Motor Test Rig

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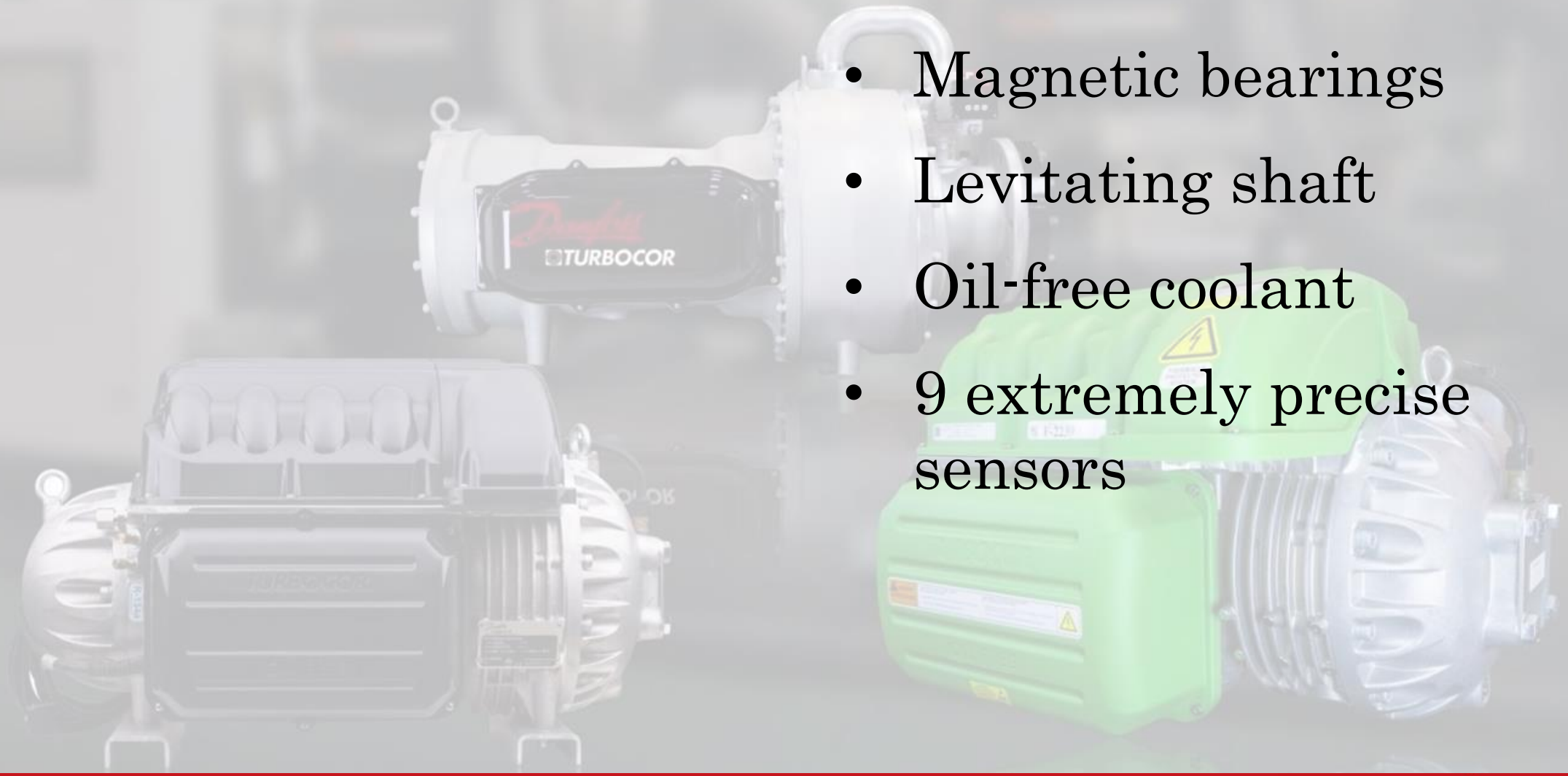
OUTLINE

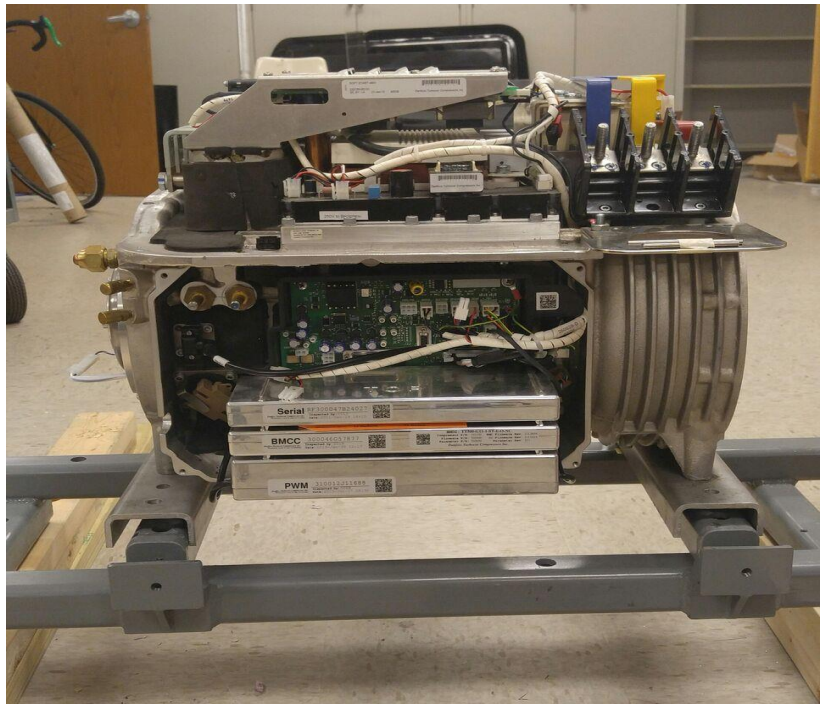
- Project overview
- Approved design
- Design process
- Operation process
- Schedule
- Acknowledgments
- Conclusion

WHY DANFOSS' COMPRESSORS ARE DIFFERENT



- Magnetic bearings
- Levitating shaft
- Oil-free coolant
- 9 extremely precise sensors

DANFOSS TURBOCOR'S COMPRESSOR



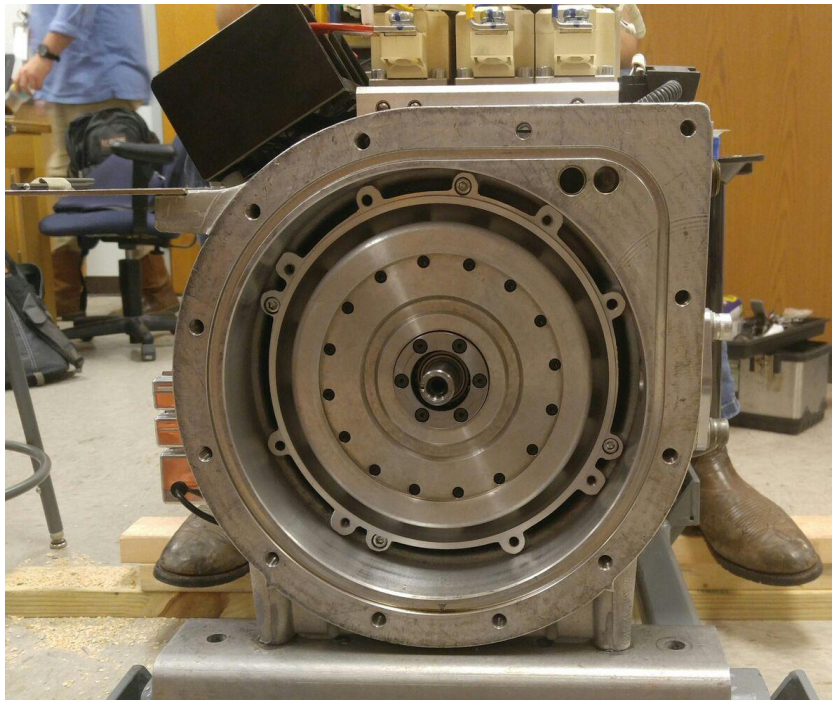



Fig. 1. TT-500 compressor

PROJECT OVERVIEW

MOTIVATION

Danfoss Turbocor manufactures compressors but don't have a mechanism to determine the torque load and power efficiency of the compressors when external components are attached.

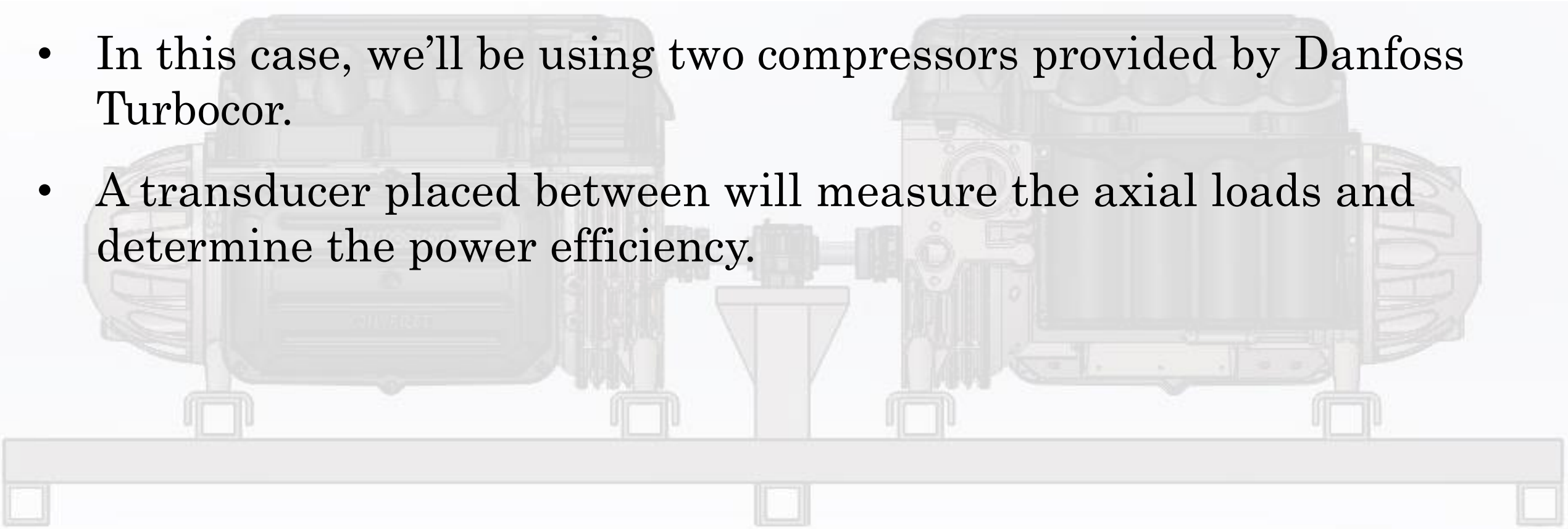
GOAL STATEMENT

To design a motor test rig that determines the torque load and power efficiency of Danfoss Turbocor's compressors running up to speeds of 10,000 rpm's.

PROJECT OVERVIEW

WHAT IS A MOTOR TEST RIG?

- Treating one compressor as a motor and the other as a generator.
- In this case, we'll be using two compressors provided by Danfoss Turbocor.
- A transducer placed between will measure the axial loads and determine the power efficiency.



PROJECT OVERVIEW

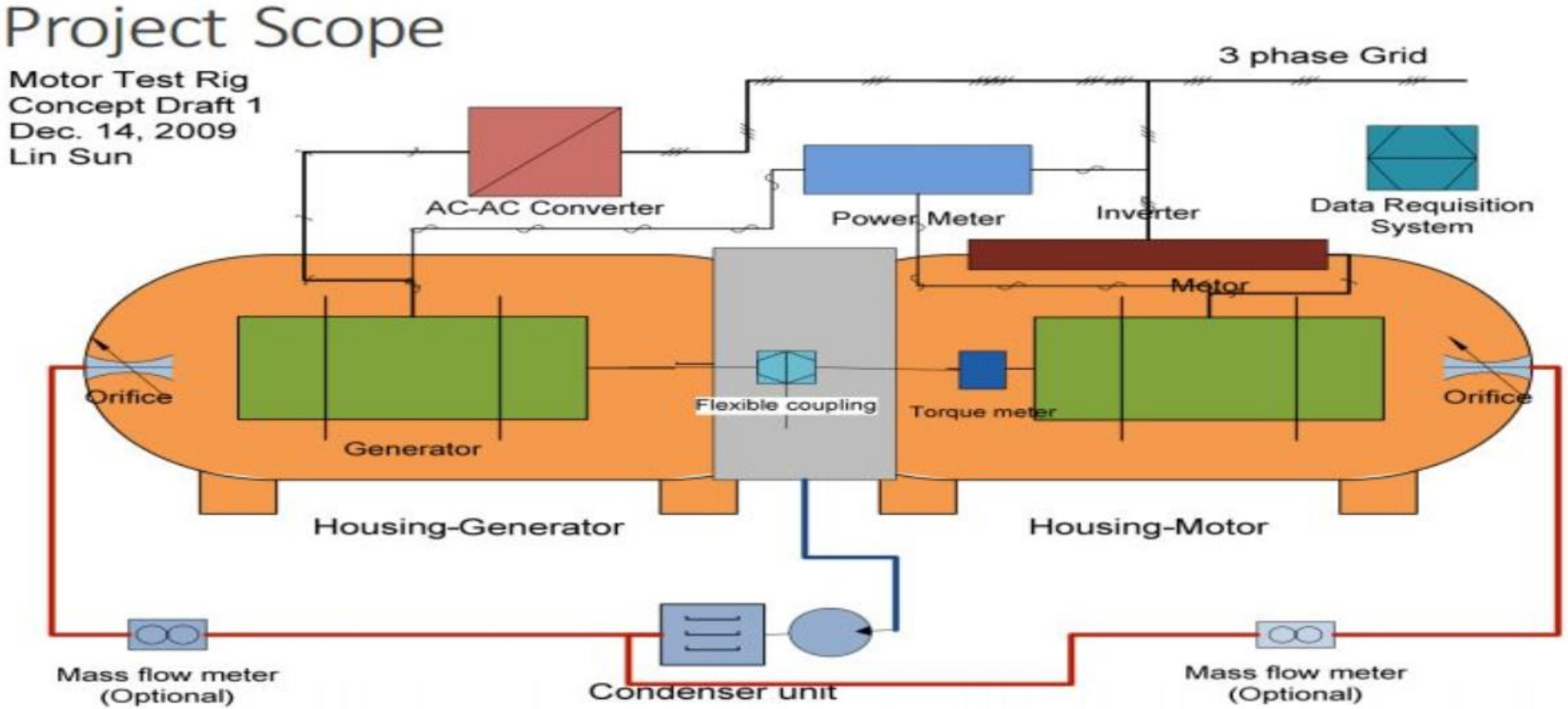


Fig. 2. Motor test rig - original project scope

LAST YEAR'S DESIGN

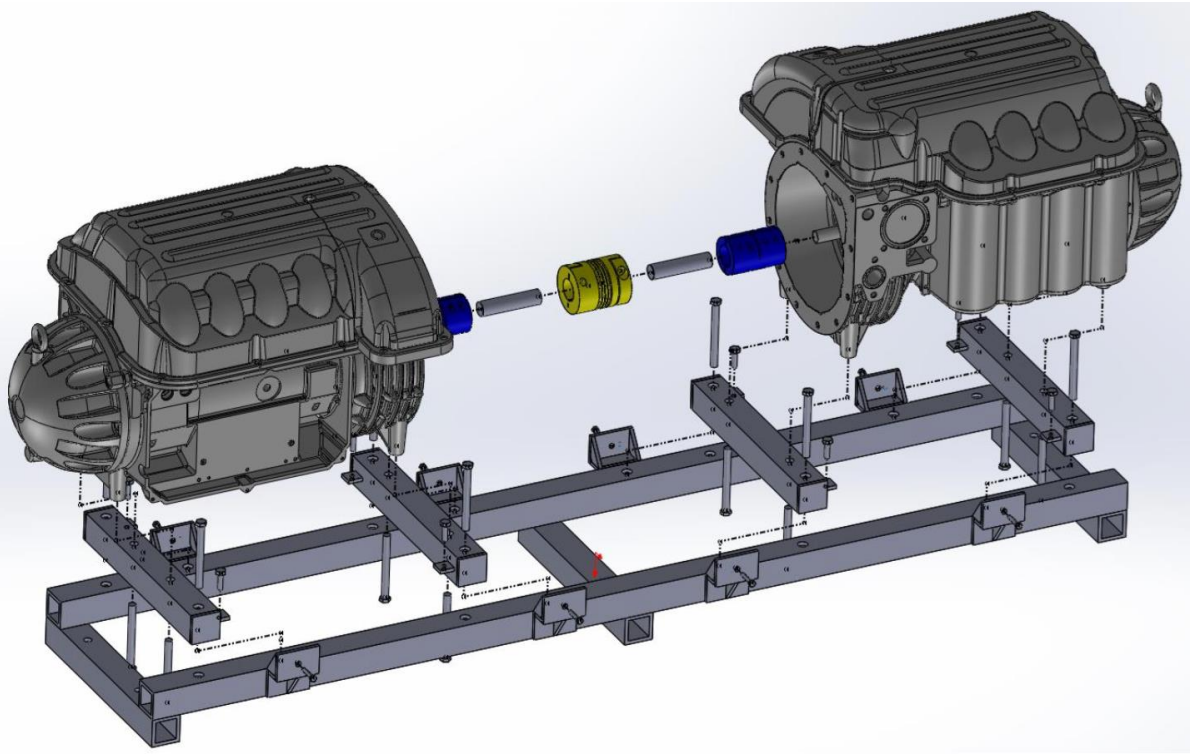


Fig. 3. Motor test rig – last year's design

- Two rigid couplings.
- One large flexible coupling.
- Two stainless steel shafts.
- Base frame.
- Aligned using a dial alignment system, lateral screw sets, shims.

LAST YEAR'S DESIGN: RESULTS

- Aligned the system well enough to successfully connect the two levitated compressor shafts.
- Able to run at relatively low speeds (1,000 rpm compared to 40,000 rpm high).
- The external components vibrated and eventually shut down from force exerted on internal shaft.

LAST YEAR'S DESIGN: PROBLEMS

From analyzing their system and their results:

1. Misalignment
2. Complexity of design and set up
3. Compressors fighting each other

Effects of these problems in the system:

- System oscillates at higher speeds and compressors turn off

PROJECT OVERVIEW

OUR OBJECTIVES

1. Improve alignment in the system
2. Simplify the setup and operating process
3. Reduce vibrations
4. Achieve a higher rpm (Goal: up to 10,000 rpm)

APPROVED DESIGN

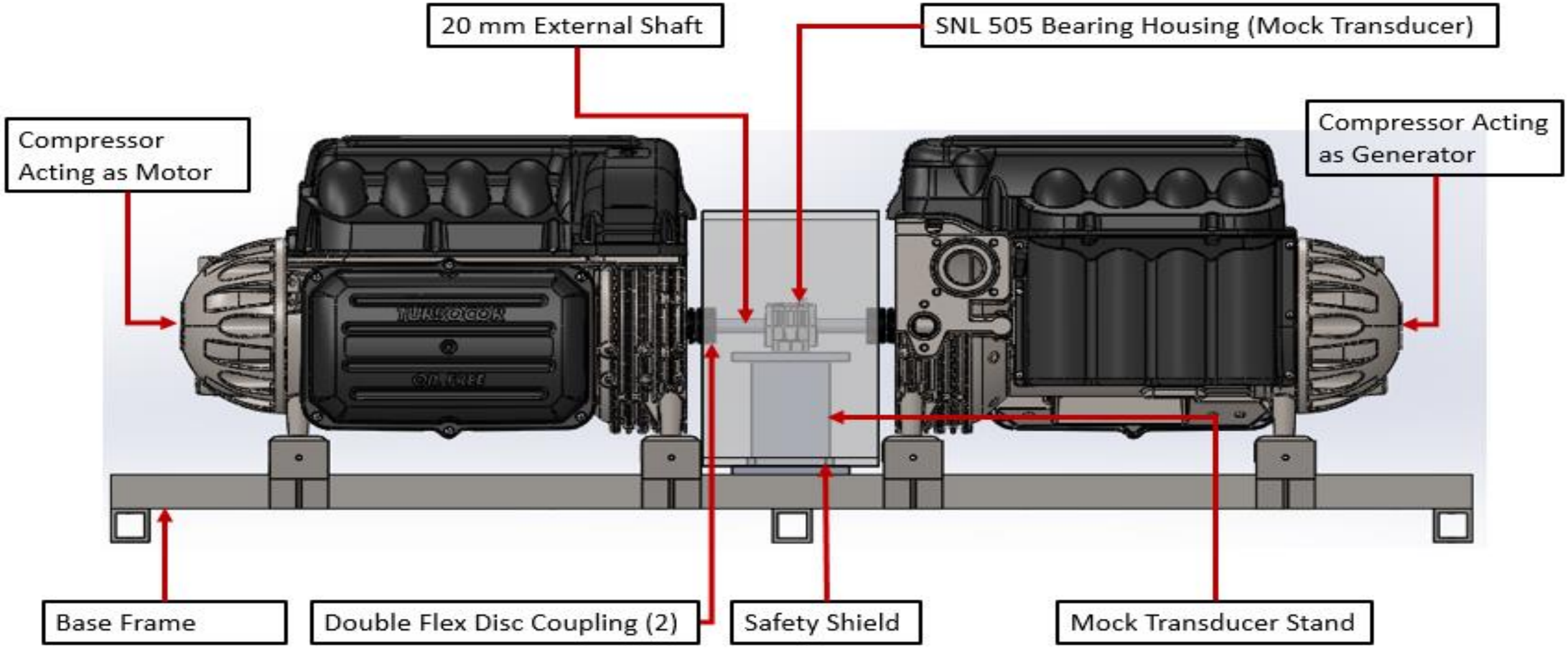
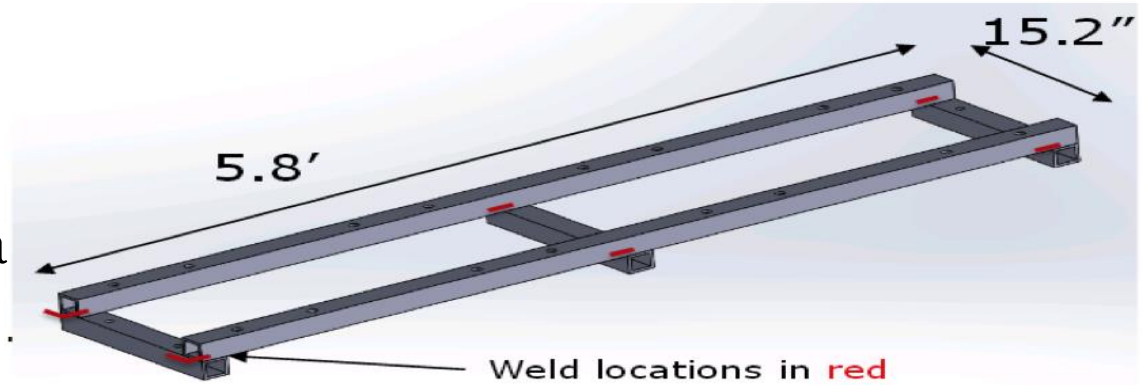


Fig. 4. Motor Test Rig

DESIGN PROCESS

BASE FRAME DESIGN

- 2"x 2" mild steel tubing (¼" thick)
  - Chosen for its ability to resist warping during welding and availability
- FEA Showed a maximum stress of 0.34 MPa
  Steel yield strength: 250 Mpa
- Status: Manufactured



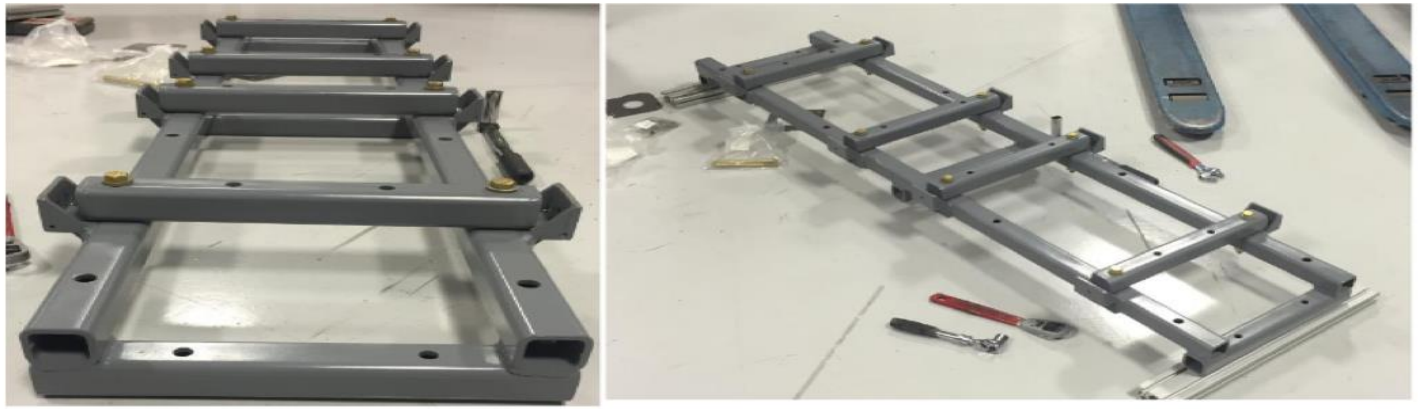


Fig. 5. Base Frame Stand

Fig. 6. Base Frame Von Mises Stress

DESIGN PROCESS

DOUBLE-FLEX DISC COUPLINGS

Fig. 7. Zero-Max double-flex disc coupling

- Quantity: 2
- Adjustable Collar (not keyway)
- 22mm shaft connecting to 20 mm shaft
- Up to 9,500 rpm
- Status: Purchased and delivered

DESIGN PROCESS

TORQUE TRANSDUCER

Fig. 8. Magtrol TMHS 310 torque transducer

- Total Price: $10,861
  - Transducer: $8,250
  - Power Supply: $2,380
  - ER 113 Signal Cable: $231
- Quantity: 1
- Torque Rating: 50Nm nominal; 100Nm over range
- High Speed Applications: up to 32,000 rpm
- Stainless Steel Shaft Diameter: 20h6 mm
- Status: Denied due to price and lead time

DESIGN PROGRESS

MOCK TRANSDUCER (BEARING HOUSING)

Fig. 9. SNL 505 bearing housing

- Quantity: 1
- Roller Bearing in Housing
- High Speed Applications: up to 17,000 rpm
- Diameter: 31.5 mm (Compatible with desired bearing)
- Status: Purchased and delivered

DESIGN PROCESS

MOCK TRANSDUCER (BEARING AND ADAPTER SLEEVE)

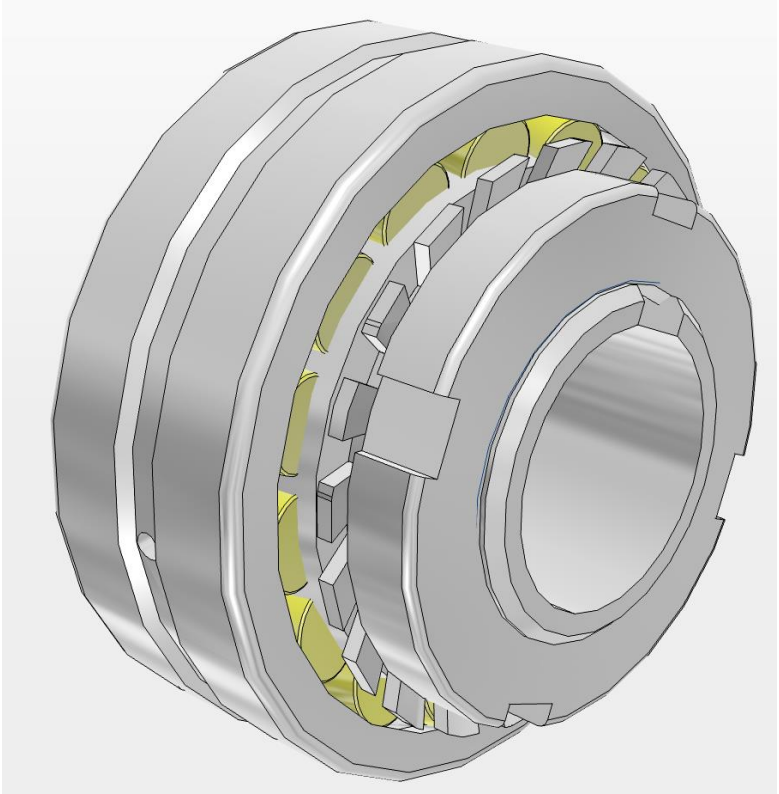


Fig. 10. Spherical roller bearing with adapter sleeve

- Quantity: 1
- Roller bearing
- 2 x FRB 5/62 Locating rings
- High Speed Applications: up to 17,000 rpm
- Bearing outer diameter: 31.3 mm
- Stainless Steel Shaft Diameter: 20 mm (Compatible with couplings ordered)
- Status: Purchased and delivered

DESIGN PROCESS

MOCK TRANSDUCER STAND

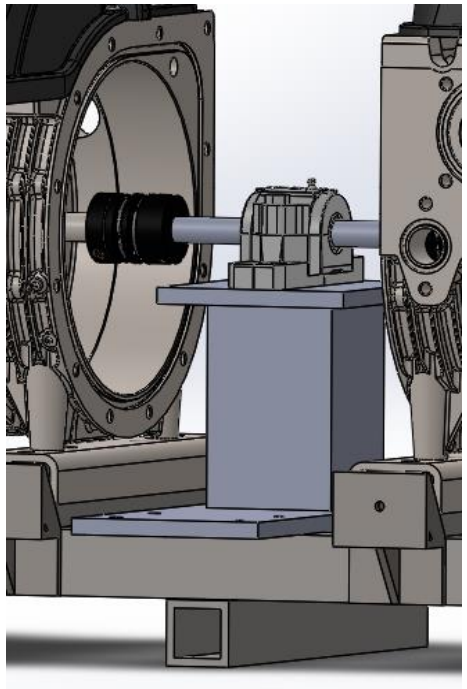


Fig. 11. Mock transducer stand with emphasis connecting to compressor

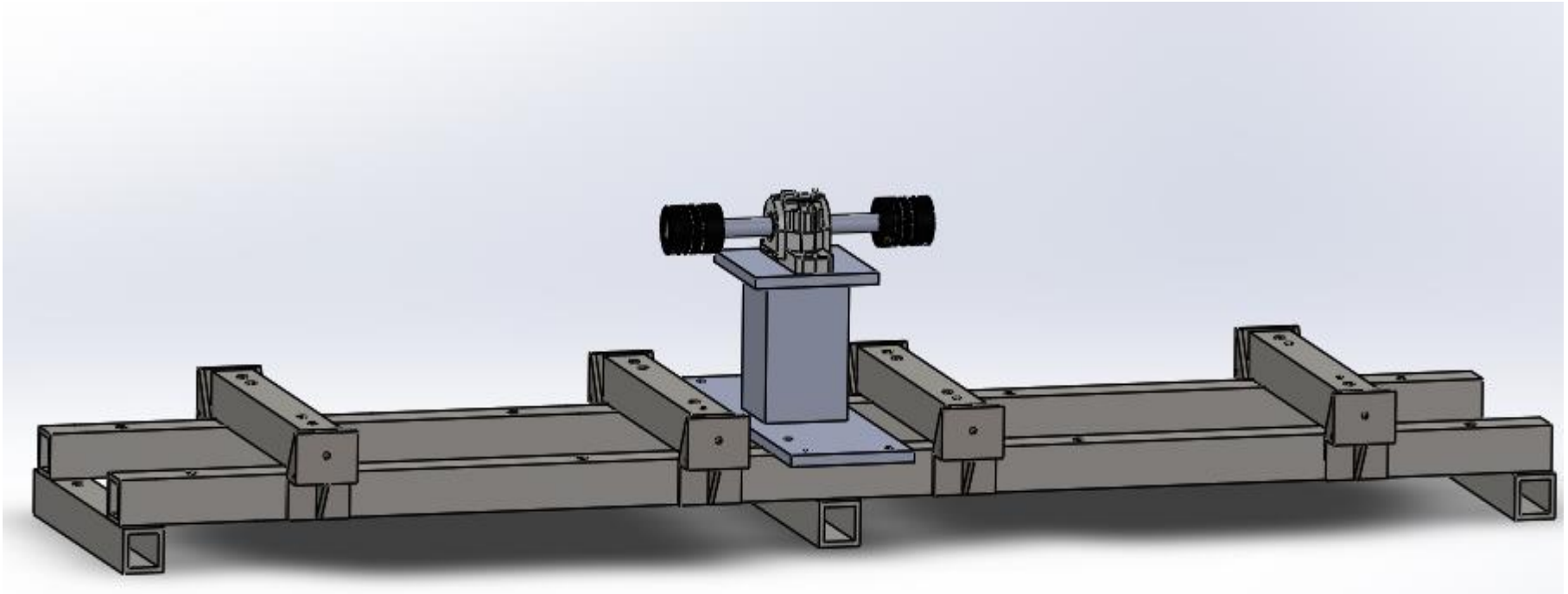


Fig. 12. Test rig with focus on rigid components

DESIGN PROCESS

SAFETY SHIELD

- The housing will be made out of acrylic
  - Exceptional impact strength: 336.286-640.544 J/m (Charpy impact strength)
  - Outstanding clarity
- Status: In progress

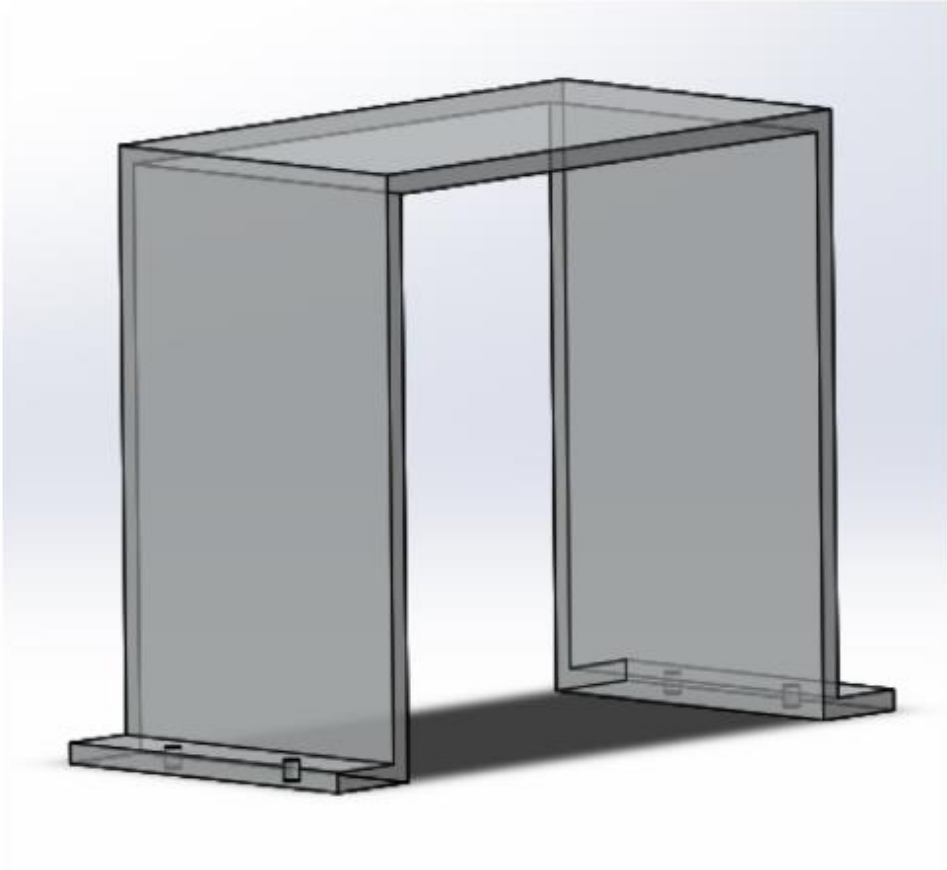


Fig. 13. Safety Shield

DESIGN PROCESS

LASER ALIGNMENT TOOL

Fig. 14. SKF Shaft Alignment Tool TKSA 31

- Price: Approximately $4,192
- Quantity: 1
- Accurate up to 5 microns
- Live position-correction feed
- Status: Purchased and delivered

OPERATION PROCESS

LASER ALIGNMENT TOOL

Fig. 15. SKF shaft alignment tool TKSA 31

- Each dimension input box can be clicked at any time.
- The units English or Metric can be selected from the settings menu before the alignment is started.

OPERATION PROCESS

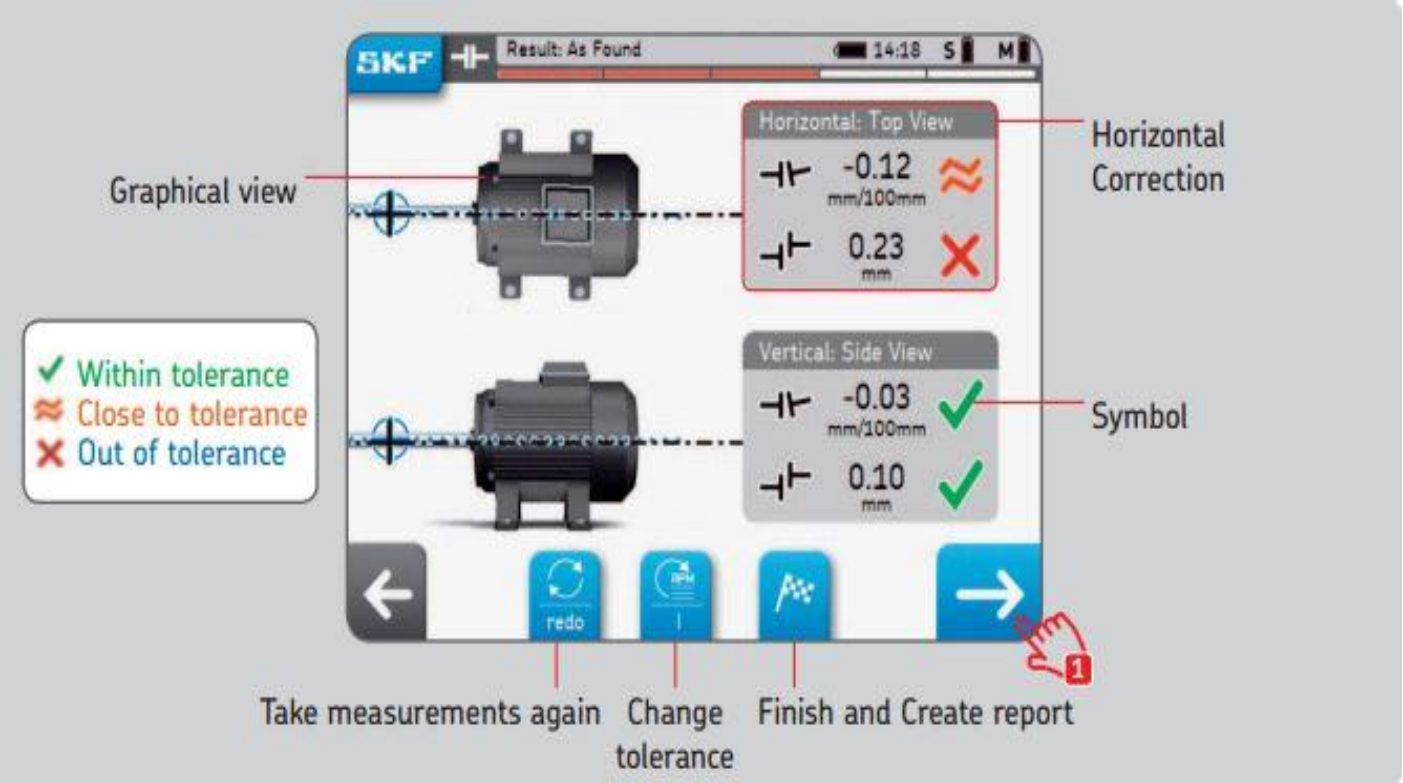
LASER ALIGNMENT TOOL

Fig. 16. SKF shaft alignment tool TKSA 31

- The first position for measurement is the 9 o'clock position. Followed by the 12 o' clock position and 3 o'clock position.
- A triangular wedge will indicate the required position of the measuring units during each step.
- Once the blue wedge turns green, a measurement will be taken by the sensor.
- Once the measurement is taken, the sensor will move to the next position.

OPERATION PROCESS

LASER ALIGNMENT TOOL



- The results page shows the coupling and feet adjustment values.
- The symbols compare the results to the tolerance range that was input.
- The black line being where the motor should be, the blue line being where the motor currently is.

Fig. 17. SKF shaft slignment tool TKSA 31

OPERATION PROCESS

LASER ALIGNMENT TOOL

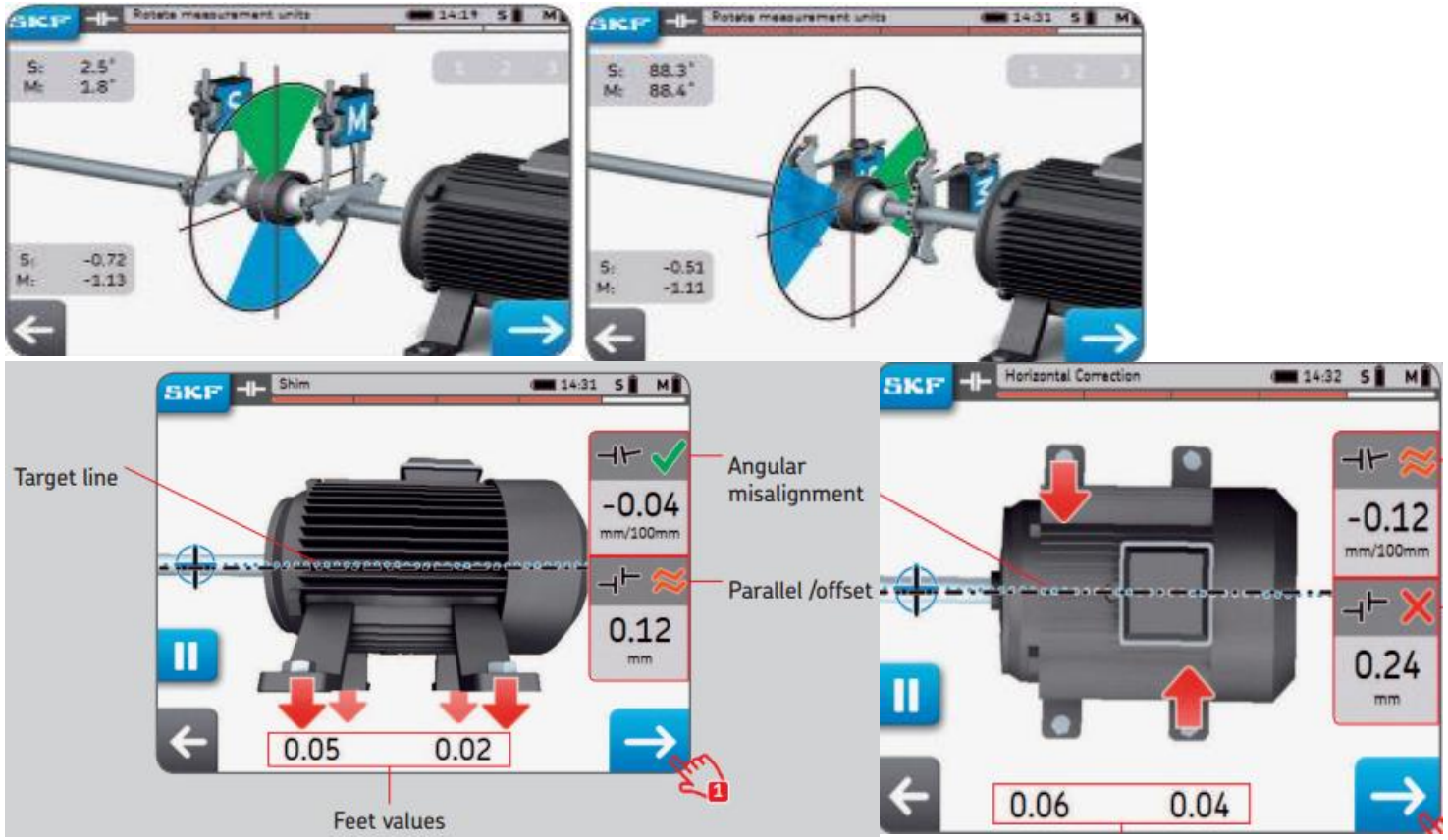


Fig. 18. Vertical and horizontal corrections

- Start by rotating the M sensor at the 12 o'clock or 6 o'clock position and validate.
- The arrows show in which direction the motor has to be moved.
- STOP when the coupling values are within tolerance and both Green marks are shown.
- Repeat that same process horizontally. Start by rotating the MU at the 9 o'clock or 3 o'clock position.

OPERATION PROCESS

Lateral Screw Set Alignment

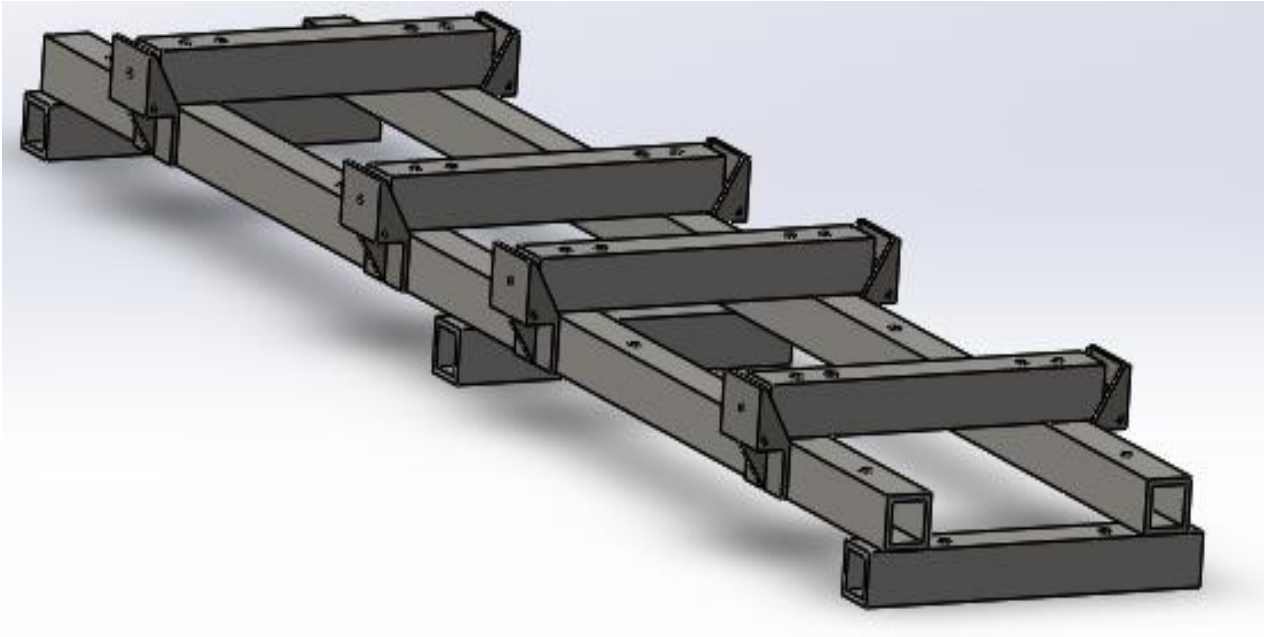


Fig. 19. Screw set location

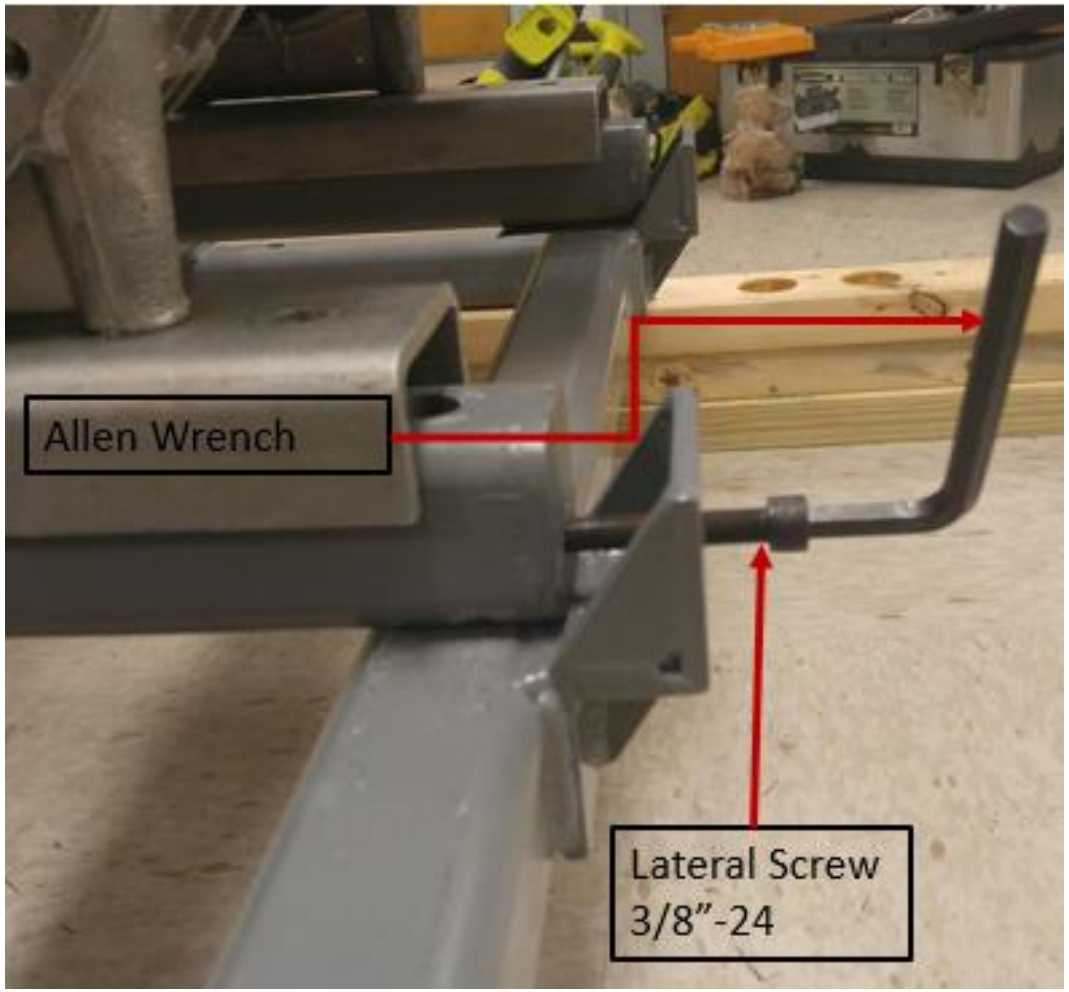


Fig. 20. Lateral set screws

OPERATION PROCESS

Vertical Shim Alignment

- The shims are made of brass and stainless steel
- Thickness varies from 0.001 inch to 0.031 inch
- A= 57mm, B=51mm, C=11mm

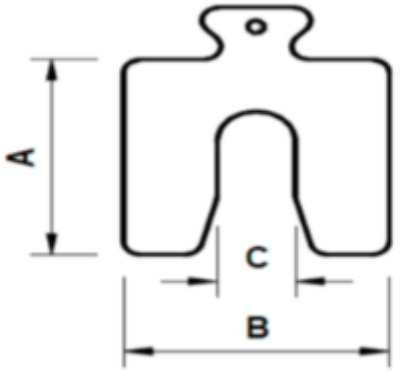


Fig. 21. Shim dimensions

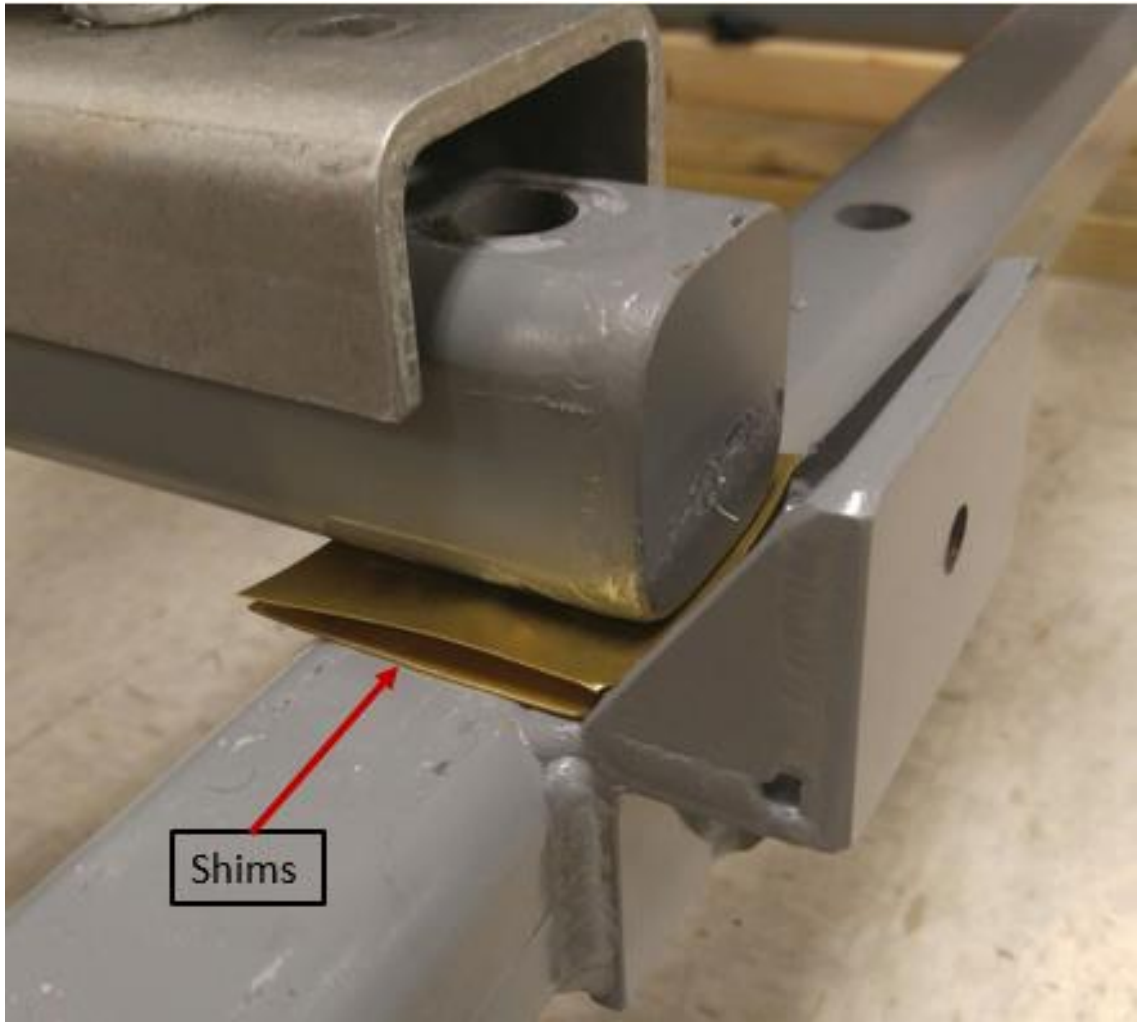


Fig. 22. Shims on motor test rig

OPERATION PROCESS

ALIGNMENT METHODS

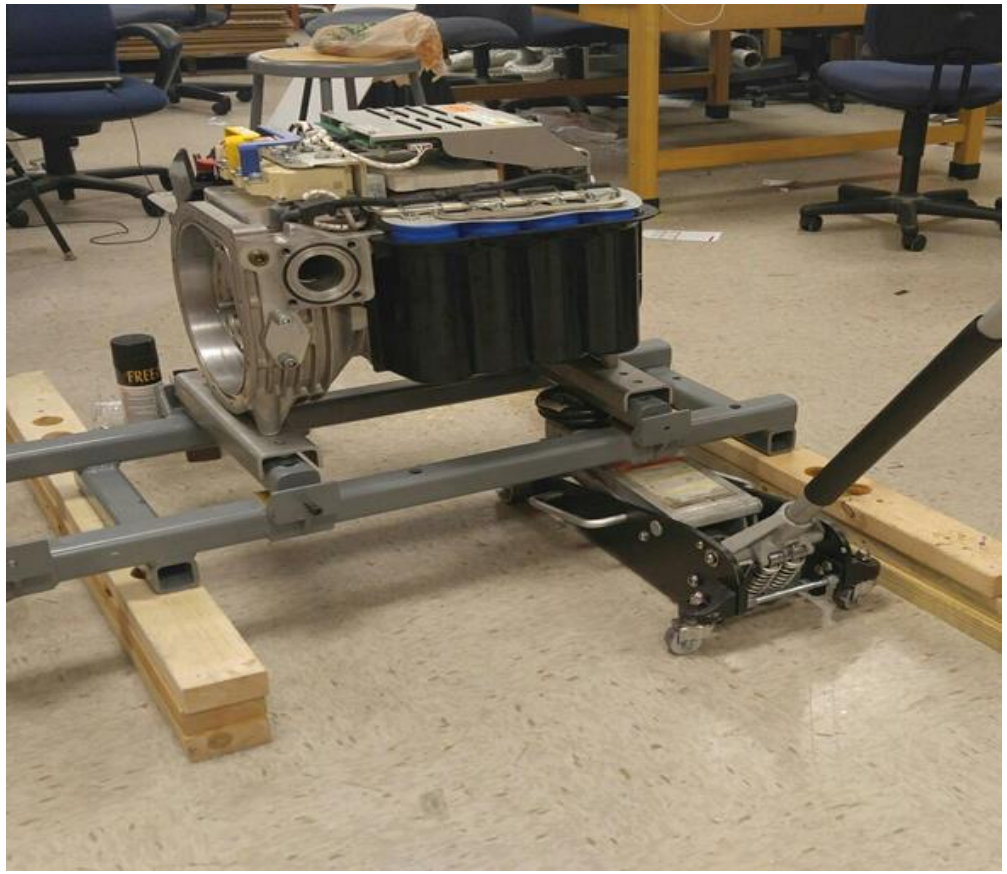


Fig. 23. Jack

- The test rig will be lifted vertically by using a car jack
- This will allow a much easier way to lift the compressor at each point to put in shims
- Max lifting capacity is 2 tons
- Lowest clearance is 6" so the entire stand will need to be lifted on wooden block in order for the car jack to slide through

APPROVED DESIGN

Exploded Assembly To Emphasize Component Location

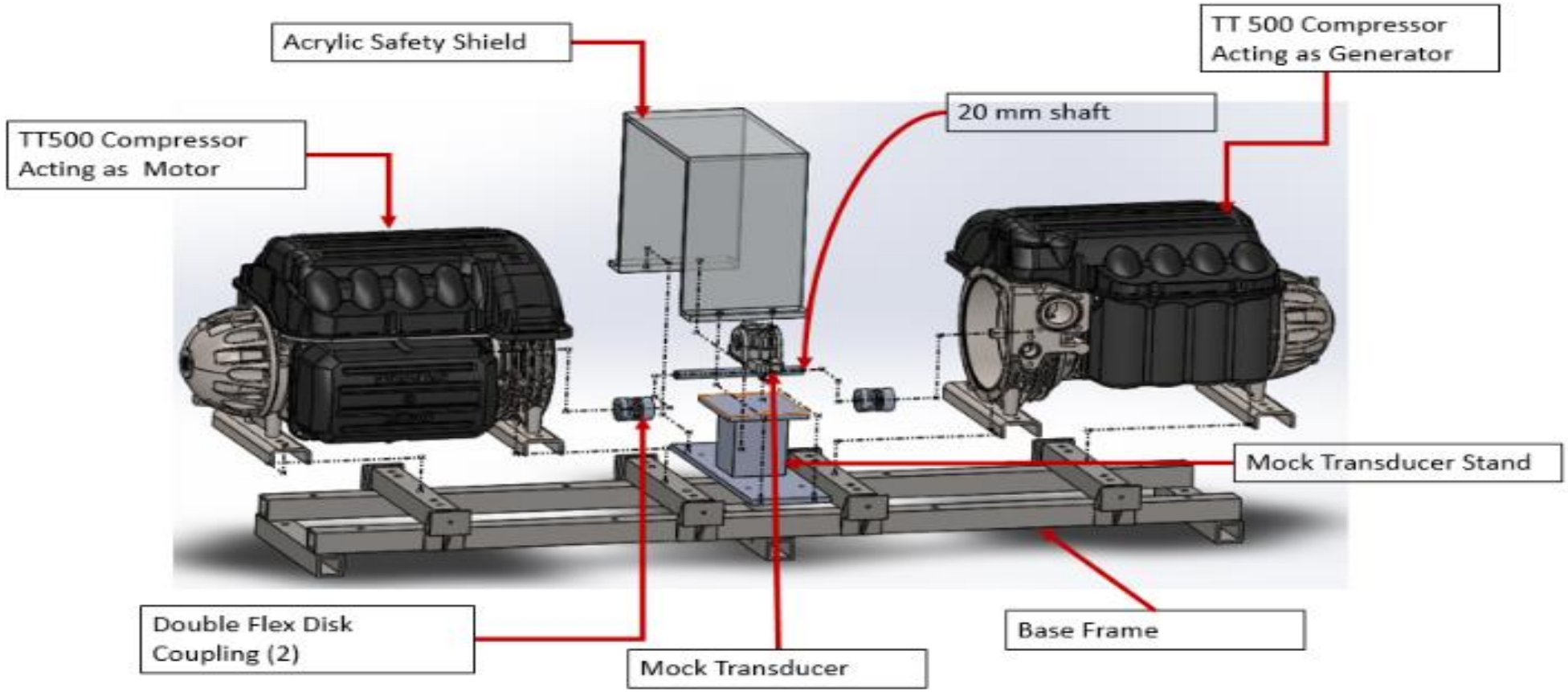


Fig. 24. Motor test rig

CURRENT STATE OF PROJECT

- We will be able to test the couplings and shaft with the laser alignment tool within the next few days.
- We are waiting on a few final components to be delivered in order to begin testing of entire rig next week.
- The results from running the motor test rig will be included in the final report.

COST BREAKDOWN

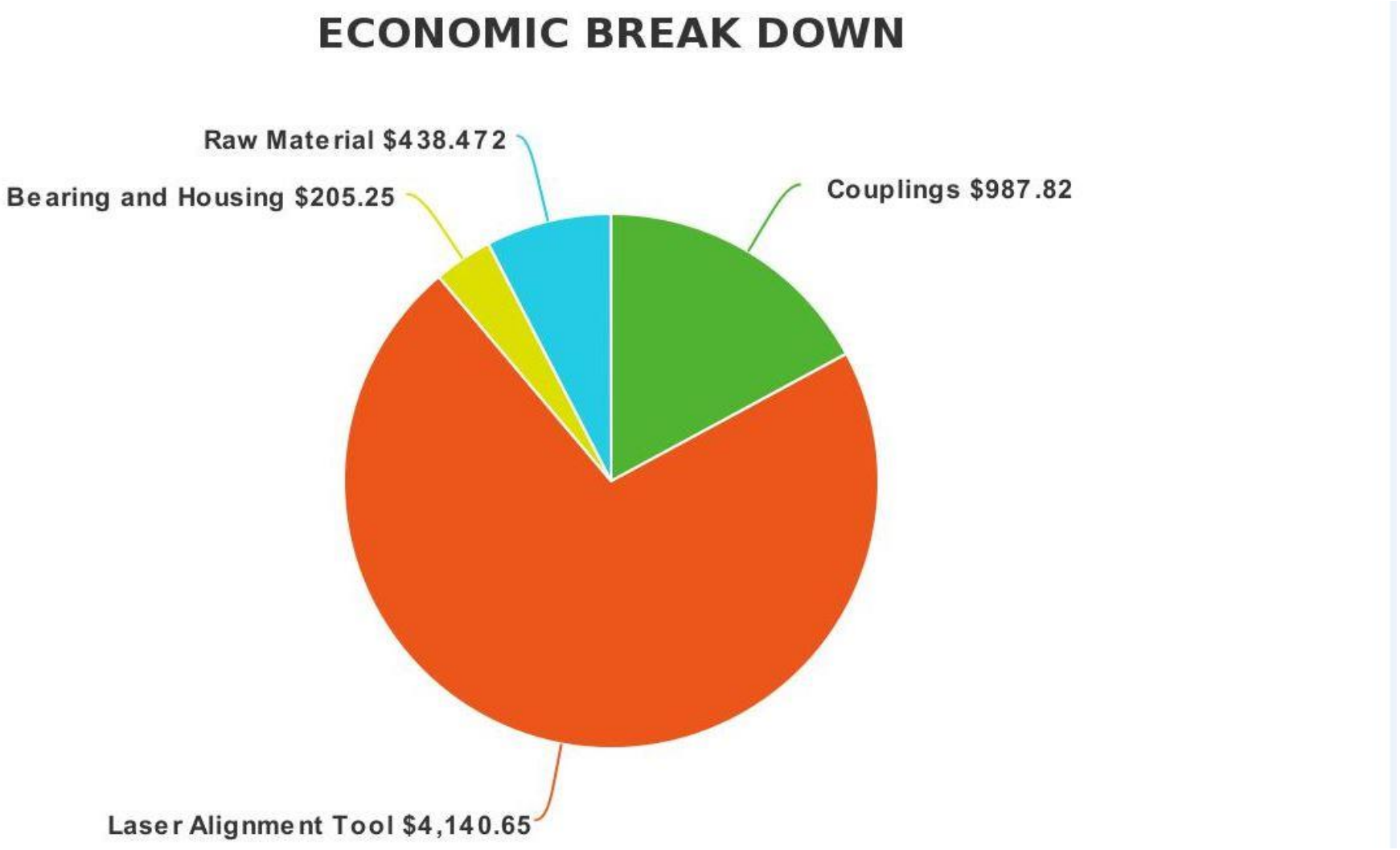


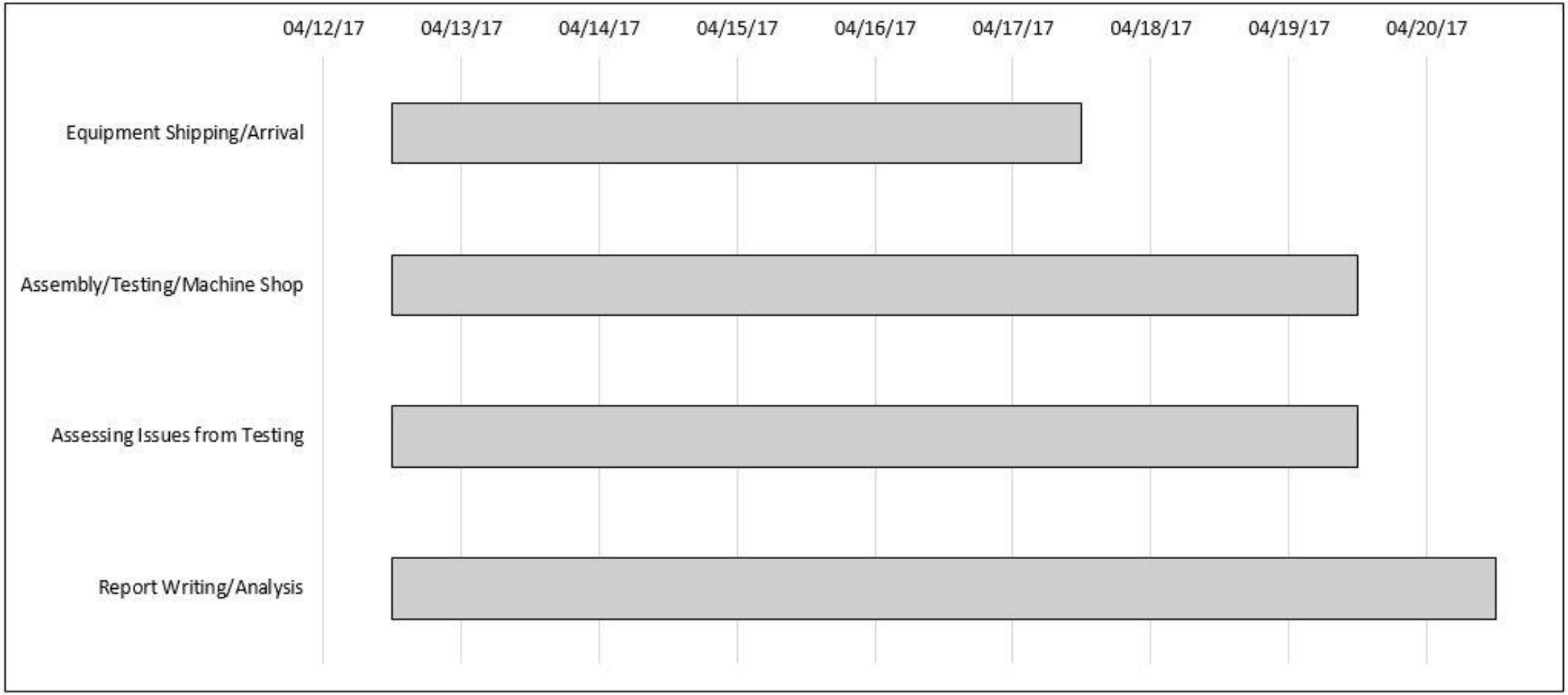
Fig. 25. Motor Test Rig

PROBLEMS FACED

- Miscommunication with suppliers caused some major set backs and re-ordering of parts.
- Machine shop requests take a long time to get processed and lead time was not correctly accounted for.

SCHEDULE

Table 1. Gantt Chart



CONCLUSION/ACKNOWLEDGMENTS

- Thanks to last year's Senior Design team for their contribution to the Motor Test Rig and all the recommendations they left for our group to implement.
- Thanks to Danfoss Turbocor for sponsoring the project, all their employees that gave us guidance throughout the year, and the resources that they gave us access to.
- Thanks to our Senior Design Advisor Dr. Hollis for helping add to the design theories and always being there for any questions we needed answered.
- Thanks to Dr. Shih for taking over the class mid year and always giving us the constructive criticism our team needed to hear.

REFERENCES

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- http://eng.fsu.edu/me/senior_design/2016/team04/finalreport.pdf
- http://www.skf.com/binary/30-227821/MP5430EN.pdf
- http://3.imimg.com/data3/FW/MO/MY-5715853/bearing-housing-500x500.jpg
- http://www.aetnaplastics.com/products/d/makrolon
- https://www.youtube.com/watch?v=GtYlNY8hHDc&t=2s

QUESTIONS?