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# DESIGN AND MANUFACTURING OF NEW UNWEIGHING SYSTEM

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## ABSTRACT

Significant advances in neurological research producing growing evidence that spinal cord neuron have a capacity for memory independent from the brain has prompted the rehabilitation using unweighing systems which enables partial weight bearing therapy and conducted with the assurance of patient comfort and safety. The objective of this paper is to design and manufacture of a device that helps patient where weight bearing is to be carefully regulated during walking. The device would be able to perform partial unweighing and tell the physician how much weight we are reliving from the patient in a simple reliable and easy to use mechanism. The device consists of large metal frame with a suspended rope from its center. The rope connected to harness and vest to support the patient as he walks on a treadmill. The inside of the metal frame is a set of pulleys, power screws, bearings and two single stage bevel gear reducer , one at each side. The design of the whole mechanism is done using Inventor soft ware package while the outside frame is designed and checked by the help of SAP2000 software package followed by real manufacturing of it. The device is tested on a real patient and it helps in their quick recovery.

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## 1. INTRODUCTION

The patients who have suffered a stroke or are recuperating from another neurological disorder can improve walking ability using the unweighing systems which accommodate the displacement of the center of gravity that occurs during normal gait. The unweighing system helps the recovery of spinal cord injury, Traumatic Brain Injury, Parkinson's Disease, Low back patients, Older Adult and Orthopedic Patients [1].
The unweighing systems are recently used for patients where weight bearing is to be carefully regulated during walking. Previously a guess of the amount of weight we could remove, which means more cautious more conservative in the treatment. Nowadays with the help of the unweighing devices equipped with load sensors and digital display connected to computers tells the physical therapist the exact amount of weight will be relieved from the patient. The unweighing system accompanied with treadmill helps patients with stroke to eliminate the fear of falling. The designed device works great in conjunction with treadmills, balancing devices etc. Significant advances in neurological research produce growing evidence that spinal cord neurons have a capacity for memory independent from the brain has prompted the rehabilitation. Using repetition of motor skills to remodel the body, the treadmill with the unweighing system can be done while the patient is participating in, in-patient rehabilitation immediately following the neurological event, which cause gait impairment. The device allows single point suspension and allows unrestricted pelvic rotation [2]. By initial unweighing support up to 40% of the body weight spinal cord injury can be reduced and regain functional gait through partial weight –bearing therapy the rehabilitation begins through 1-3 months following onset when there is the most plasticity of the central nervous system. Greater potential for recovery low back pain can be reduced using the device to regain pelvic rotation and provide vertical traction in conjunction with exercise [3]. *There are some companies design the unweighing devices and keeps the know how of the design. These companies are specialist in physical therapy instrumentation and devices their devices are expensive about approximately 300 000 Egyptian Pounds with treadmill, while the introduced Design Cost about 25000 Egyptian Pound without treadmill*.

In the present paper a design and manufacturing of unweighing device depends on simple mechanism consists of some pulleys, cables, gearboxes mounted inside large metallic frame. The mechanism connected to external load cell to measurer the exact amount of the weight relieved from the body weight by a simple easy to maintenance way. The output from the load cell is connected to external analog to digital display. The digital display can be rotates to allow measurement from both sides and it can work using battery or normal AC current with large digital display and output can be sent to computer with computer interface. Using two hand levers connected to each side allow using the device from both sides. It is preferable to use the left side to adjust the patient height since its power screw pitch is double the left one, then one can use the right lever to partial unloading of the patient body weight.

## 2. THE CONCEPT OF THE UNWEIGHING DEVICE

The concept of the device depends on a simple mechanism consists of some pulleys, cables, single stage bevel reducers connected together and mounted inside a large metallic frame. The unweighing device is a simple reliable and easy to use device,

since it contains no complicated circuits. All components of the device are designed to withstand load up to 300Kg. Normal standard design technique are used for the design of the device elements. The operation of the device start by rotation of a hand fixed at both sides of the device. This hand transmit the torque to a small bevel gearbox, the out put from the gear box is send to power screw nut, the power screw nut is connected to rope passing through some pulleys, at the end of the ropes the patient is supported via suitable harness and vest. The motion of the power screw nut let the rope tensioned, the tension in the rope transmitted to the patient through the harness . The lifting mechanism is connected to load cell for measuring the exact amount of the weight relieved from the body weight. The output from the load cell is connected to external analog to digital display. Using two hand levers connected to each side allow using the device from right and left sides. But it is preferable to use the left side to adjust the rope according to the patient height since its power screw pitch is double the left one, then one can use the right lever to partial unloading of the patient body weight. One of the main objectives of the design is to minimize the force derived from hand of nurse or physician to the device-rotating hand lever, therefore single stage bevel reducer, power screw and double pulley were used.

### 2.1 Design and Manufacturing of theDevice Frame

The frame of the unweighing device is the outside structure which contain the whole mechanism (pulleys, gearboxes, wire, power screws..etc ) inside it , therefore , the frame must be rigid and safe against loading and unloading of patient and during his exercise. The frame dimensions are 115 width x 115 depth x 240 height. The frame consists of two parts the lower part which designed from square section tube 10cm x 10 cm, the tube thickness is 0.3 cm, with height 100cm and the tube is welded with another tube perpendicular on it and having cross section 5 cm x 10 cm. 4 wheels are connected to the end of this part to allow frame movement, the schematic drawing of this part is seen in Fig.(1). The upper part is considered as inverted u shape with the same square cross section using a folded sheet. The inner side of this section is removable to allow insertion of the different mechanisms and pulleys inside the frame, so it is easy for maintenance and repair as shown in Fig. (2).
. A finite element stress analysis is done using a finite element package SAP2000. The frame is taken as 7 beam elements as shown in Fig. (3). The frame material is chosen as steel with the standard young's modulus, E equal 200 Gpa and Poisson's ratio, $\nu$ equal 0.3 The force on the frame is 3000 N applied at the middle of frame span and downward. 3D analysis is obtained including deflection, normal, shear and bending moment diagrams as shown in figures 4-5. The output file of the analysis indicate that the frame section is safe and its stress not exceed the yield stress

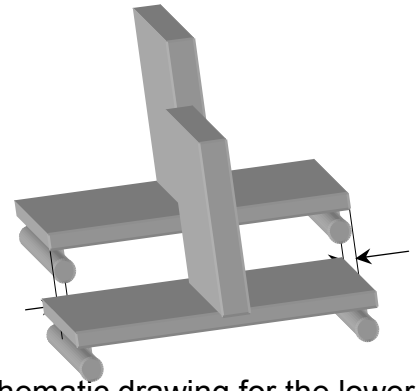

Fig.1. Schematic drawing for the lower part of the device

## 2.2 Design and Manufacturing of the Interior Mechanism

The interior mechanism for the un-weighing system was designed to carry a maximum load of 300 Kg. Based on this load, force analysis was carried out to find the appropriate loads at different parts of the system.
For design calculations, the Autodesk Inventor design accelerator was used, which provides simple design, selection, and checking procedures for different components of the mechanical system (Gears, Bearings, Power Screw, Feathers, Pins).
Design considerations:

1- Materials used for different components of the structure and the mechanical systems were selected from those available materials in the local market.
2- For the gears in the gearbox, relatively soft material was chosen (Teflon) to minimize the noise during operation.
3- For the power screw, different screw pitches were chosen to provide different un-weighting speeds (fast and smooth modes).
4- The load cell position is outside the main frame (direct access for maintenance, calibration and repair issues).

The manufacturing of the interior mechanism can be realized by using the conventional machining processes such as turning, milling, and drilling according to the part features and specifications. Fig. (6) shows the detail Drawing of the device gearbox, while Fig. (7) show the 3-D of the gearbox and the power screw.

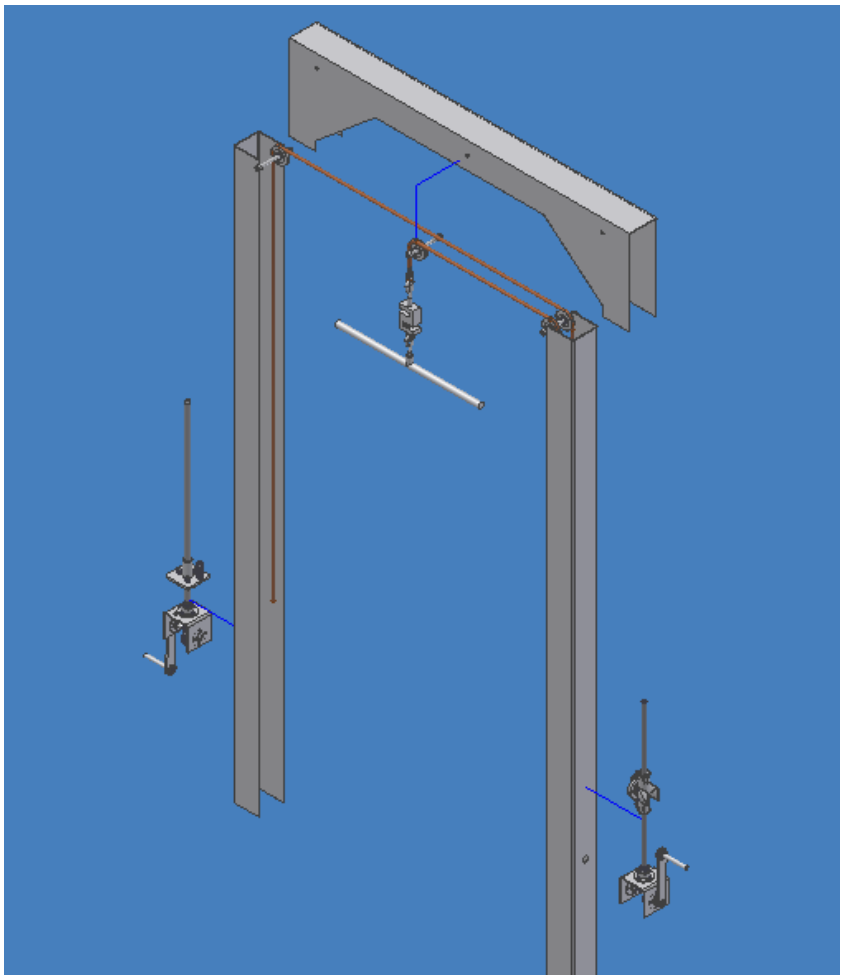

Fig. 2 . 3-D drawing of the Upper part of the device frame

### 2.3 Device Load Cell

A load cell is a transducer, which converts force into a measurable electrical output. Although there are many varieties of load cells, strain gage based load cells are the most commonly used type. Before strain gage-based load cells became the method of choice for industrial weighing applications, mechanical lever scales were widely used. Mechanical scales can weigh everything from pills to railroad cars and can do so accurately and reliably if they are properly calibrated and maintained. The method of operation can involve either the use of a weight balancing mechanism or the detection of the force developed by mechanical levers. The earliest, pre-strain gage force sensors included hydraulic and pneumatic designs. In 1843, English physicist Sir Charles Wheatstone devised a bridge circuit that could measure electrical resistances. The Wheatstone bridge circuit is ideal for measuring the resistance changes that occur in strain gages. Although the first bonded resistance wire strain gage was developed in the 1940s, it was not until modern electronics caught up that the new technology became technically and economically feasible. Since that time, however, strain gages have proliferated both as mechanical scale components and in stand-alone load cells. Today, except for certain laboratories where precision mechanical balances are still used, strain gage load cells dominate the weighing industry. Strain gage load cells offer accuracies from within 0.03% to 0.25% full scale and are suitable for almost all industrial applications.
Load cell designs can be distinguished according to the type of output signal generated (pneumatic, hydraulic, electric) or according to the way they detect weight (bending, shear, compression, tension, etc.)
Strain-gage load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gages are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension, and two in compression, and are wired with compensation adjustments. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load. Other load cells are fading into obscurity, as strain gage load cells continue to increase their accuracy and lower their unit costs. There are many types of load cells. According to the design requirement and since the rope is subjected to tension S-Type load cell is chosen. S-Beam load cells get their name from their S shape. S-Beam load cells can provide an output if under tension or compression. They provide superior side load rejection. It is used for applications that include precision weight and force measurements. S beam load cells used for force measurement from 50 through 2000 kg. The sensing element incorporates bonded foil strain gages of the highest quality and are sealed for protection against most environmental effects. For the above mentioned reasons and because its cheap and easy to be interfaced with many digital display S type load cell with load carrying capacity up to 500 kg is obtained. Fig. (8) gives the details of the used S type load cell while table1 gives the load cell dimensions

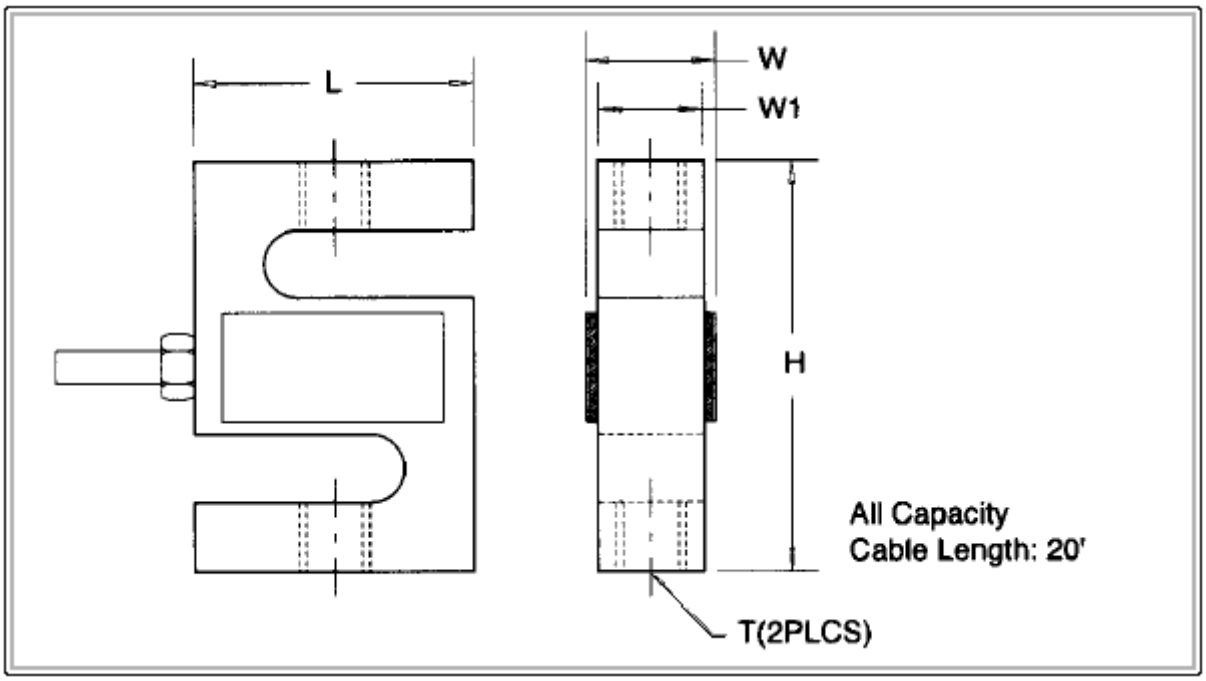


Fig.8. S- Type Load Cell

Table 1. S Type Load Cell Dimensions

| Length ( Cm) | Width (cm) | Height( Cm) |
|---|---|---|
| 5 | 3 | 8 |

S beam SPECIFICATIONS

| | |
|---|---|
| Rated Output (R.O.): | 3 mV/V nominal |
| Nonlinearity: | 0.05% of R.O. |
| Hysteresis: | 0.03% of R.O |
| Nonrepeatability: | 0.02% of R.O. |
| Creep in 20 Min: | 0.03% of R.O. |
| Zero Balance: | 1.0% of R.O. |
| Compensated Temp. Range: | 15° to 115°F |
| Safe Temp. Range: | -65° to 200°F |
| Temp. Effect on Output: | 0.08% of Load/°F |
| Temp. Effect on Zero: | 0.08% of R.O./°F |
| Terminal Resistance: | 350 ohms nominal |
| Excitation Voltage: | 10 VDC |
| Safe Overload: | 150% of R.O. |

**2.4 Digital Display**

The output from the load cell is sending to the output digital display which contain analog to digital card. The output digital display model is XK3190-A7 with the following specifications

- A/D converting theory and sampling rate: Double integration, 10-15 times/time
- Operating temperature 0- 50 $C^o$
- Power supply 1) AC 180-240 V, 50 Hz 2- built-in rechargeable battery 6V
- External dimension and weight: 265x190x170mm, 1.53 kg

The output display connected to the device via a liver which allowed to rotate 360 degree to help the nurse or physician in using the device from front or rear position. The complete View of the designed and manufactured unweighing device is shown in Fig. (9)

## 3. CONCLUSIONS

In the present paper a brief discussion about the benefits of the unweighing devices for helping the patients who have suffered a stroke or are recuperating from another neurological disorder. The unweighing system helps the recovery of spinal cord injury, Traumatic Brain Injury, Low back patients, Older Adult and Orthopedic Patients. A design and manufacturing of unweighing device depends on simple mechanism consists of some pulleys, cables, gearboxes mounted inside large metallic frame is introduced. The design of the frame and the inside mechanism depends on the available market material. The device allows single point suspension and allows unrestricted pelvic rotation. The frame is designed and checked against failure using Sap2000 Finite element package while the internal mechanisms is designed and checked for failure using Inventor machine component package. Normal, shear and bending moment diagrams are obtained. The output from both packages of the analysis indicate that the frame section is safe and its stress not exceed the yield stress, and the inside machine component is also safe. The device is designed in a simply and easy way for maintenance and repair because the load cell and the digital display mounted out side the device and can be assembled and disassembled easily. The digital display is allowed to rotate 360 degree to help using the device in both directions. Two levers are fixed on the frame to help using of the device as a gait trainer.

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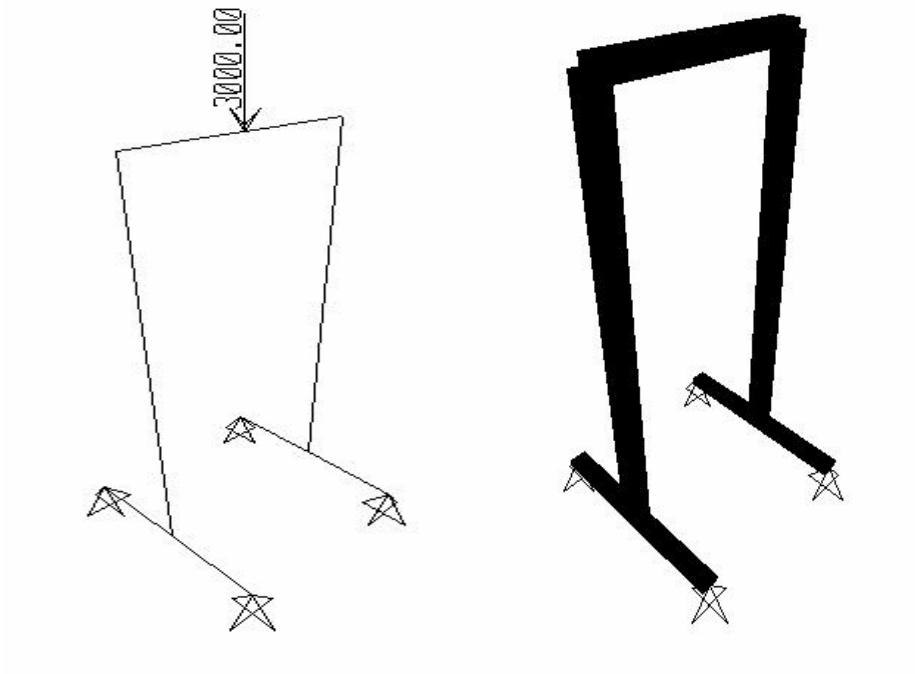
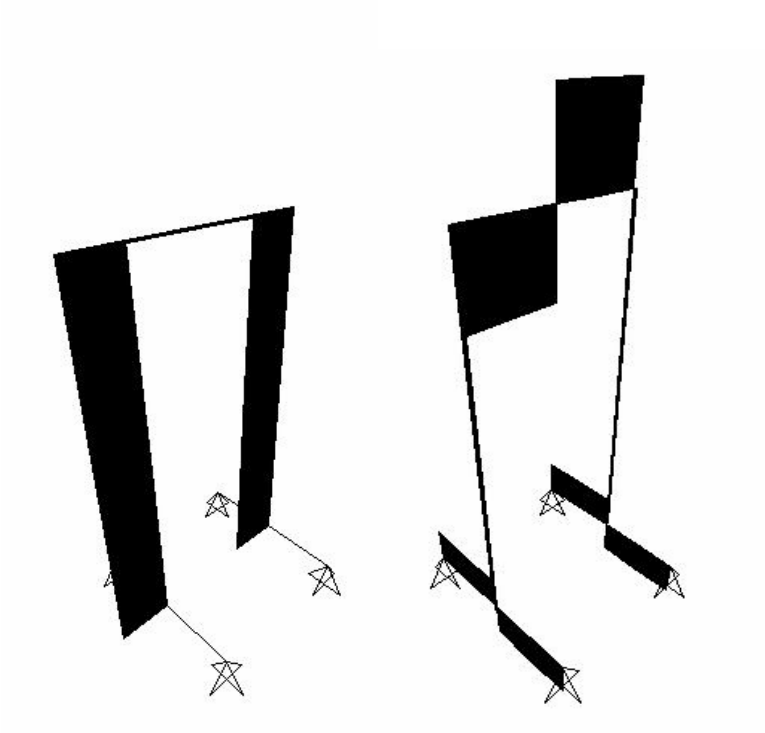



(a) (b)

Fig.3) Finite Element representation of the designed Frame
a) Applied load b) Frame elements mesh



(a) (b)

Fig. 4. Analysis of the Three dimensional frame subjected to

concentric Load a) axial force diagram b) shear force diagram

Fig. 5 . Analysis of the Three dimensional Frame subjected to concentric Load a) Bending moment diagram

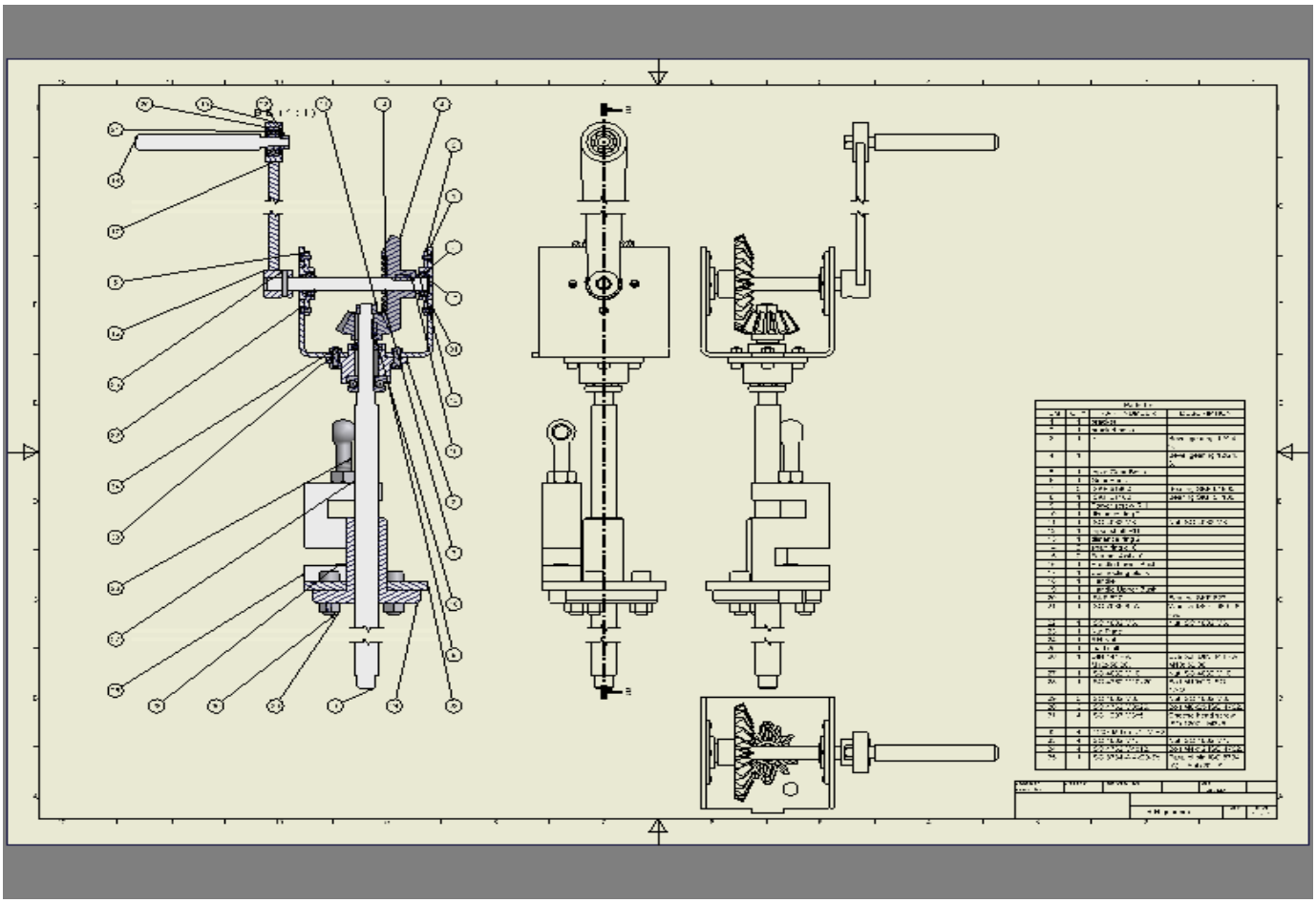
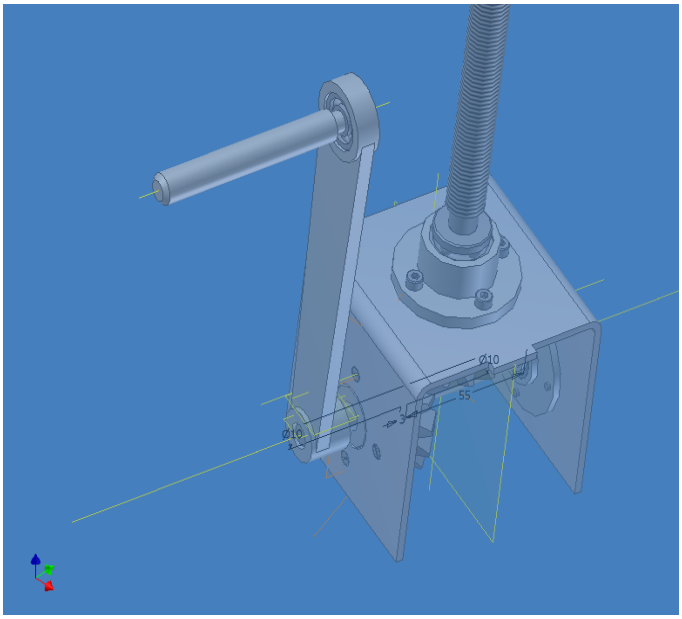
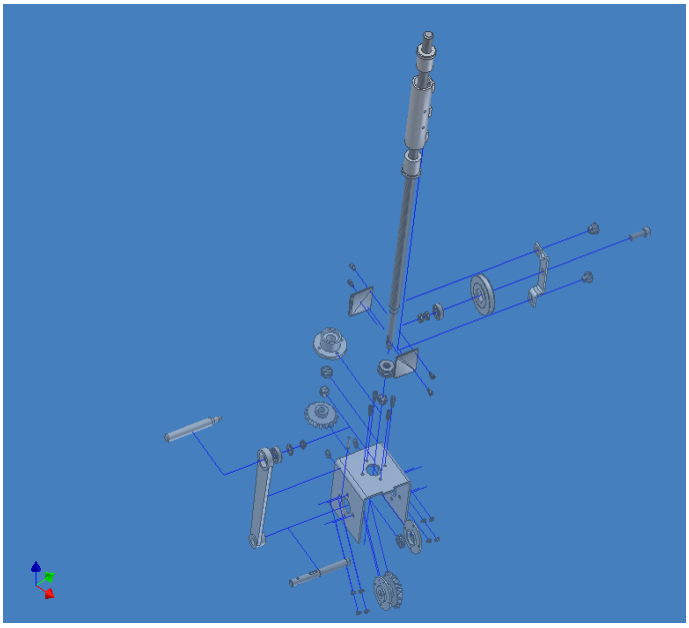


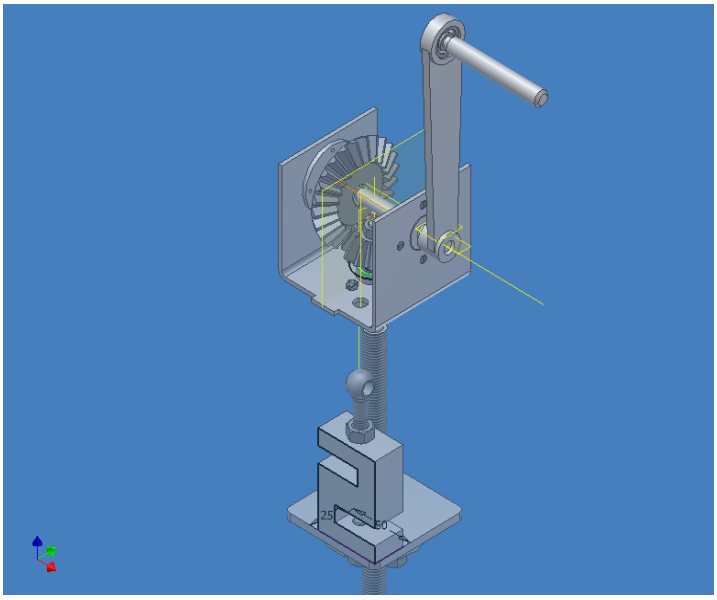
Fig. 6. Detail drawing of the designed Gearbox and rotating liver



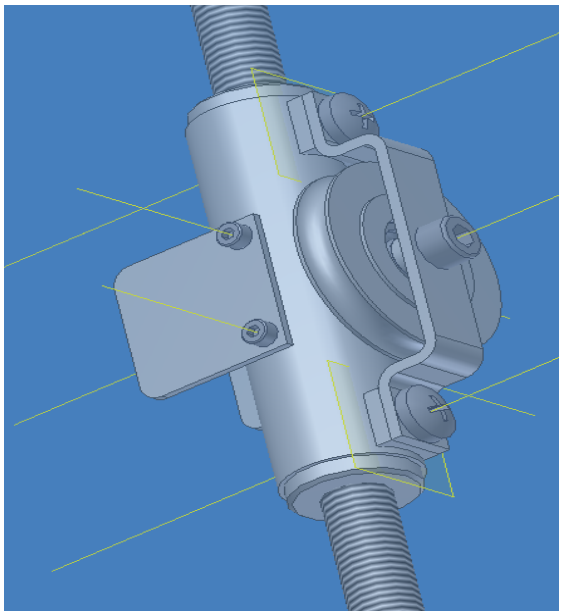

(a)



(b)




( c)



(d)

Fig. 7. Three dimensional view of gear box and power screw
Disassembly of the gear box and the power scrow
a) Left gearbox b) left gear box dis assembled
c) wright gearbox d) power screw

Fig. 9. Photo for the complete Designed and manufactured unweighing Device