio on a gripper located at remote site. The various degrees of freedoms possessed by the MSM can allow many combinations for the movement of the gun on the slave arm. These qualities of MSMs can be implemented in defense sector to attack the enemy with better aiming, while avoiding their exposure from the danger of getting shot by the enemy. A gun can be attached to the gripper of the slave arm, which can be controlled by the soldier on the other side of the shielding, thus defending him from the enemy's bullets.

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## 9. BIOGRAPHIES

**Mr. Sanket Baban Gorade**

BE- Mechanical Engineering  
Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India - 400614

**Mr. Atul Rajendra Dighe**

BE- Mechanical Engineering  
Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India - 400614

**Mr. Rutuparna Prabhakar Kale**

BE- Mechanical Engineering  
Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India - 400614

**Mr. Ameya Sujay Bhase**

BE- Mechanical Engineering  
Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India - 400614

**Dr. A. S. Bhongade**

Professor,  
Bharati Vidyapeeth College of Engineering, Navi Mumbai, Maharashtra, India - 400614