Quarter Scale Tractor Pull Sled

Justin Dougherty

Traever Guingrich

Scott Nipple

April 15, 2004

Objective: Redesign and completion of pulling sled for testing of ASAE Quarter Scale Tractor

Goals of the project

- Modify existing engine and drivetrain layout
- Additional support for sled frame and drive chain system changes
- Create a hydraulic system to raise and lower the front axle and drive the steering system
- Complete the operator station and controls
- Implement safety devices for the system
- Gain practical experience for future engineering projects

Engine and Drivetrain Improvements

▪Engine was moved laterally to remove 10 degree angle in driveshaft
▪Transmission and engine both lowered 6 inches to allow free travel of weight box down rails
▪Radiator and gas tank moved to the right side of the sled to eliminate drive chain interference
▪Hydraulic pump mounted to utilize engine fan belt drive

Cost Analysis

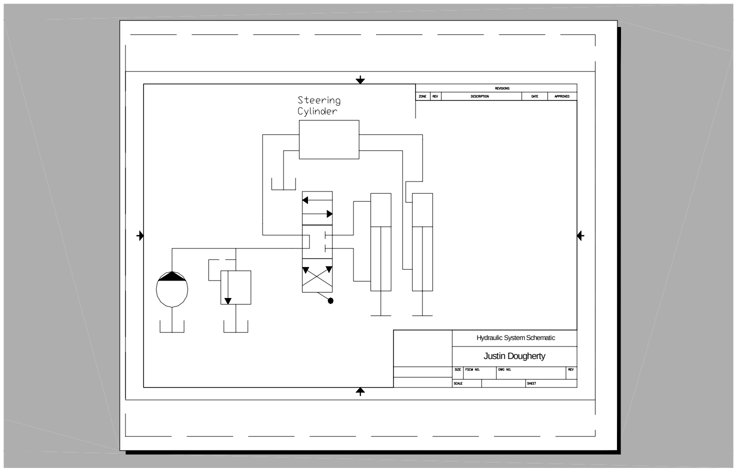
•Many features of the sled were donated from the ABE department and free to use
•Front axle, hydraulic pump and reservoir, steering wheel and bracing metal acquired at no cost.
•Brake system components: $50
•Components purchased for hydraulic system include the filter and hydraulic lines and fittings. Estimated total cost $110
•Tire repair: $38
•Battery and chain: $67
•Engine manual: $35
•Estimated Total Cost: $300

Operator Station and Controls

▪Operator Station allows driver to operate all functions of sled
▪Transmission shifter used to control box speed and gear when sled is self propelled; Modified from original size to be used from Station
▪Includes clutch, ignition and throttle controls for engine
▪Flooring, step and handrail added

Frame and Chain Drive Modifications

▪Additional bracing added to skid plate to prevent bending
▪Hitch added to rear
▪New gears ordered and inserted to prevent chain slippage
▪Additional skid added to rear of main plate to prevent digging into ground during pull-back
▪Idler added to maintain tension in chain from transmission to main axial driveshaft
▪Rubber bushings added to decrease vibration and slightly raise sprockets
▪Groove cut in frame to allow room for chain to run without interference



Hydraulic System

- Front axle used from John Deere 4400 for raising and lowering skid plate and steering
- Reel pump from same implement used to drive a complete hydraulic system
- Includes use of hydraulic steering and cylinder to lift front axle
- Three position tandem solenoid actuated valve used for axle movement

Picture at left shows the hydraulic wiring diagram for the system

System Safety Devices

- Torque converter used to disengage drive shaft when box is fully forward or fully reset on rails
- Drum brakes on rear axles were restored to working order and used with emergency brake lever
- Shielding over moving equipment
- Tractor kill switch mounted along frame to operator station

Calculations for selection of Torque Limiter

ANSI 60 Chain has a maximum allowable load of 1980 lb_f and an ultimate strength of 9920 lb_f.

Explanation of the gear numbering below: Gear 1 connects to the the chain that drives the weight box. Gear 2 is turned by a torque applied through a shaft by gear 1. Gear 2 uses a chain to turn gear 3 on the jack shaft. Gear 3 applies a torque through the jack shaft to gear 4. Gear 4 uses a chain to turn gear 5 on another shaft. Gear 6 lies within the 90 degree gearbox and is turned by the shaft connected to gear five. Gear 6 turns gear 7, and gear seven turns the main shaft running the length of the sled.

$\phi_{gear1} := 4in$ $\quad \phi_{gear2} := 3.317in$ $\quad \phi_{gear3} := 2.898in$ $\quad \phi_{gear4} := 7.715in$

$\phi_{gear5} := 4in$

The coefficient of static friction generated between the steel wheels and the rails can be estimated as .74 from the website:
http://www.physlink.com/Reference/FrictionCoefficients.cfm

Kyle Folk on last years team had an estimated value of .78 so the larger value will be used. If it is estimated that 2000 lb is absolute largest weight that can be placed in the box.

Force seen on the chain connected to the weight box.

$N := 2000lbf \quad \mu := .78$

$F_{chain} := \mu \cdot N \qquad F_{chain} = 1560lbf$

$F_{gear2} := F_{chain} \cdot \frac{\phi_{gear1}}{\phi_{gear2}} \qquad F_{gear2} = 1.881 \times 10^{3} lbf$

$F_{gear4} := F_{gear2} \cdot \frac{\phi_{gear3}}{\phi_{gear4}} \qquad F_{gear4} = 706.645lbf$

$Radius_{gear5} := \frac{\phi_{gear5}}{2} \qquad Radius_{gear5} = 2in$

$Torque_{shaft} := F_{gear4} \cdot Radius_{gear5} \qquad \boxed{Torque_{shaft} = 1.413 \times 10^{3} in \cdot lbf}$

Calculation of forces when sled is fully raised.

The angle calculated from previous analysis of the sled for the front axle is 5.71 degrees.

$\theta := 5.71deg$

$mg_1 := 2000lbf$

$N_1 := mg_1 \cdot \cos(\theta) \qquad N_1 = 1990.076lbf$

$F_x := mg_1 \cdot \sin(\theta) \qquad F_x = 198.987lbf$

$F_{chain2} := F_x + N_1 \cdot \mu \qquad F_{chain2} = ■ lbf$

$F_{gear2b} := F_{chain2} \cdot \frac{\phi_{gear1}}{\phi_{gear2}} \qquad F_{gear2b} = ■ lbf$

$F_{gear4b} := F_{gear2b} \cdot \frac{\phi_{gear3}}{\phi_{gear4}} \qquad F_{gear4b} = ■ lbf$

$Radius_{gear5b} := \frac{\phi_{gear5}}{2} \qquad Radius_{gear5b} = 2in$

$Torque_{shaftb} := F_{gear4b} \cdot Radius_{gear5b} \qquad \boxed{Torque_{shaftb} = ■ in \cdot lbf}$

It was recommended that the torque limiter be sized for 50% of the breaking strength of any component.

$Fifty\%_{chain} := \frac{1980lbf}{2} \qquad Fifty\%_{chain} = 990lbf$

$F_{gear2c} := Fifty\%_{chain} \cdot \frac{\phi_{gear1}}{\phi_{gear2}} \qquad F_{gear2c} = 1.194 \times 10^{3} lbf$

$F_{gear4c} := F_{gear2c} \cdot \frac{\phi_{gear3}}{\phi_{gear4}} \qquad F_{gear4c} = 448.448lbf$

$Radius_{gear5c} := \frac{\phi_{gear5}}{2} \qquad Radius_{gear5c} = 2in$

$Torque_{shaftc} := F_{gear4c} \cdot Radius_{gear5c} \qquad \boxed{Torque_{shaftc} = 896.896in \cdot lbf}$

Opportunities to Gain "Hands On" Skills

- Repairing worn out brakes on the rear axle.
- Numerous opportunities to improve welding skills with new frame additions
- Learning how to operate the shop mills and cutting equipment to construct pieces for the project
- Using hand drills, grinders, and other tools
- Obtaining components from a variety of sources including: John Deere 4400 combine and John Deere 55 Special.