Skid-Steer Self-Leveling Valve

Team: S3L

Team Members: James Andrews, Jason Burant, Matt Melbye, Jacob Roley

Advisor: Dr. Daniel Williams

MSOE

2018 SPRING

Abstract

The purpose of this project was to design, prototype, and test a fully hydraulic bi-directional skid-steer self-leveling system. A skid-steer is a motor-driven, fluid-powered machine with a wide range of applications including material handling, earth moving, and construction. The figure at right Depicts the components of the skid-steer that pertained to the project.

A medium frame skid-steer loader was considered. The final solution is a machined manifold with 14 HYDAC cartridge valves integrated into the existing hydraulic system of a Wacker Neuson Skid-Steer.

Introduction

Self-leveling refers to automatically maintaining the bucket (or attachment) orientation without operator intervention. Bi-directional self-leveling refers to the ability to maintain the angle during both raising and lowering of the boom.

Problem/ Need

Self-leveling valves provide the following:

I. Increased operator efficiency & focus
II. Increased Jobsite Safety

Assumptions/ Limitations

This design utilizes a fixed-ratio flow-divider to divide a portion of the boom cylinder return flow to the bucket cylinder. To self-level with this method, it is assumed that the skid-steer linkages are designed in a way that a fixed-ratio of flow can be divided between the two cylinders to effectively level the bucket with a ±8-degree angle tolerance.

Design Requirements

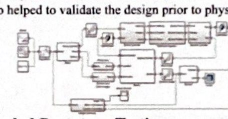
The following constraints and objectives were developed for the scope of the project:

I. Maintain desired skid-steer bucket angle tolerance of ±8° throughout boom stroke
II. Must use existing hydraulic system components
III. Operator must be able to control bucket independent of boom movement
IV. No additional electronics or solenoid operated valves
V. Scalable across different model sizes and lift configurations

Testing Approach

Mechanical & Hydraulic Simulation

The self-leveling system design was first validated by creating a MATLAB SimScape model of the hydraulic schematic. SimScape was used to simulate the self-leveling system connected to a dimensionally accurate solid model of a Wacker Neuson skid-steer. The model helped identify issues with overrunning loads, which led to the addition of two needle valves into the system. It also helped to validate the design prior to physical testing.

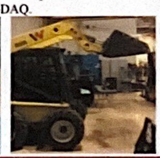


Bread-boarded Prototype Testing

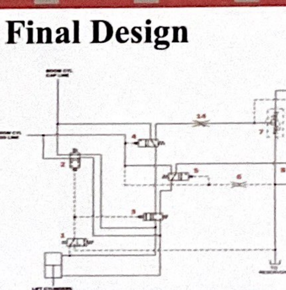
The self-leveling system prototype was assembled using HYDAC valves and various hydraulic fittings/ hoses supplied by the MSOE Fluid Power Institute. Two needle valves were used to replace the boom and bucket cylinders and replicate varied bucket loads. Flow meters were used to monitor the flow rate of hydraulic oil being supplied to each cylinder. Pressure transducers were placed at specific spots throughout the system in order to verify pilot-pressures. A DAQ system was used to accurately capture flow and pressure data during testing.

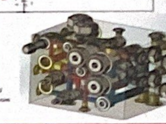
Skid-Steer Testing

Several hydraulic lines were disconnected from the skid-steer and connected to the self-leveling system prototype. The self-leveling capability of the prototype was evaluated using a plum-bob analog angle sensor. Tests were performed with 0 and 1500-pound loads. Pressures and flows were also monitored using the DAQ.

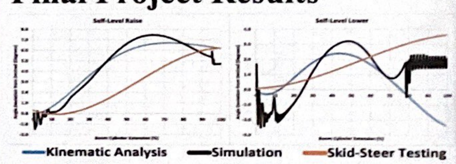


Final Design





Final Project Results

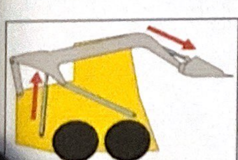


Machine Test Results	Maximum Angle Deviation (degrees)					
	Self-Level Raise			*Self-Level Lower*		
	Low Idle	Medium Idle	High Idle	Low Idle	Medium Idle	High Idle
Bucket	8.5	7.0	6.0	6.0	5.0	5.5
Fork+1500 lb	6.0	6.5	6.0	6.5	3.5	6.0
Average	7.0	6.8	6.0	6.3	4.3	5.8

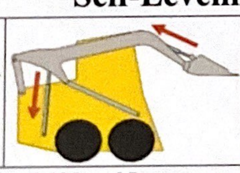
Conclusions & Areas of Improvement

The self-leveling valve prototype met all design requirements. Moving forward, custom flow dividers can be developed for the Wacker Neuson SW-20 to improve the self-leveling performance. Based on kinematic analysis, an ideal ratio of 54% (raise) and 24% (lower) would hold the angle within ±5° and ±3° for raise and lower, respectively. In addition, performance will be enhanced through further tuning and by condensing the valves into the designed machined manifold. Many additional losses were present on the prototype due to the addition of hoses, bends, and fittings.

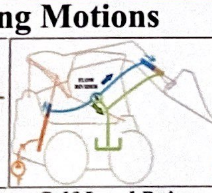
Self-Leveling Motions



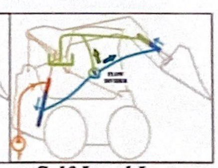
Self-Level Raise



Self-Level Lower



Self-Level Raise

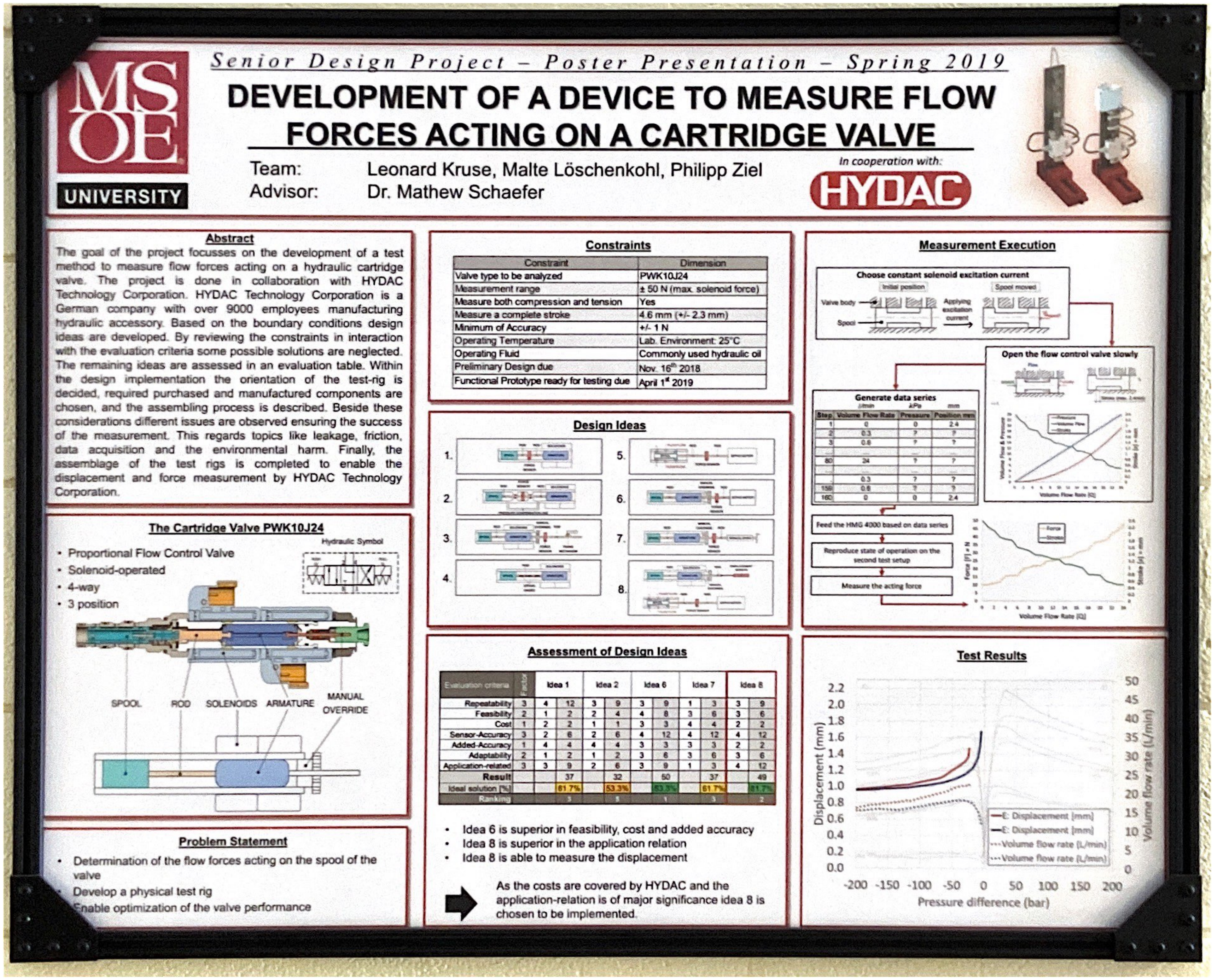


Self-Level Lower

Acknowledgements

The S3L project was sponsored by HYDAC and Wacker Neuson. Appreciation is also extended to MSOE Fluid Power Institute for their generous contribution of space, hydraulic components, and fluid power expertise.

HYDAC WACKER NEUSON FPI



Senior Design Project – Poster Presentation – Spring 2019

MSOE UNIVERSITY

DEVELOPMENT OF A DEVICE TO MEASURE FLOW FORCES ACTING ON A CARTRIDGE VALVE

Team: Leonard Kruse, Malte Löschenkohl, Philipp Ziel
Advisor: Dr. Mathew Schaefer

In cooperation with: HYDAC

Abstract

The goal of the project focusses on the development of a test method to measure flow forces acting on a hydraulic cartridge valve. The project is done in collaboration with HYDAC Technology Corporation. HYDAC Technology Corporation is a German company with over 9000 employees manufacturing hydraulic accessory. Based on the boundary conditions design ideas are developed. By reviewing the constraints in interaction with the evaluation criteria some possible solutions are neglected. The remaining ideas are assessed in an evaluation table. Within the design implementation the orientation of the test-rig is decided, required purchased and manufactured components are chosen, and the assembling process is described. Beside these considerations different issues are observed ensuring the success of the measurement. This regards topics like leakage, friction, data acquisition and the environmental harm. Finally, the assemblage of the test rigs is completed to enable the displacement and force measurement by HYDAC Technology Corporation.

The Cartridge Valve PWK10J24

- Proportional Flow Control Valve
- Solenoid-operated
- 4-way
- 3 position

Problem Statement

- Determination of the flow forces acting on the spool of the valve
- Develop a physical test rig
- Enable optimization of the valve performance

Constraints

Constraint	Dimension
Valve type to be analyzed	PWK10J24
Measurement range	± 50 N (max. solenoid force)
Measure both compression and tension	Yes
Measure a complete stroke	4.6 mm (+/- 2.3 mm)
Minimum of Accuracy	+/- 1 N
Operating Temperature	Lab. Environment: 25°C
Operating Fluid	Commonly used hydraulic oil
Preliminary Design due	Nov. 16th 2018
Functional Prototype ready for testing due	April 1st 2019

Design Ideas

1. 2. 3. 4. 5. 6. 7. 8.

Assessment of Design Ideas

Evaluation criteria	Factor	Idea 1		Idea 2		Idea 6		Idea 7		Idea 8	
Repeatability	3	4	12	3	9	3	9	1	3	3	9
Feasibility	2	1	2	2	4	4	8	3	6	3	6
Cost	1	2	2	1	1	3	3	4	4	2	2
Sensor-Accuracy	3	2	6	2	6	4	12	4	12	4	12
Added-Accuracy	1	4	4	4	4	3	3	3	3	2	2
Adaptability	2	1	2	1	2	3	6	3	6	3	6
Application-related	3	3	9	2	6	3	9	1	3	4	12
Result			37		32		50		37		49
Ideal solution [%]			61.7%		53.3%		83.3%		61.7%		81.7%
Ranking			3		5		1		3		2

- Idea 6 is superior in feasibility, cost and added accuracy
- Idea 8 is superior in the application relation
- Idea 8 is able to measure the displacement

As the costs are covered by HYDAC and the application-relation is of major significance idea 8 is chosen to be implemented.

Measurement Execution

Step	Volume Flow Rate (l/min)	Pressure (kPa)	Position mm
1	0	0	2.4
2	0.3	?	?
3	0.6	?	?
...	...	...	...
80	24	?	?
...	...	...	...
.	0.3	?	?
159	0.6	?	?
160	0	0	2.4

Test Results

An Optimized Acoustic Levitator for Science Experiments with Liquid Samples

MSOE UNIVERSITY

By: James Bant, Tyler Braun, Naoto Hall, Bernice Kubicek, Isaac Otterson & Christian Tango-an

Advisor: Dr. Michael Sracic

Sponsor: Dr. Kamlesh Suthar

Spring 2019

U.S. DEPARTMENT OF ENERGY | Office of Science | Argonne NATIONAL LABORATORY

MOTIVATIONS

Argonne National Laboratory has partnered with MSOE senior design teams for the past three years to develop a more stable and efficient acoustic levitator. Previous teams have increased stability with two and three-axis systems, but were unsuccessful at levitating water or unsuccessful at running for the desired time.

Research in new materials, chemicals and substances are conducted using mainly microscopic slides. This current method creates contact and it contaminates the specimen. Acoustic levitation is a new and effective concept that is used to remove the contact and the contamination for a raw and precise reading.

CHALLENGES

Objectives:

- Levitation of 100 µm - 1 mm water droplet
- Particle Stability of 100 µm
- 30 minute levitation runtime
- Decrease noise with anechoic foam
- Frame alignment with an alignment jig

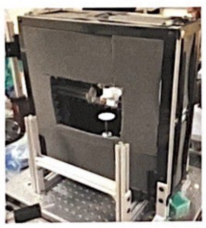
Constraints:

- Two-axis system
- Two Horns and reflectors
- Use of existing horns
- Operation above human hearing
- 8-12 wavelengths within the pressure field
- Size constraint of 24x24x24 in
- Power source 120 V, 20 A

SYSTEM DESIGN

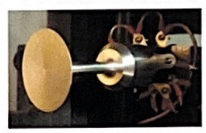
Anechoic Foam

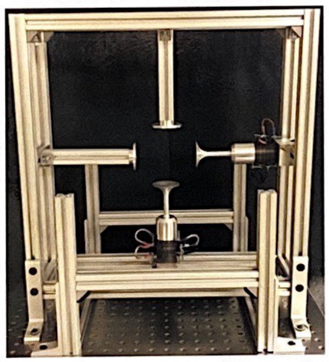
- Reduce effects of environmental noise
- Dissipate sound waves produced from machine

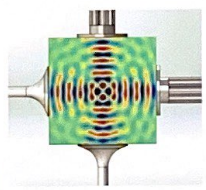


Horn and Transducer System

- Piezo stack optimization sweep—6 piezoelectric discs
- Torque optimization sweep—20 ft-lb torque

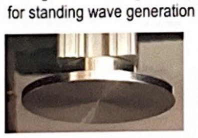






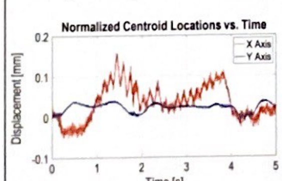
Reflectors

- Designed reflector geometry for standing wave generation



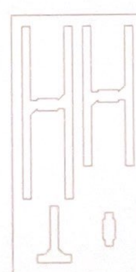
Particle Stability Analysis

- 1000 fps camera used for capturing images
- Post processing to determine particle stability and dimensions



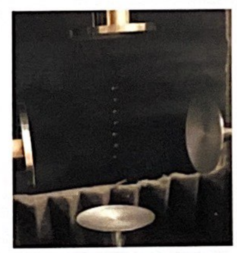
Alignment Jig

- 1/4 inch Acrylic Plexiglass
- CNC laser cut
- Accurate frame alignment
- Precisely aligns transducers and reflectors
- Decreases assembly time



ACHIEVEMENTS

- Inserted water droplets using a syringe
- Levitated water for over 18 minutes
- Captured droplet levitation
- Developed stability capturing method
- Achieved a particle stability of 18%
- Levitated 1.95 mm water droplet
- Created an isolating an-echoic chamber



TEAM FLOAT

ACKNOWLEDGEMENTS

This research used resources of the Advanced Photon Source, a U.S. Department of Energy (DOE) Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357. This capstone project was also made possible by the sponsorship of Dr. Kamlesh Suthar and the guidance of Dr. Michael Sracic, Roger Hajny, Jeffrey MacDonald, and the Electrical Engin[illegible]ing Senior Design Team.

Team Turbolab: Gas Turbine Senior Design

Spring 2019

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Project Advisor: Dr. Prabhakar Venkateswaran

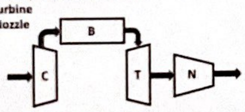
Abstract

The goal of the Turbolab Senior Design Project is to create a thrust generating gas turbine engine that can be used as an educational tool by future MSOE students in their thermodynamics courses. The engine will utilize a GT1544 turbocharger, which provides cost effective compressor and turbine components. Components designed and fabricated separately include a combustion chamber, nozzle, fuel and ignition system, lubrication system, and data acquisition system. The final project deliverables include a safe and reliable gas turbine engine, necessary instrumentation to conduct a thermodynamic analysis of the system, a lab procedure with background and methodology, and documentation for proper maintenance and safe use of the system. Despite other educational gas turbine engines costing over $60,000, the initial projected cost of this apparatus is $1,974 (not accounting for the work of the Turbolab team members). This low projected cost forces the Turbolab design team to make economical decisions, and leaves room for students to further refine the system in the future.

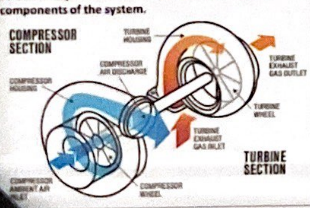
Introduction and Theory

The following schematic shows the Brayton Cycle, which forms the core of a gas turbine engine and consists of:

- C-Compressor
- B-Burner/Combustion chamber
- T-Turbine
- N-Nozzle



The image below is a diagram of a basic automotive turbocharger, which provides the compressor and turbine components. This creates two of the main components of the system.

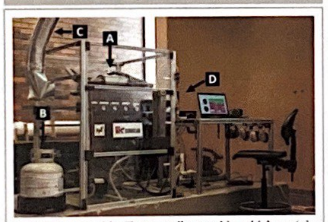


Design Requirements

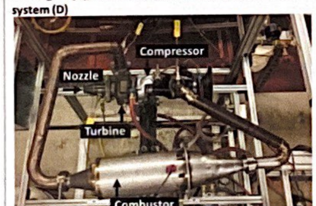
Adaptation of the turbocharger to fit the needs of our system by:

- Adequately document all procedures for future design teams as well as classes using the system for experimentation
- Designing and building a functioning combustion chamber
- Developing a Robust and reliable start-up sequence
- Creating a lab-ready system that is compliant with MSOE's standards of safety, useable by students given proper training and supervision by a professor
- Install sufficient instrumentation to monitor the engine operation and collect data which can be used to conduct thermofluid system analysis
- Utilizing a turbocharger as a foundation for the design of the gas turbine

Final Assembly



Complete assembly: The overall assembly, which contains the engine (A), fuel tank (B), exhaust (C), and control system (D)



Main Components: The brayton cycle components of the system

Flame Stabilization Testing

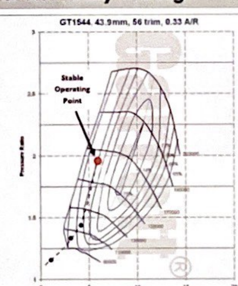
Flame stability: The flame's ability to remain in the same spatial location despite variations in and fuel flow rates, turbulence levels, or fuel quality.

Bluff body: An un-streamlined body placed in the approach flow to generate a recirculation zone which aids with flame stabilization.

Experiment summary:

- Scaled version of a Bunsen burner
- Various bluff bodies were tested
- The flame with no bluff body (left) was simple to stabilize, but the length was not consistent, meaning there was a large amount of unsteady vertical movement.
- Steel cylinder (middle) became much less variable. The flame sat in the recirculation zone of the flow and got shorter (chosen in final design).
- The aluminum coin (right) sat just above the rim of the coin and circulated behind the coin. The length got considerably shorter and has next to no variation.

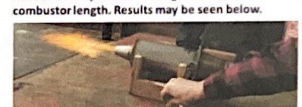
Final Assembly Testing



Above is a compressor map specified for the turbocharger at hand. Points include startup and one stable operating point.

Combustion Chamber Testing

The combustor chamber was tested extensively to determine the geometrical and flow parameters needed to keep the flame length shorter than the combustor length. Results may be seen below.



Initial testing: Unstable flame

Final testing: Short, stable flame

Future Work

Prospects include, but are not limited to:

- Advanced fuel injection system, including different fuel types and throttle
- Adding the ability to operate the system remotely
- Improving overall combustor efficiency

Acknowledgements

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