PURDUE UNIVERSITY

CAPSTONE EXPERIENCE 2014

Hydraulically-Powered Grain Cart Axle with Tracks and Variable Motors

Agricultural & Biological ENGINEERING

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Figure 1: Existing prototype

Problem Statement/Objective

As the size and capability of grain carts continue to increase, a need for improved tractive ability and reduced tractive footprint arises. Consequently, some manufacturers began to offer models equipped with free-rolling tracks. However, due to tractive limitations, free-rolling tracks have reached the pinnacle of their utility. Thus, Terra Drive Systems (TDS), recognizing a business opportunity in which they could further expand their Mud Hog brand, decided to offer a universal hydraulically-powered tracked axle system. Considering the numerous grain cart manufacturers, designing for a universal platform is becoming more difficult and even more crucial in areas of performance, manufacturability, and ease of installation. The objective of this project is to assist with the completion of the axle system and to provide an analysis of the work that has previously been completed.

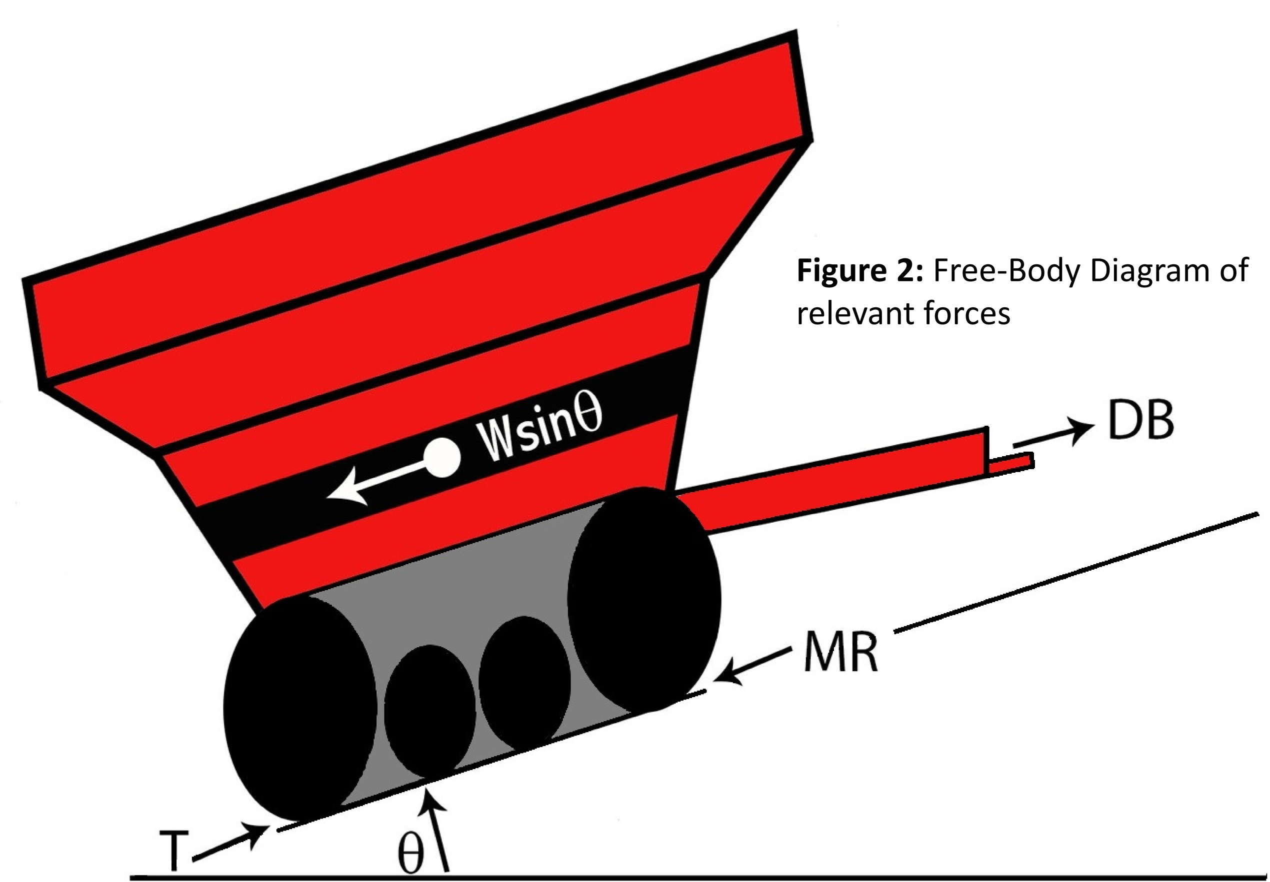

Figure 2: Free-Body Diagram of relevant forces

Tractive Model Overview

- Programmed within Microsoft Excel
- Enables the user to play around with multiple parameters in order to optimally size the hydraulic motors used to power the tracks
- Provides a rough approximation of tractive ability under a wide variety of conditions (topography, soil condition, etc.) utilizing the anticipated output from the previously-sized motors
- Has accommodations to allow the comparison of four tractor-cart-environment combinations at once
- The maximum tractive force output per motor is 5,177 lbs.

Outputs (Traction)									
WD	Dynamic Load Per Track	163916.9667	N	147614.2345	N	163916.9667	N	147614.2345	N
DWI	Dynamic Weight Index	1		1		1		1	
Bn	Mobility Number	16.57102643		16.42993441		15.67065718		18.40115486	
MRR	Motion Resistance Ratio	0.18086573		0.182161289		0.189533833		0.165861038	
MG	Motion Resistance (Grisso)	6664.902152	lb_f	6045.02238	lb_f	6984.321732	lb_f	5504.098547	lb_f
M	Motion Resistance (CAT)	1842.5	lb_f	1659.25	lb_f	1842.5	lb_f	1659.25	lb_f
MRS2	Motion Resistance (Snow, 2 inches)	921.25	lb_f	829.625	lb_f	921.25	lb_f	829.625	lb_f
MRS4	Motion Resistance (Snow, 4 inches)	1363.45	lb_f	1227.845	lb_f	1363.45	lb_f	1227.845	lb_f
MRDS	Motion Resistance (Dirt, Smooth)	921.25	lb_f	829.625	lb_f	921.25	lb_f	829.625	lb_f
MRDN	Motion Resistance (Dirt, Sandy)	1363.45	lb_f	1227.845	lb_f	1363.45	lb_f	1227.845	lb_f
MRMM	Motion Resistance (Mud, Minimal)	1363.45	lb_f	1227.845	lb_f	1363.45	lb_f	1227.845	lb_f
MRMI	Motion Resistance (Mud, Intermediate)	3445.475	lb_f	3102.7975	lb_f	3445.475	lb_f	3102.7975	lb_f
MRMS	Motion Resistance (Mud, Severe)	5527.5	lb_f	4977.75	lb_f	5527.5	lb_f	4977.75	lb_f
MRSM	Motion Resistance (Level Soft Sand, Minimal)	2211	lb_f	1991.1	lb_f	2211	lb_f	1991.1	lb_f
MRSI	Motion Resistance (Level Soft Sand, Intermediate)	3869.25	lb_f	3484.425	lb_f	3869.25	lb_f	3484.425	lb_f
MRSS	Motion Resistance (Level Soft Sand, Severe)	5527.5	lb_f	4977.75	lb_f	5527.5	lb_f	4977.75	lb_f

Performance

Incline Angle (°)	Soil Condition	Tractive Ability	Deficiency (lb_f)	Tractive Ability	Deficiency (lb_f)	Tractive Ability	Deficiency (lb_f)	Tractive Ability	Deficiency (lbf)
0	Grisso Method	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	CAT Method (5% of Static Wt.)	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Snow, 2 inches	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Snow, 4 inches	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Dirt, Smooth	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Dirt, Sandy	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Mud, Minimal	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Mud, Intermediate	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Mud, Severe	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Level Soft Sand, Minimal	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Level Soft Sand, Intermediate	Adequate	0	Adequate	0	Adequate	0	Adequate	0
0	Level Soft Sand, Severe	Adequate	0	Adequate	0	Adequate	0	Adequate	0
2.5	Grisso Method	Adequate	0	Inadequate	638.5113729	Inadequate	1498.08282	Inadequate	292.0773404

Figure 3: Some of the calculated outputs and the anticipated resulting tactive performance

Hydraulic System Overview

To start off, an interesting problem arose: the worst case scenario for the system (mud) is not the same as the worst case loading (firm soil). Force from the motors was stipulated to be 26% of the total propulsive force needed. The loaded cart weight is 71,080 lbs., which translates to 33,185 lbs per track after subtracting the weight on the drawbar. The tractor requirements are 60 gpm, 2,900 psi, and a minimum of four remote valves. The results from our calculations and design decisions are:

- Displacement Required = 895 cc for worst loading
- Motor Chosen – SAI Hydraulics TV 3.5 1,000-0 cc
- Valve Block - 3 Parker High Flow 2 Way Poppet Valves

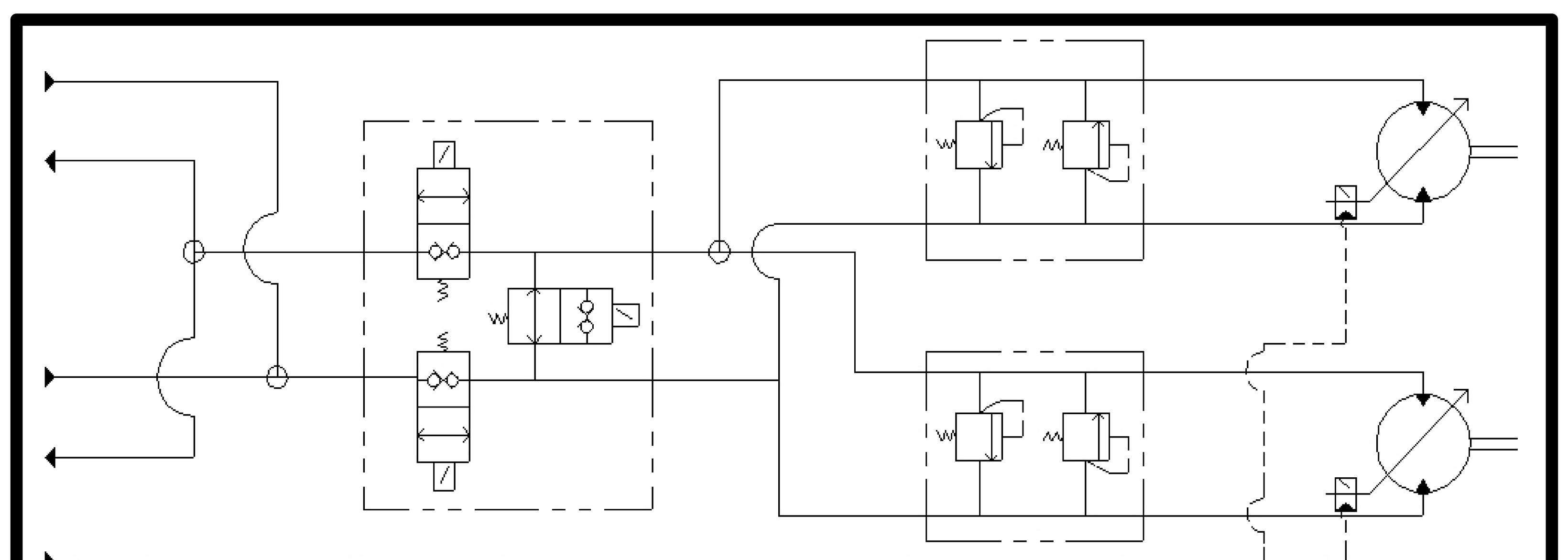

Figure 4: This is the final hydraulic schematic. To the left, the triangles represent connections to the tractor. The dashed lines surrounding the three groups of valves in the middle distinguish the separate valve bodies. To the right, the motors will then connect to the drive wheels of the tracks.

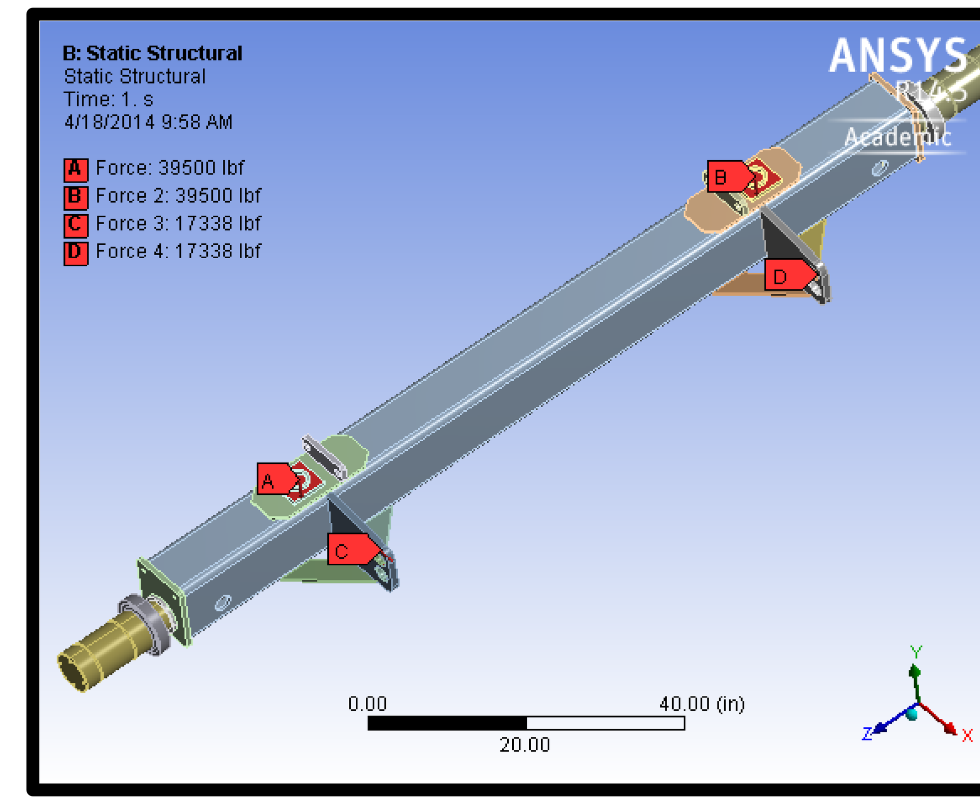

Figure 5: Axle and Spindle Assembly under Loading Scenario 2

Axle and Spindle Assembly Finite Element Analysis Overview

In order to assess the probable range of stresses and deformations in the axle and spindle, four loading scenarios were created to project forces likely to arise during operation.

- Load Scenario 1: forces due to fully-loaded grain bin
- Load Scenario 2: forces due to fully-loaded grain bin and maximum drawbar pull
- Load Scenario 3: forces due to fully-loaded grain bin on slope and maximum drawbar pull
- Load Scenario 4: forces due to sudden stop with fully-loaded grain bin

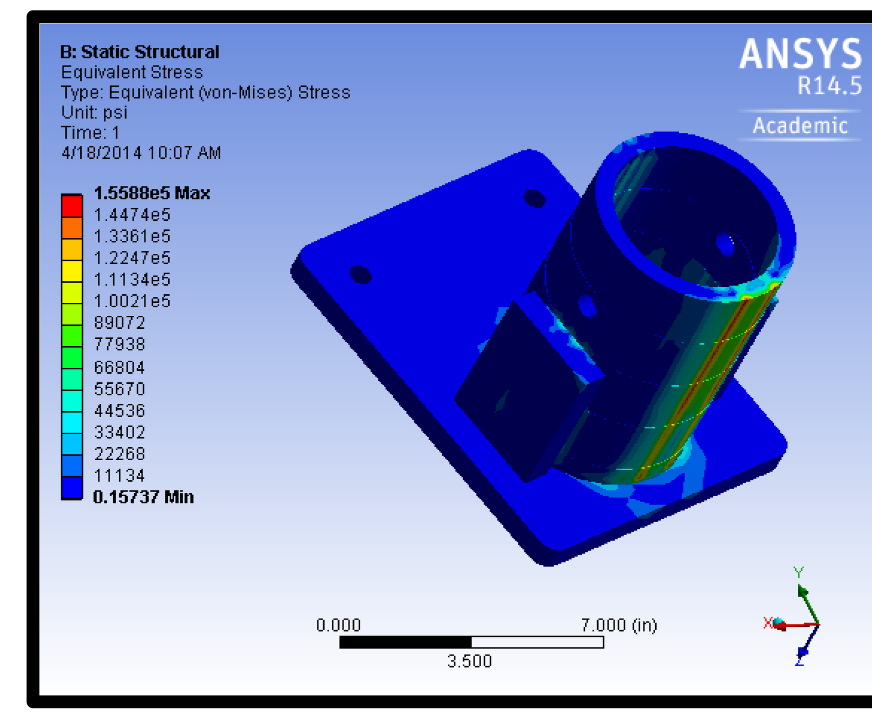

Figure 6: Spindle Support Stress Concentrations for Load Scenario 2

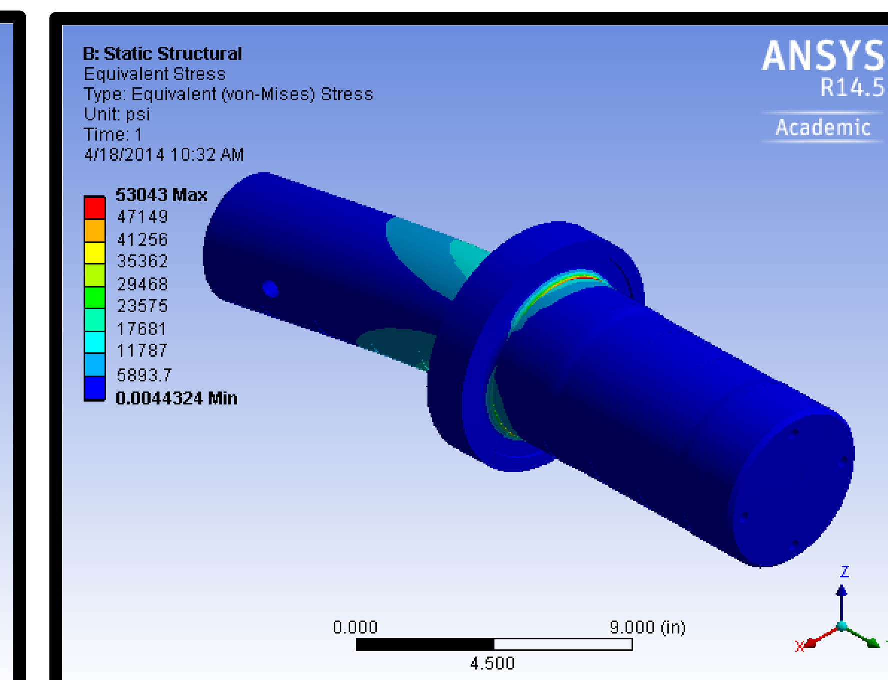

Figure 7: Spindle Stress Concentrations for Load Scenario 2

Possible Improvements/Recommendations for Future Work

- **Tractive Model**
  - Perform tests on the existing cart system in order to gather empirical data that can be used to more accurately model the soil-track interactions
  - Add capability to handle 3-D topography
  - Include accommodations for wheeled systems
- **Hydraulic System**
  - Add outputs to control program for the extra two solenoid valves
  - Add two wires/connectors to wire harness for extra solenoid valves
- **Axle and Spindle Finite Element Analysis**
  - Optimize axle and spindle components to reduce areas of stress concentrations based on Finite Element Analysis
  - Cycle analysis for load scenarios that exceed material yield strength

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