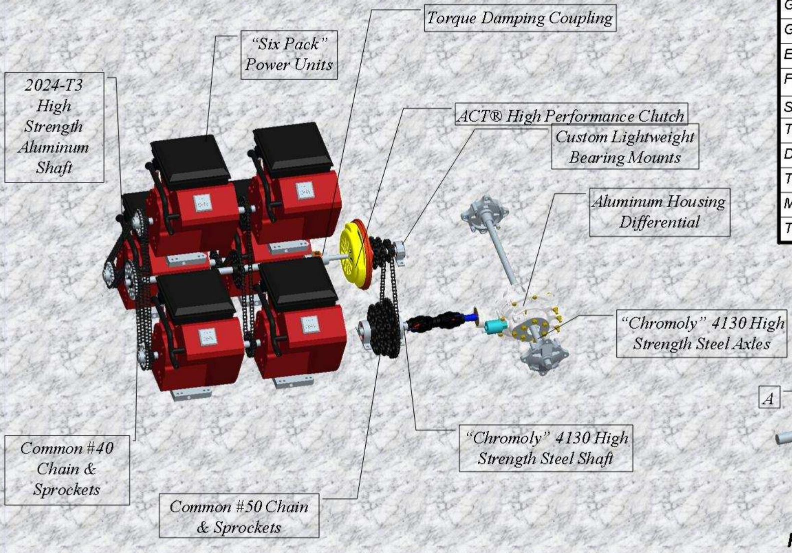
DRIVE TRAIN DESIGN FOR PQS07

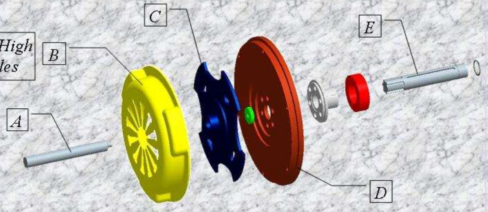
Designer:
Greg Long

DESIGN FEATURES



DRIVE TRAIN SPECIFICATIONS

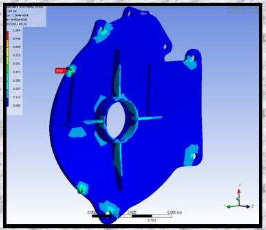
Gross Horsepower	96HP
Gross Torque	138 ft-lbs
Engine Reduction Ratio	1.52 : 1
First Gear Reduction Ratio	2.45 : 1
Second Gear Reduction Ratio	1.68 : 1
Third Gear Reduction Ratio	1.36 : 1
Differential Reduction Ratio	4.11 : 1
Top Vehicle Speed	27.8 mph
Minimum Vehicle Speed	5.11 mph
Towing Capacity	2500 lbs



PQS07 Clutch Mechanism

Torque transfers from common shaft [A] to friction disk [C]. Engagement and disengagement occurs by means of operating the pressure plate [B] causing the pressure plate and flywheel [D] to rotate with the friction disk. Torque is then transferred to the output shaft [E] to power the rest of the drive train.

Bell Housing Plate



Stress analysis of clutch bearing plate that supports the thrust loading of the clutch. Gusset bracing was added to reduce stresses from FEA analysis

ANALYSIS

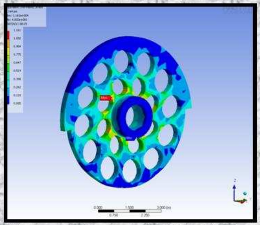
Design for Strength

- *Verify component dimensions based on predicted stresses of the particular component*
- *Efficient allocation of material to optimize the power per weight ratio of the tractor*

Design for Weight

- *Stress analysis determines how much unneeded material can be deleted from a component*
- *Reducing drive train weight reduced rotating inertia and increases power transfer efficiency*

Transmission Drive Sprocket



Drive sprockets were analyzed to determine how much unneeded material could be removed. FEA was conducted to optimize the power to weight ratio of the drive train

Stress analysis was conducted on the predicted high stress components of the drive train. Finite element analysis (FEA) was conducted through the use of ANSYS Workbench® to provide verification of design stresses. Components such as shafts, sprockets, mounting plates, and axles were analyzed with FEA to optimized the design for both strength and weight.

DRIVE TRAIN BILL OF MATERIALS

Components	Material
Engine Sprockets	#40 Chain Steel Type
Common Shaft Sprockets	#40 Chain Steel Type
Chain for Engines	Common #40 Chain
Common Shaft	2024-T3 Aluminum
Flange Bearings	1" Roller Bearing
LoveJoy Coupler	L100 Series Cast Iron
Key Stock	1/4" and 3/8" Mild Steel
Geo Metro Flywheel	10 Cast Iron
ACT Clutch	7 1/2" High Performance
Timken TSL Bearings	Sealed Tapered Roller
Transmission Shaft (upper)	1" 4130 High Strength Steel
Transmission Sprockets	#50 Chain Steel Type
Transmission Chain	Common #50 Chain
Transmission Shaft (lower)	1 1/4" 4130 High Strength Steel
Bottom Shaft Bearings	Sealed Roller
Polaris Driveshaft	Premium Cast Iron
Dana Differential	Aluminum Housing
Polaris Axles	Case Hardened Steel
Axle Shaft Material	1 1/4" 4130 High Strength Steel
Axle Tubes	2 1/2" Mild Steel Tubing
Axle Bearings	40mm Polaris Roller
Rear Wheel Hubs	Premium Cast Aluminum

FABRICATION

Custom fabrication of components provided valuable shop experience while learning the basics of machining and welding. Most components are stock items that required minor modifications.

Common sizes were used to make the components of the tractor readily replaceable and serviceable. Modifications included keyway cutting, axle shortening, flywheel, and sprocket weight reduction.

Newly designed components were the custom aluminum bearing mounts and the flywheel mounting hub.

Front Chain Drive

Front drive sprockets and chains where manufactured for lightweight and strength. Engine configuration tests proved the drive train performance.

Transmission Drive Sprockets

Reduction of weight was critical in the design of the drive train. Each sprocket was machined to optimize the power transfer to weight ratio.

PURDUE UNIVERSITY

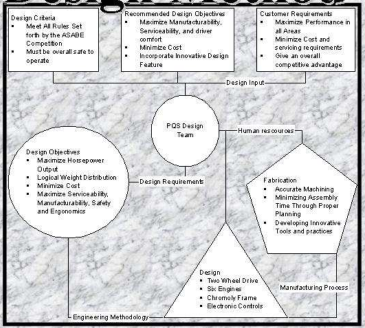
Title. Greg Long, John Mahrenholz MSE-ABE

April, 18 2007

Quarter Scale Tractor Design Competition

Designers:
Greg Long—Drive-Train
John Mahrenholz—Frame
April 18, 2007

Design Method



Cost Analysis

Frame			
Components		**List Cost**	**Our Cost**
1.00 x .125 6061 T6 DRAWN RD TUBE ALUM		$30.90	$30.90
1 X 1 X .065 4130 SQUARE TUBE		$440.02	440.02
1.00 X 1.00 X .125 HR STEEL ANGLE		$14.83	$14.83
3"x.25"x20' Aluminum Plate		$200.00	$200.00
6061 T6 Aluminum I-beam		$30.00	$30.00
Sheet-metal		$150.00	$0.00
Hitch Material		$100.00	$10.00
Sub-Total		$965.75	$725.75
Drive-Train			
Components		**List Cost**	**Our Cost**
Engine Sprockets		$49.08	$49.08
Common Shaft Sprockets		$22.86	$22.86
Chain for Engines		$29.20	$29.20
Common Shaft		$57.82	$57.82
Flange Bearings		$10.00	$10.00
LoveJoy Coupler		$26.00	$26.00
Key Stock		$4.00	$0.00
Geo Metro Transmission		$1,200.00	$150.00
ACT Clutch		$267.00	$0.00
Timken TSL Bearings		$40.00	$40.00
Transmission Shaft (upper)		$14.03	$14.03
Transmission Sprockets		$76.07	$76.07
Transmission Chain		$21.00	$21.00
Transmission Shaft (lower)		$21.94	$21.94
Bottom Shaft Bearings		$48.57	$48.57
Polaris Driveshaft		$98.79	$50.00
Dana Differential		$540.00	$0.00
Polaris Axles		$561.58	$110.00
Axle Shaft Material		$4.00	$0.00
Axle Tubes		$520.00	$130.00
Axle Bearings		$3.12	$2.00
Rear Wheel Hubs		$93.59	$16.00
Snap Rings (External and Internal)		$17.85	$17.85
Chain Rub Blocks for Chain Idler		$11.58	$11.58
Bell housing Plate		$5.00	$0.00
Top Shaft Bearing Housing		$7.00	$0.00
Axle Tube Bearing Mount Material		$6.00	$0.00
Sub-Total		$3,756.08	$904.00
Labor and Engineering Time			
	Time (hrs)	**Rate (per hr)**	**Cost**
Skill Level A	50	$40.00	$2,000.00
Skill Level B	70	$20.00	$1,400.00
Engineering Design	750	$50.00	$37,500.00
Sub-Total	870		$40,900.00

Acknowledgements

Academic Support:
- *Agricultural and Biological Engineering Dept.*

Organizational Support:
- *American Society of Agricultural Biological Engineering – Competition leadership and organization*
- *National Fluid Power Association – Donations to purchase materials to build hydraulic dynamometer to test and brake-in engines*
- *Purdue SAE Solar Team – Donation of man-power, knowledge, and carbon-fiber*

Industry Support:
- *Daimler Chrysler – Grant support*
- *AED Motorsports – Discount raw materials*
- *Polaris Industry – Discount drive-train components*
- *Dana-Spicer – Donation of differential*
- *Real Wheel – Discount on rear rims*
- *BMF Machining*
- *Kaman Ind. – Discount drive-train materials*
- *Competition Sponsors – Judge and competition staff*

Advisors:
Academic Advisor – Dr. Joseph Irudayaraj
Technical Advisor – Dr. John Lumkes

Detailed Weight Analysis

Subsystem	Part or Assy	Weight (lbs)	Subsystem	Part or Assy	Weight (lbs)
Drive-Train	Engine Sprokets (6)	5.34	Frame	Back Main Frame Rails	9.87
Drive-Train	Com. Shft. Sprokets (2)	3.8	Frame	Front Lower Frame Rails	3.38
Drive-Train	Chain (40)	5	Frame	Middle Brace	2.84
Drive-Train	Com. Shft.	2.1	Frame	Front Bolster Mount	0.39
Drive-Train	Com. Shft. Bearings (2)	0.75	Frame	Front Axle	14.84
Drive-Train	LoveJoy Coupler	1.25	Frame	Lower Engine Mounts	5.74
Drive-Train	Clutch Input Shft.	0.5	Frame	Back Top Frame Rails	1.97
Drive-Train	Bellhousing w/ bearings	8.5	Frame	Back Angle Frame Rails	2.08
Drive-Train	Bellhousing plate assembly	3.125	Frame	Bell Housing Mount	4.17
Drive-Train	Clutch/Flywheel	16	Frame	Frame Cross Member	1.24
Drive-Train	Starter (Reverse)	6	Frame	Large Gussets	0.34
Drive-Train	Clutch Output Shft	1.34	Frame	Back Up Angle Frame Rails	1.68
Drive-Train	50_16 Sprok	0.8	Frame	Right Rear Axle Tube	7.91
Drive-Train	50_21	1.12	Frame	Left Rear Axle Tube	4.18
Drive-Train	50_23	1.25	Frame	Hitch Assembly	5.22
Drive-Train	Clutch Out Shft Pillow w/bear	0.6	Frame	Vertical Chain Support	0.64
Drive-Train	Chain (50)	1.26	Frame	Wheelie Bar Supports	2.04
Drive-Train	Bottom Shft	2.8	Frame	Bumper Bars	0.87
Drive-Train	Bottom Shft Pillow w/bear (2)	2	Frame	Rear Axle Mounts	2.69
Drive-Train	50_43	4.68	Frame	Back Up Angle Flanges	0.24
Drive-Train	50_38	3.15	Frame	Back Up Angle Flanges2	0.19
Drive-Train	50_36	2.35	Frame	Chain Bank Shields	3.61
Drive-Train	Driveshaft	4.75	Frame	Chain Brace	0.07
Drive-Train	Dana Diff	35	Frame	Rack Brace	1.88
Drive-Train	Axles	8	Frame	Engine Chain Shields	10.41
Drive-Train	Rear Tires	60	Frame	Chain Guides	0.39
Drive-Train	Rear Hubs/bearings	5	Frame	Engine Triangle Mount	5.05
Drive-Train	Engines (6)	480	Frame	Under Top Engine Support	2.03
	Subtotal	666.465	Frame	Under Top Engine Supp2	1.63
			Frame	Front Upper Frame Rails	3.11
Drive-Train	Subtotal	666.465	Frame	Small Engine Spacers	0.33
Frame	Subtotal	123.38	Frame	Large Engine Spacers	0.38
Steering	Front End Assembly	17.2	Frame	Engine Triangle Vert. Brace	1.97
Electronics	Everything	35	Frame	Bolts	10
Driver's Station	Carbon, Pedals, Floor Pans	14	Frame	Welds	10
Fuel	Everything	7		Subtotal	123.38
Brakes	Calipers, Rotors, Lines	4			
Exhaust	Everything	20			
Total		**887**			

PQS06 Pulling Team

PQS05 Pulling Team

PQS04 Pulling Team

Description of the Competition

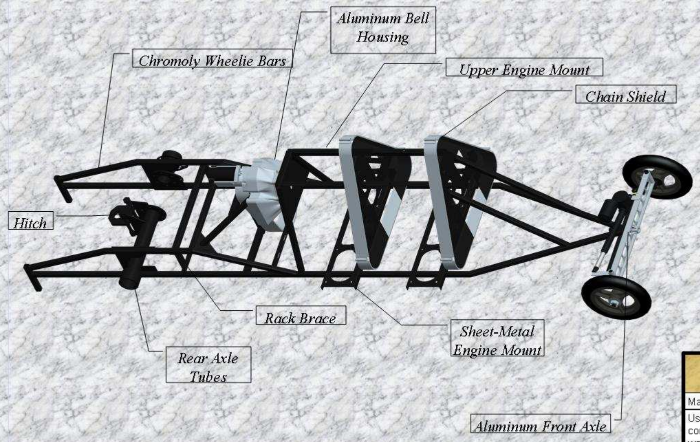
The ASABE International Quarter Scale Competition challenges students to design and build a small scale pulling tractor to compete against other colleges. Through involvement in the competition, students gain practical experience in the design of drive systems, structural frame, tractor performance, and material characteristics. In addition, students develop skills in communication, leadership, teamwork, fundraising, and test & development. The competition prepares students to be future professional engineers.

PQS06 Pulling Progressive Sled at Competition

Frame Design for PQS07

Designer:
John Mahrenholz

Design Features



Details

- *Material—ANSI 4130 Steel (a.k.a. Chromoly)*
  - *High Strength: Density Ratio*
  - *Easily welded*
    - *Low carbon steel can also be welded to reduce costs*
- *Cross Section—Square Tube*
  - *Easy to cut*
  - *Easy to jig*
- *Shape—Expanded Truss*
  - *Use Engines for Structure*
  - *Better Visibility*

Design Summary

Manufacturability	Safety	Ergonomics	Serviceability
Use of steel as main component decreases weld complications Limited number of welded joints Expanded cross section eases component placement	Extra enforcement around the operator station limits the risk of operator injury due to frame failure Sharp corners on the frame have been eliminated to reduce the risk of operator and service technician injury.	The expanded cross section allows engines to be place lower which increases operator visibility Free rotating bolster style front end increases ride comfort over rough terrain	Steel components allow most welds to be repaired at local machine shops by an experienced welder. The expanded cross section allows easy engine and drive-train removal for servicing the tractor.

Hitch Calculations

Class	1050	1300	Units
Max Chain Load Predicted	1900	2500	lbf
Min Chain Load Predicted	1250	1500	lbf
Chain Angle	20.2434	20.2434	deg
Max Dynamic Weight Transfer from Chain	657.4169	865.0223	lbf
Min Dynamic Weight Transfer from Chain	432.5111	519.0134	lbf
Tire Roling Radius	12	12	in
Max Dynamic Torque Transfer from Load	21391.67	28146.94	in*lbf
Min Dynamic Torque Transfer from Load	14073.47	16888.16	in*lbf
Horizontal Distance from Hitch Pt. to Axle	5	5	in
Max Dynamic Torque Transfer from Chain	3287.085	4325.111	in*lbf
Min Dynamic Torque Transfer from Chain	2162.556	2595.067	in*lbf
Max Total Dynamic Torque on Axle	24678.76	32472.05	in*lbf
Min Total Dynamic Torque on Axle	16236.02	19483.23	in*lbf
No Ballast Tractor Weight	1040	1040	lbf
Estimated No Ballast Tractor CG	27.3	27.3	in
Moment Created from CG	28392	28392	in*lbf
Wheel Base	87	87	in
Available Ballast Weight	10	260	lbf
Ballast Location from Rear Axle	-10	35	in
Min Total Weight on Front @ End of Pull	3.748951	7.986672	lbf
Max Total Weight on Front @ End of Pull	113.7175	177.169	lbf

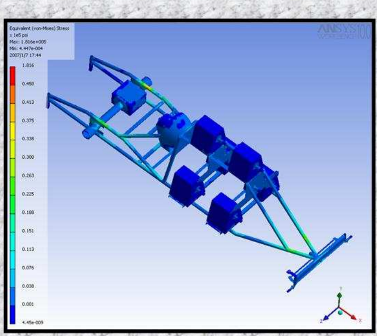
Modeling & Analysis

Pro/Engineer® for Solid Modeling

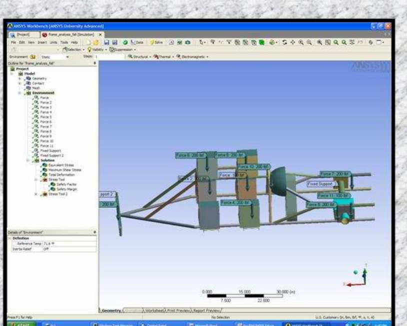
- *Determine spatial locations for components*
- *Easy modification without cost of material*

ANSYS Workbench® for Stress Analysis

- *Determine how much material to remove*
- *Under given loads, will the frame fail?*



Along with analysis of individual components, the entire frame was analyzed to determine the effects of combined loading



Loading conditions were determined from analysis of previous pulling performance, traction estimates, and drive-train gearing ratios.

The Completed rolling chassis of the frame weighs only 225lb.

Frame Bill of Materials

Form	Quantity	Dimensions	Metal Type	Notes
Round Bar	1	1" x 60"	2024 Aluminum	
Round Tube	1	.75" x .058" x 60"	Chromoly	
Plate	1	3" x .25" x 240"	5052 Aluminum	WxTxL
I-Beam	1	3" x 1" x .125" x 24"	Aluminum	HxWxTxL
Round Tube	1	1" x .125" x 60"	Aluminum	
Square Tube	2	1" x .065" x 240"	Chromoly	Closest Whole Lengths to 50'
Square Tube	1	1" x .065" x 120"	Chromoly	
Angle	1	1 x .125" x 120"	Mild Steel	

Fabrication

Individual Frame Rails were place on the jig table and secured with wooden blocks. This method insured frame rails would be identical once taken out of the jig.

Weld areas were properly prepared before laying down weld material. Corners were machined for proper fit-up, and steel was cleaned with Acetone to remove contaminants.

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Title: Greg Long, John Mahrenholz MSE-ABE
April, 18 2007