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Portable Continuous Offset Weight (PCOW) System

EML 4501 Spring 2020
Group 22

Abstract

The Portable Continuous Offset Weight System (PCOWS) is designed to provide a continuous weight offset for users with neuromuscular conditions seeking rehabilitative exercise on elliptical trainers augmented with Functional Electrical Stimulation. The PCOWS approaches the customer needs from a unique, yet simplistic approach. This is a wholly inclusive unit that mounts to the ceiling aside from the user operated control panel, which would mount on the wall adjacent to the elliptical trainer. The unit includes a motor that lifts the user from a seated position using a fabric harness. Once the patient is suspended, the elliptical trainer is wheeled under the patient. The patient is lowered onto the trainer, the weight offset is entered, and the workout begins. The same motor receives the force reading from the force sensor and lowers or lifts the patient according to the desired offset. This system is unique among its competitors for multiple reasons. The first is its compatibility. This unit is not dependent on the type of elliptical trainer the user has available. The second is the compactness of the unit. The system is wholly included in a plate attached to the ceiling. This means there is not a requirement for any floor space while not in use. The combination of the compactness and the compatibility allows for it to be portable as long as the desired location has beams that can support the weight of the patient.

System Operation

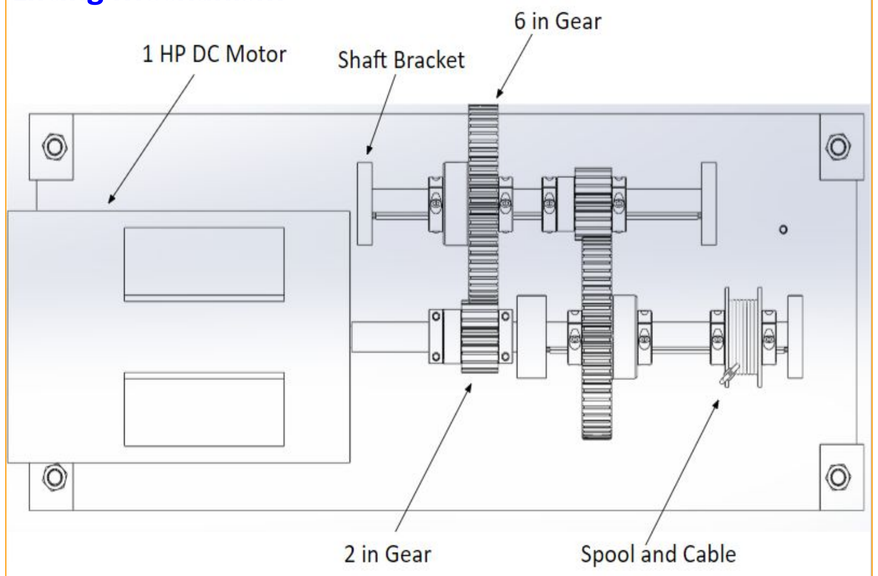
Lifting

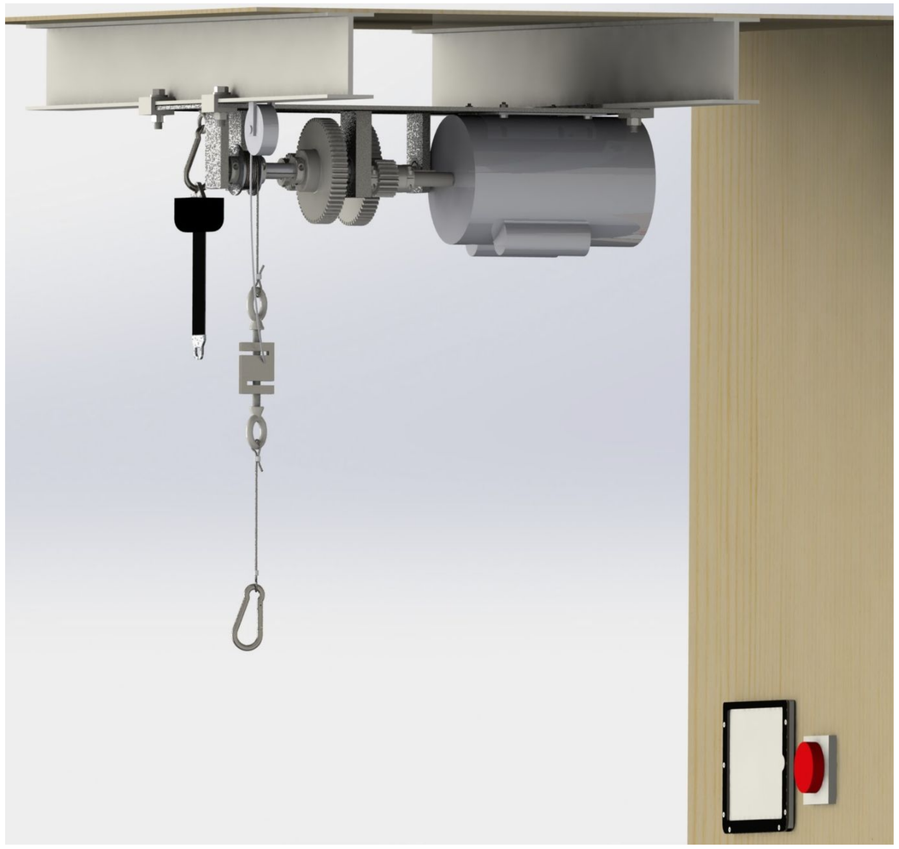
The lifting mechanism is motor attached to a plate mounted in the ceiling. The motor output runs into a gearbox which then outputs to a spool. A cable directly attaches to this spool. The cable is then connected to a harness that is attached to the user. To lift the user, the lift command is entered on the control panel on the trainer and the motor begins to turn in a controlled manner, lifting the user.

Weight Offset

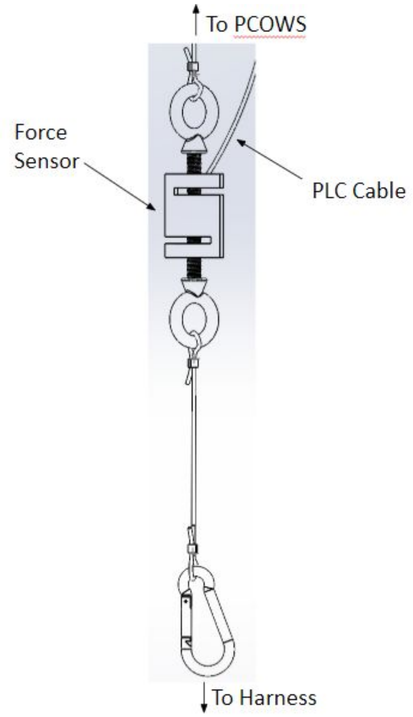
The weight offset system operates using the same motor, gearbox, spool mechanism. The desired weight offset is entered on the control panel before the exercise begins. A force sensor attached to the cable that is holding the weight of the patient is used to provide the system with the force the user is feeling. From this force reading the motor then rotates the spool to lift and lower the patient to maintain a constant feeling of the desired weight offset.

Lifting Mechanism



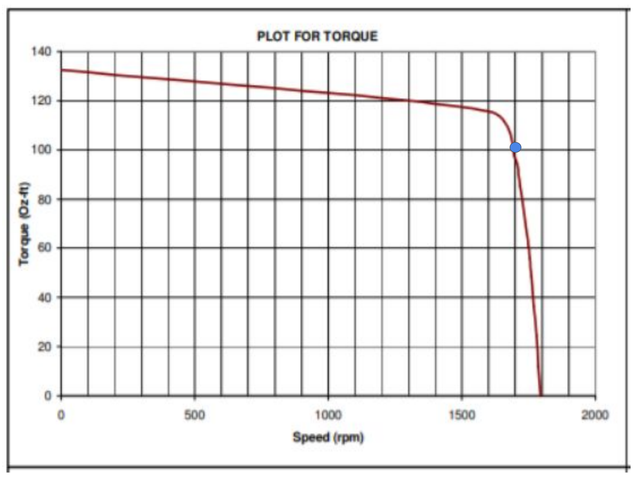


Weight Offset System



Unique Design Analysis

The system described above is the first continuous wight offset support that is developed for use with an elliptical trainer to require no additional frame/ support system. All other solutions to this problem require the use of a frame/ support system to hold the user and all mechanism included in the weight offset support system. Our innovative design is unique to these solutions by simply attaching to the ceiling. This system significantly reduces cost, complexity, and allows for usage in a variety of places that other solutions simply do not offer.



Cost

Type of Cost	Cost ($)
OTS	2737.32
Raw Materials	213.30
Manufacturing and MFG Labor	176.25
Energy Consumption	0.10
Assembly	15

•The manufacturing labor considers the overhead costs, any benefits, and manufacturing salary. The energy consumption is an estimated cost of the energy consumed while manufacturing. Assembly labor is the salary for the assembly worker.

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- Must fit inside a medical or rehabilitation facility, taking into consideration clearance through doors, load-bearing capacity of floors, floor footprint, and ceiling height.
- If powered, runs from 120 VAC electricity from a standard wall outlet with 10-amp breaker capacity
- Allows the user to stand and exercise on a standard elliptical machine without interfering with the elliptical machine's operation
- Supports the full weight of the user up to the full capacity of the elliptical machine-
- All design margins have an acceptable factor of safety
- Includes a fail-safe system to catch the user, preventing a fall should the primary system fail
- The user is lifted from the wheelchair and placed on the elliptical trainer at safe and comfortable speeds
- The system will prevent the suspended user from swinging and/or hitting the elliptical trainer or the wheelchair during transfers to/from the wheelchair or elliptical.
- Allows the user to translate unencumbered in the vertical direction during exercise
- Prevents the user from losing balance in a sagittal (backward or forward) fall
- Prevents the user from losing balance in a transverse (left or right) fall
- Lifts the user from a seated position (e.g., a wheelchair) to fully suspended
- Moves the fully suspended user from their original location over a standard elliptical trainer
- Holds the user suspended over the elliptical trainer while they are being strapped into the trainer
- Accommodates user body sizes ranging from a 5% female to a 95% male
- Once user is attached to the elliptical trainer slowly transitions to pre-set offset weight
- Allows user to select offset weight to any value between 0% and 100% of their body weight
- Can be mounted from structural members in walls or ceilings or can sit on the floor.
- Provides continuous user-defined offset weight support for the user while the user is exercising
- Offset weight support feels continuous to the user despite the repeating periodic motion of their exercise
- Must provide pre-set weight offset over the full vertical, horizontal, and transverse range of the user's motion during exercise
- Design is programmable
- Has intuitive user interface
- Prototype cost for materials cannot exceed $4,000
- Emergency shutoff which can be activated by user or nearby trainer
- Automatic Shutoff
- Visual indicator shows system is on, what mode is functioning, and how much weight is being offset.
- Operational lifetime exceeds three times lifetime of elliptical trainer
- FES stimulation connections must be accessible
- Overall footprint of lift system cannot exceed 2.43 m X 3.05 m (8′ X 10′)

- Must fit through 80 in x 36 in area
- Must weigh less than 50 lbs per square foot
- Should not be larger than 35 square feet
- Must be less than 9 ft tall
- Must be powered by 120 VAC with 10-amp breaker capacity
- Allows for 88"x"23"x 34" of space for user to use elliptical
- Must support up to 350 lbs
- Safety factor must be equal or greater to 2
- Fail-safe cable must support 1600 lbs of impact force
- Speeds do not exceed 1 foot per second
- System and/or other objects must not be within 1 foot of the user while being transported
- Allows at least 95 inches vertically between the floor and the bottom of the top of the machine
- User's center of mass must remain within 6 inches of the support point in the sagittal direction
- User's center of mass must remain within 6 inches of the support point in the transverse direction
- System supports 100% of users weight up to 350lbs max
- System must be able to move at 4 feet horizontally
- User must be held at least 14 inches above ground
- System fits heights between 58.6 in and 74.8 in
- At least 3 seconds for transition
- Allows for weight offset between 0% to 100% of client's weight, using a whole number of percent.
- All 8 subsystems are either mounted to walls or ceiling or sitting on the floor.
- Weight offset must equal chosen weight offset input, with an uncertainty of 0.5%
- User experiences weight support equal to weight offset input, with an uncertainty of 0.5%
- Net force in horizontal and transverse directions must be under 5 lbf. Net force in vertical direction is equal to weight offset input, with an uncertainty of 0.5%
- Allows user or trainer to input weight offset from 0% to 100% of client's weight, using a whole number of percent
- User Interface passes standard
- Cost is less than $4000
- Must include switch or button that stops all motion within 0.25 seconds and is located 15in or less away from user
- All systems shut off within 0.25 seconds if force on the system exceeds 450 lbf at any time, if the force exceeds 375 lbf for 3 consecutive seconds, or if the rate of force increase exceeds 120 lbf/s
- Visual indicator must be easily visible from 10 ft. away
- Key component cycles must be designed for infinite life
- Distance from waist must not exceed 8"
- Footprint must not exceed 8′ x 10′

- Lifting/Lowering Sub-system
- Transport Sub-system
- Harness Sub-system
- Spotter Sub-system
- Fail-safe Button Sub-system
- Weight Balance Sub-system
- Visual Indicator Sub-system
- Automatic Force-Based Shutoff Sub-system

- Overall footprint of design is 28" X 12"
- DC Permanent Magnet motor runs on 90 volts and 10 amps
- Cable attaches to user and enables them to exercise while components of weight offset system operate above them
- Force sensor can operate on loads up to 1,000 lbs
- System Components have minimum factor of safety of 1.3
- Safety seatbelt connects to user harness and will suspend user if cable fails
- Cable connects to user and lifts him/her up at 1 ft/sec until he/she is properly suspended so elliptical can be moved under them
- Harness is adjustable to satisfy all user body sizes
- Motor performs offset weight functions based on user input on visual indicator screen
- Mounting Plate attaches to I-beams in ceilings and connects to all system components
- Force sensor continuously provides output readings allowing for the motor to make constant adjustments
- Force sensor readings are processed with a PLC and commands for motor output are carried out with use of an Arduino
- Visual indicator screen allows for user/trainer input of user's weight and their desired weight offset
- Button next to visual indicator screen on wall or button attached to user harness can be pushed to activate emergency shutoff
- Coding paired with force sensor readout will shutoff system if force exceeds 450 lbs at any time, 375 lbs for three consecutive seconds, or if the rate of force increase exceeds 120 lbf/sec
- Component materials were selected based on yield strength to ensure the required number of cycles the system could endure
- An electrical box is attached to the ceiling I-beam to enclose electrical components of the force sensor and motor controller, this box has a door that can be opened if electrical adjustments are needed