Structural Analysis and Testing of Injected Molded Plastic Drive Train Shields for Self-Propelled Mower Conditioners

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WINDROWER DRIVE TRAIN SHIELDING

BACKGROUND

- Traditional windrower designs utilized stamped steel shielding to cover the drive train on one or both sides of the header.
- Plastic shields offer several potential advantages:
  - Reduced header weight
  - Increased impact resistance
  - Less effort to open and close

Conventional steel shielding on the side of a Self-Propelled Windrower header.

R & D OBJECTIVES

- Develop solid model of the plastic shield and weldment used to reinforce hinge.
- Evaluate lower cost alternatives to weldment for reinforcement.
- Validate modeling with experiments using a prototype shield instrumented with strain gauges.

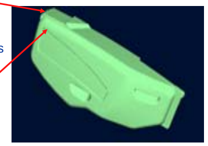
New plastic drive train shielding.

SOLID MODELING & FINITE ELEMENT ANALYSIS

CURRENT SYSTEM ASSEMBLY

Steel hinge plate that bolts onto the plastic shield.

Weldment molded into the plastic shield that reinforces upper corner where the hinge plate attaches.

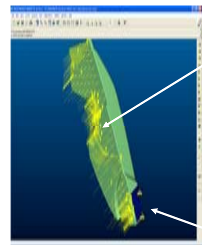


Plastic shield solid model.

DESIGN ISSUES

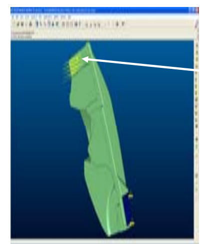
- Determine if the expensive weldment can be replaced with simple reinforcing tubes that do not require welding.
- Assemblies evaluated:
  - Shield with current inner welded assembly.
  - Shield with four tubes and open middle holes in plastic.
  - Shield with four tubes and no middle holes in plastic.
- Solid models need to be developed for each assembly.
- Finite element analysis must be performed to determine if yielding of the plastic around the reinforcements will occur.
- Simulation results need to validated with lab testing.

LOADING & BOUNDARY CONDITIONS



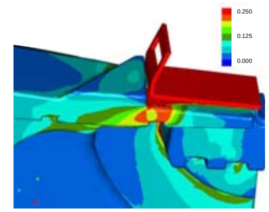
Field Loading Condition:
Uniform loading simulates a worst case condition – a 50 MPH wind load while the shield is locked open.

Boundary Conditions:
Zero displacement in the x, y, and z directions at the hinge.

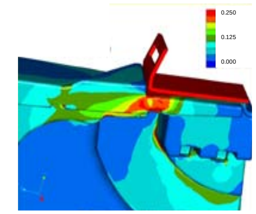


Experimental Loading Condition:
This loading simulates the laboratory conditions used to validate the simulation results – a concentrated load at the end of the shield. The magnitude of this load is equal to the integral of the in-field loading.

FINITE ELEMENT ANALYSIS



Von Mises effective stress (MPa) for the shield and *weldment assembly* with open holes in the plastic and a 225 N (50 lb) point load at the end.



Von Mises effective stress (MPa) for the shield and *four tube assembly* with open holes in the plastic and a 225 N (50 lb) point load at the end.

KEY FINDINGS

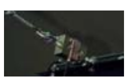
- Saint-Venant's priniciple applies. Specifically, a concentrated load at the end of the shield produced similar stresses (magnitudes and distributions) compared to the uniformly distributed loading used to model the wind load.
- Both the weldment and four tube assembly provided sufficient reinforcement to prevent yielding of the plastic shield when subjected to the loading associated with a 50 MPH wind.
- The lower cost tube inserts are an acceptable reinforcing alternative to the more expensive weldment assembly.
- Experimental validation of the model can be achieved with concentrated loads applied at the end of the shield.

LABORATORY TESTING

EXPERIMENTAL SETUP

- Shield mounted on an actual header subframe that was fixed to the floor.
- Shield latched in the up (open) position and constrained at the hinge plate
- A 225 N test load was applied along the upper surface of the shield normal to the shield surface.
- Load was applied using a turnbuckle until the target load was achieved.
- Shields were loaded to simulate wind load on both side surfaces.
- Test loads were measured at 1 Hz using a load cell attached to shield.
- Prototypes tested:
  - Shield with current welded assembly
  - Shield with four tubes and no middle holes in plastic

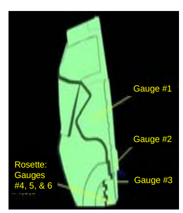
Turnbuckle and load cell used to apply and monitor the load.



Instrumented shield support structure and load application structure used for testing.

STRAIN MEASUREMENTS

- Three linear gauges and one rosette gauge mounted on each prototype shield.
- Signal Conditioning using a Model 2150 *Vishay Measurements Group* Strain Gauge Conditioner and Amplifier System.
- Amplified signals recorded using a PC-based data acquisition system that included a *National Instruments* DAQ 16-bit A/D card.
- Data processed and recorded with software written in LabView.
- Data recorded at 1 Hz.

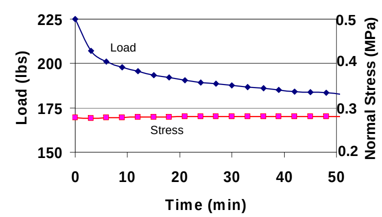


Gauge locations used for testing.

LabView code to collect and process strain gauge and load cell data.

Gauges mounted on the prototype shield.

TESTING RESULTS



Typical test result for the shield with the tube reinforcement. Stress data is from gauge #2. Load relaxation was evident for both the tube reinforced and weldment reinforced shields.

KEY FINDINGS

- Stresses were greatest at gauges #2 and #3, but no yielding of the plastic was observed for loads equal to the anticipated wind load.
- Measured stresses were about 10% higher than the stresses predicted by the finite element analysis.
- Both shields exhibited creep; the load relaxation was less severe with each successive loading cycle.
- Deflection measurements for the shield with no weldment indicate a maximum shield tip deflection of 43 mm corresponding to the 225 N loading.
- Results confirm the modeling predictions for maximum stress, but load creep and deflection still needs to be properly modeled.

CONCLUSIONS

- Solid models of the plastic drive train shield with different reinforcing assemblies were developed; finite element models predicted stresses were greatest in the plastic around the mounting hinge reinforcement.
- Experiments with instrumented prototype shields confirm the stress predictions from the finite element model.
- A simple tube reinforcement design provides a cost effective alternative to a more expensive tube and plate weldment.
- A shield with simple tube reinforcements provides sufficient strength at the shield hinge to prevent yielding of the plastic shield when subjected to a load equivalent to a 50 MPH wind.
- Both the simple tube reinforced shield and the weldment reinforced shield exhibited creep during testing. However, this behavior was not modeled.

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