

Load Cell Rig User Guide

Author's Note - I have created this document to ensure that future users of the load cell rig that I created would be able to use it with minimal issues and be able to adapt the rig to other load cells that fit within the structure.



Background

The problem statement was to develop a rig capable of applying known forces and moments to an Interface 6A40 Load Cell (pictured below).



Figure 1. Interface 6A40 Load Cell

The load cell can be thought of as a cylinder with a 2.4" diameter and a height of 1.6". The load cell has 6, equally spaced, M5X0.8 threaded holes on the top and bottom planes, allowing for the load cell to be secured to a rig.

The load cell has 6 DOF capability meaning it can measure forces and moments in/about the three axes: x, y, and z. Naturally, this means the load cell also has limitations in the maximum forces/moments it can measure before any damage occurs, shown in the table below.

	x	y	z
Force (N)	50	50	200
Moment (Nm)	5	5	5

Table 1. Load Cell Force/Moment Limitations

As the purpose of this experiment is to measure the error of the load cell, it is paramount that the rig applying the loads is built in a precise manner.

Design Overview

The rig design (CAD model shown below) was relatively complex as it had many components. However, it can be broken down into a few sections: base plate, top spring piece, and side spring piece and loading piece. There are also 6mm diameter metal tubes that connect the top and side pieces to the base plate. These tubes were attached via J-B Weld, steel infused epoxy, while the structure was under compression. This significantly reinforced the structure and ensured that it would be able sustain loads far above what would ever be applied to load cell.

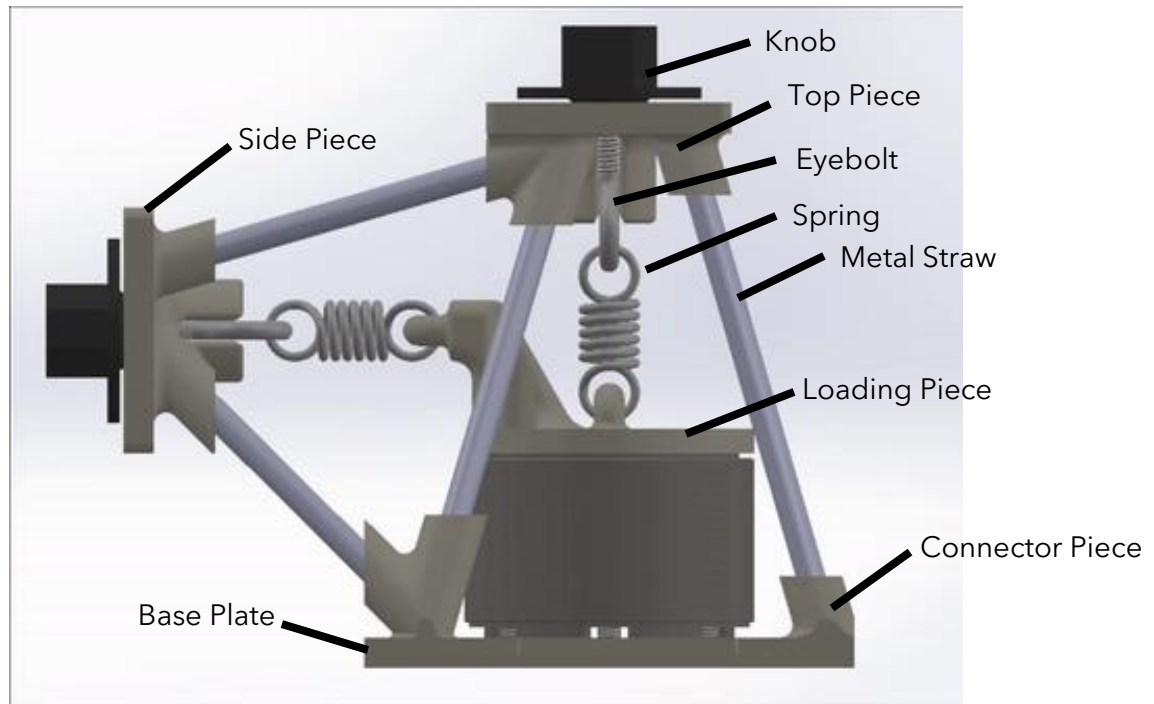


Figure 2. Complete Rig CAD Assembly

The base plate has 6 M5x0.8 clearance holes so that the load cell can be secured to its top face. Additionally, there are four wood screw clearance holes (about 0.5 cm in diameter) that this rig can then be attached to some stand. For the purposes of this experiment, the rig was intended to be attached to an orientation stand to determine if rotating the load cell affected the measurements in any way.

As seen in Figure 2, the rig uses springs to apply the loads to the load cell. The spring attaches to the top/side pieces mentioned above via eyebolts (part number shown in Table 2). These top/side pieces contain a cross-like feature that ensures that the eyebolts do not rotate when the black knob is rotated. This ensures that all the force applied by the user to actuate the spring is utilized. The knob is shaped in such a way that a $\frac{3}{4}$ inch wrench could be used to actuate the spring if necessary. However, a lip

was added to the bottom of the knob to minimize the contact area and thus friction between the knob and the top/side piece (Figure 3).

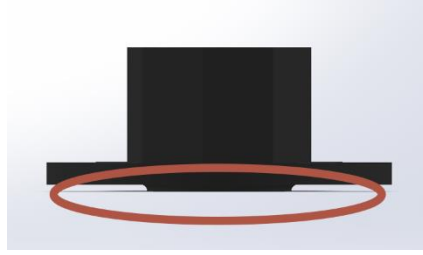


Figure 3. Knob closeup

The spring used has a spring constant of 85 lbf/in and has a maximum change in length of about 0.3" before it plastically deforms (part number shown in Table 2). This parameter was kept in mind when designing the rig and the distances were defined such that the spring cannot actuate past this value. This is convenient as it also limits the spring from applying a force larger than the load cell z-direction limit of 200N.

Part	McMaster Number
Eyebolt	9489T47
Spring	5108N588

Table 2. McMaster Part Numbers

As mentioned previously, it is very important the rig be designed precisely so that the force applied can be accurately known by the end user. This was accomplished by adding notches on the top/side pieces and a small cutout in the knob (Figure 3). Each notch is separated by 15 degrees and corresponds to an additional 0.15 lbf of force applied. By lining up the groove to the notches, the amount of additional force applied can be precisely recorded.

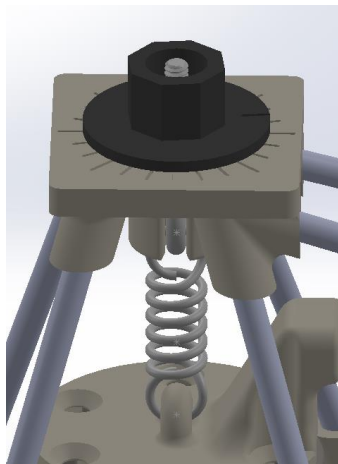


Figure 4. Knob, top-piece, eyebolt, spring interface

Finally, we come to arguable one of the most crucial components of the rig, the loading piece (Figure 5). If this piece were to fracture, the transient loads experienced could be enough to permanently damage the load cell. Thus, many purposeful design choices were made to ensure this piece was over engineered. To start, the piece was manufactured out of Formlabs tough 2000 resin for its high strength properties. The predicted elongation at the loads applied for this piece was about 4 thousandths of an inch. In addition, fillets were used to avoid stress concentrations. To apply a moment to the load cell, spring's line of action was designed to be an inch above the load cell's moment plane. This allows for a pitching moment to be simulated in the testing.

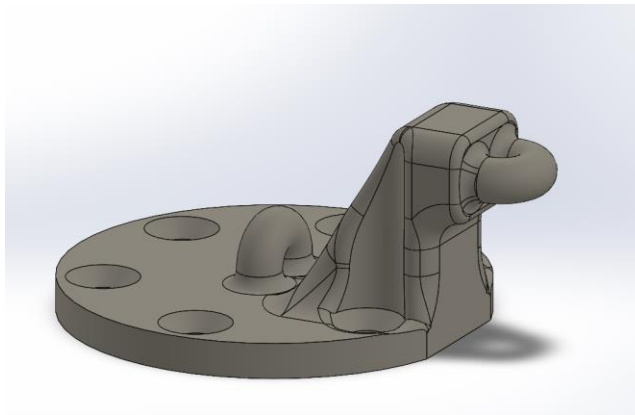


Figure 5. Loading Piece

User Steps

Before collecting data, the Interface 6A40 must be installed into the rig.

- 1) Place the rig in its unloaded position (by loosening the eyebolts)
- 2) Loosen the screws connecting the mock load cell to the baseplate of the rig and the loading piece
- 3) Remove the springs and disconnect the loading piece from the mock load cell and remove the mock load cell from the rig
- 4) Insert the Interface 6A40 load cell and resecure to the baseplate and loading piece

The next step would be to attach the load cell rig to the orientation stand using the pre-cut piece in the lab (see Figure below).

- 1) Place the pre-cut MDF piece on the center of the bolt in the orientation stand (the piece has a hole in the center to clear the bolt in the center of the orientation stand)
- 2) Use 4 wood screws to secure the MDF plate to the orientation stand (through the holes on the corner of the orientation stand)
- 3) Use 4 more wood screws to secure the load cell rig to the MDF plate

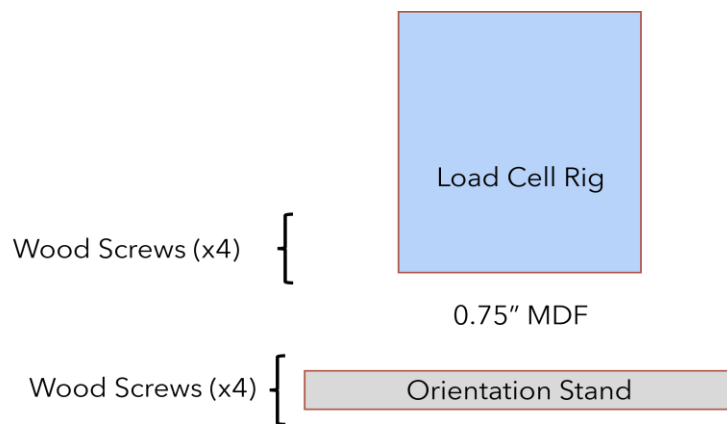


Figure 6. Load Cell/Orientation Stand Assembly

To collect data the first step is to establish the zero point. To do this, we will be taking advantage of the load cell's high resolution.

- 1) Ensure the knob is on its loosest setting and no force is being applied to the load cell
- 2) Slowly tighten the knob until the load cell's reading just begins to change
- 3) The notch associated with this point is the zero point and every additional notch is an additional 0.15lbf of force

Finally, we can collect data and begin to characterize the different types of error. The load cell interface to the computer via the LabJack data acquisition system.

- 1) Creep
 - a. Apply a constant load and collect data over a defined period of time
- 2) Hysteresis
 - a. Gradual loading and unloading using knob
- 3) Thermal Drift
 - a. Temperature change from wind tunnel flow speed
- 4) Orientation
 - a. Repeat above tests at different orientations

While adapting this rig to taller load cells is unlikely to work, implementing a shorter load cell is definitely feasible. The rig currently has a mock load cell machined out of aluminum (as mentioned above). The mock load cell has two thin adapter pieces, one on the top and the other on the bottom, that allow it to interface with the base plate and loading piece (Figure 7). The SolidWorks part file for this piece will be attached with this user guide so that a future end user could adapt this design to the dimensions of a shorter load cell.

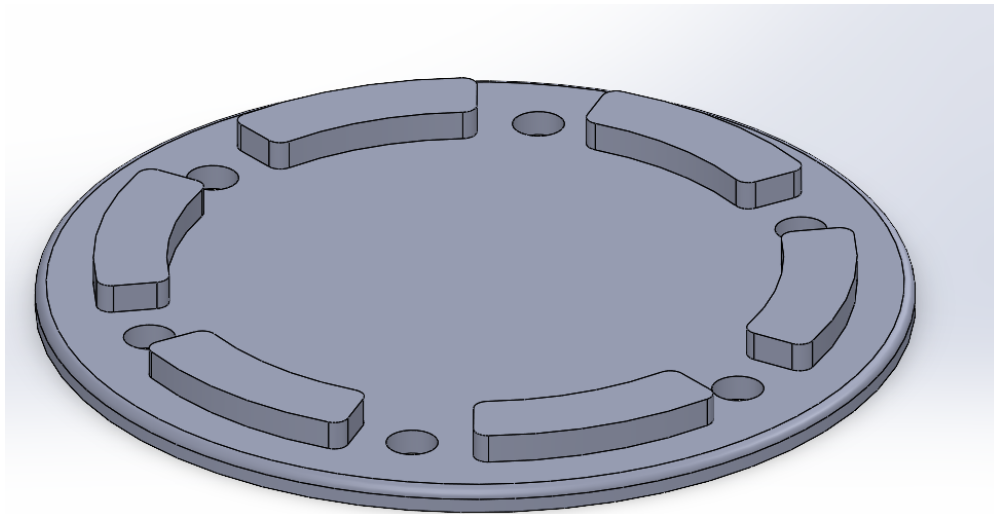


Figure 7. Load cell adapter piece

Appendix – Design Process

Designing this load cell rig was an involved process. The initial design was to create an outer box to hold the spring and an inner box to interface with the load cell (figure 7). The outer box was originally going to be manufactured from MDF wood and the inner stand would have been 3D printed. However, this design was ultimately deemed insufficient as manufacturing errors from cutting and attaching the MDF pieces together would have compounded, compromising the knowledge of the applied load. This design also relied on a single nut/bolt combination to attach the outer box to the orientation stand, which would likely be an unstable connection.

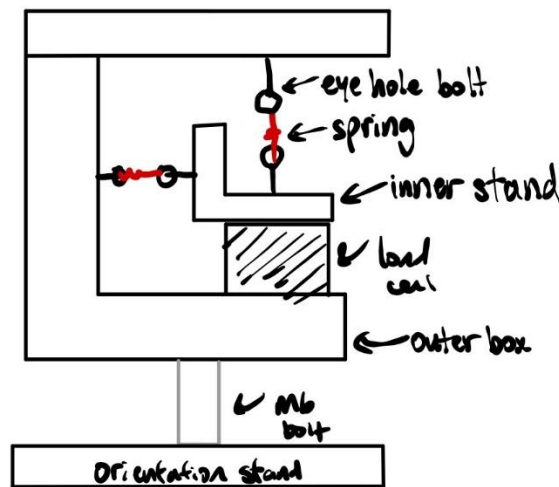


Figure 8. Initial Concept for Load Cell Rig

When in the process of redesigning the rig, the main goals were compactness and precision. These two factors would result in the most accurate measurements. This was accomplished by implementing a truss structure of sorts that eliminated the need for a bulky outer box.

Once the concept was created, the next step was creating a detailed CAD model in SolidWorks. This was challenging because a lot of the specific dimensions of the apparatus were unknown due to very complex geometries. To start, the connecting pieces that attach to the metal tubes had to be at a very certain angle that was unknown. Additionally, the spring, eyebolt, and 3D printed pieces needed to fit together perfectly while allowing for smooth movement during spring actuation. To accomplish this, the rig was designed parametrically in SolidWorks with respect to reference planes (Figure 8). This meant that if one dimension was changed, the remaining dimensions would automatically update (within a certain value).

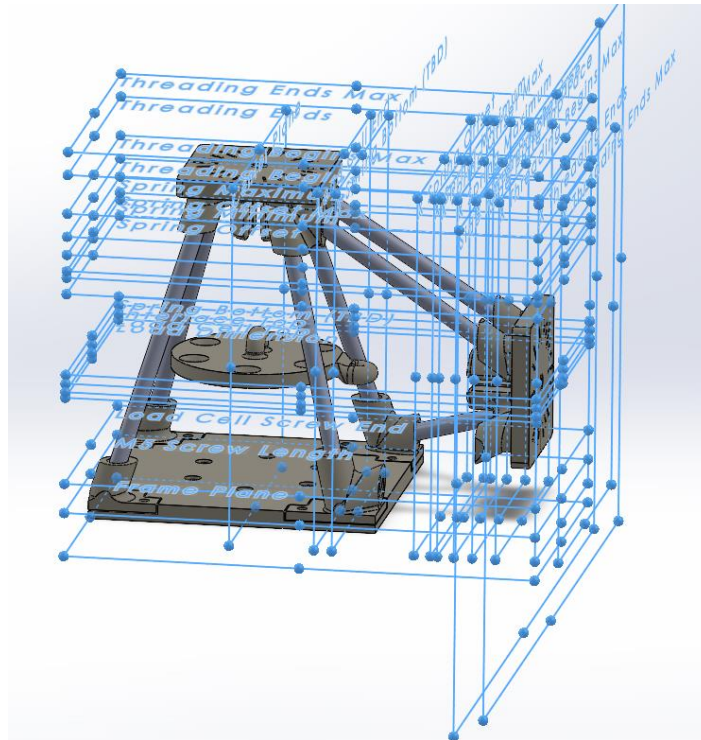


Figure 9. Reference planes for parametric modelling

To ensure that the connecting pieces were at the right angle for the metal tubes, SolidWorks surfaces features were generated. This process involved first modelling blocks that would then be cut and trimmed to result in the end product shown in the final CAD. This part of the design required some manual input and is the most susceptible to rebuild errors when changing other dimensions in the CAD.

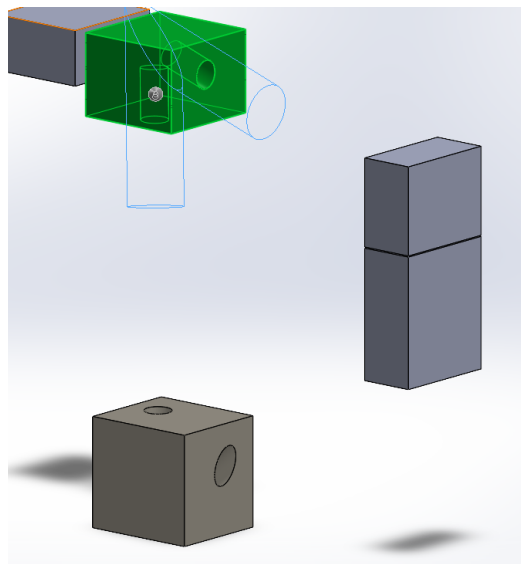


Figure 10. Connector surface operations