Wheel Force Transducer Research and Development

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W911NF-10-1-0463

2nd Interim Report.

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Abstract

This document forms the second progress report on the development of a concept wheel force transducer that can measure the forces and moments between a tire and a road on a HMMWV driven under off-road conditions. This concept development is part of a project that endeavors to develop, validate and calibrate cost effective field test equipment for measuring tire characteristics on vehicles whilst driving off-road. The proposed wheel force transducer is an important step in a renewed research effort that aims to correct the gap in current tire testing and modeling knowledge to ensure that future off-road vehicle models and simulation efforts are conducted with confidence.

The report briefly describes the detail design, sealing and finite element stress analysis of the proposed transducer. The design has been finalized and is ready for manufacturing of the first prototype.

1. Problem statement

Obtaining tire characteristics on off-road terrain for use in tire models, as well as suitable tire models represent a significant research challenge. A first, but extremely important step in this research is to develop suitable tire test equipment. Due to the difficulty of simulating off-road terrain under laboratory conditions, field test equipment, that can determine tire characteristics on vehicles whilst driving over these terrains, is required.

2. Objectives

In order to obtain tire characteristics over off-road terrain, cost-effective field test equipment is required. The proposal therefore has four main objectives [1,2]:

a) Develop a prototype 6-component wheel force transducer to measure tire forces and moments on a vehicle whilst driving
b) Develop mathematical models of the wheel force transducer
c) Validate and calibrate the wheel force transducer
d) Manufacture a set of four wheel load cells for fitment to a vehicle.

This report describes the detail design stage of the wheel force transducer required under point a) above. Special emphasis is placed on sealing the transducer against debris as well as strength analysis to eliminate stress concentrations and ensure acceptable fatigue life.

3. Detail design

The concept design of the wheel force transducer, where the space envelope, layout, basic dimensions and expected load was determined, was discussed in the first interim report [3]. Apart from finalizing the dimensions and layout, the detail design addressed two aspects namely sealing and strength.

The final sealing arrangement decided on is indicated in Figure 1. V-ring seals are used to seal the spaces between the different parts of the wheel force transducer to prevent foreign objects from entering the transducer. These seals will make the transducer splash proof and seal effectively against dust, sand, mud etc. It will however not be water proof when submersed.

Strength was analyzed by performing a Finite Element Analysis (FEM) on two load cases that are considered to be worst case. These two load cases are indicated in Figure 2. The applied load in each case in 50 kN (or 5 000 kg). This means that the vehicle can land with the full vehicle weight on one wheel and that only one of the six load cells in the wheel force transducer can carry the entire load. This resembles an extreme load case.

Finite element analysis results for Load Case 1 are indicated in Figure 3. The highest stress (230 MPa) occurs in a very localized area around the load cell bolt holes. This is due to numeric issues caused by the way the load was applied using a multi-point constraint and is not expected to present any problems whatsoever. Results for Load Case 2 (Figure 4) indicate a similar situation. Given the severity of the load cases and the very localized stresses caused by numerical error, the stresses in the areas of possible failure are below 200 MPa. This means that the load cell flanges can be manufactured from Aluminium 7075 alloy in the T6 heat treatment condition. This material has a yield strength in excess of 400 MPa which is around double the maximum stress expected. The use of aluminium also has a large advantages in terms of weight as well as corrosion.

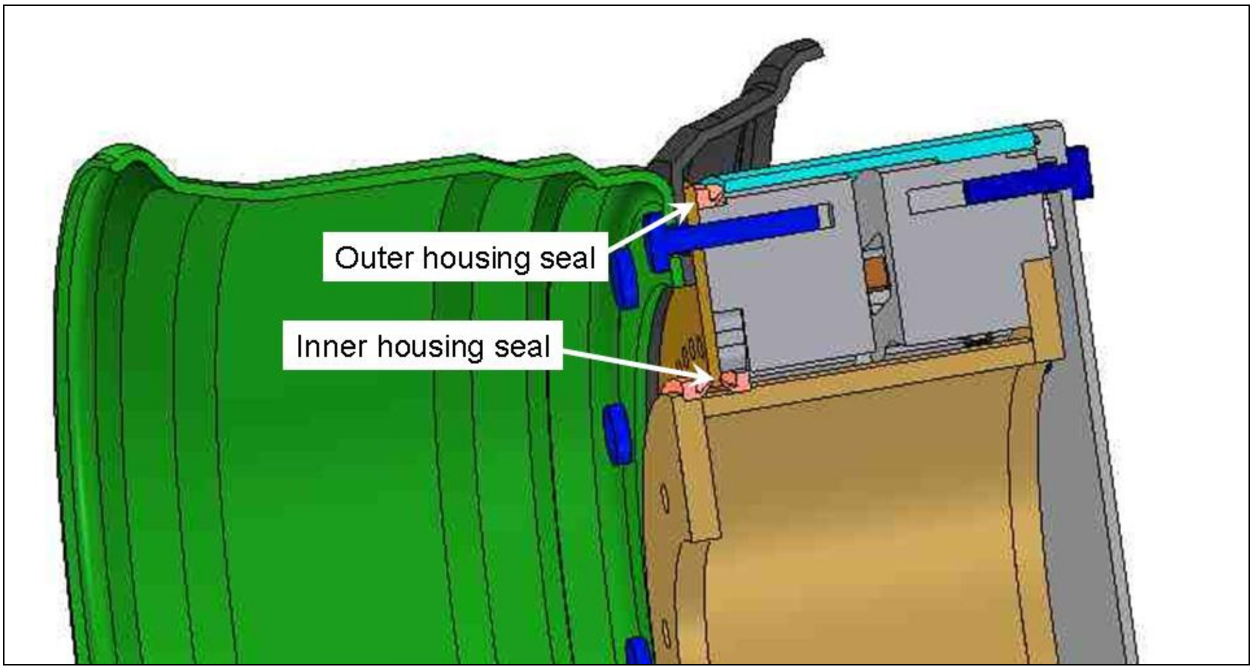

Figure 1 - Sealing

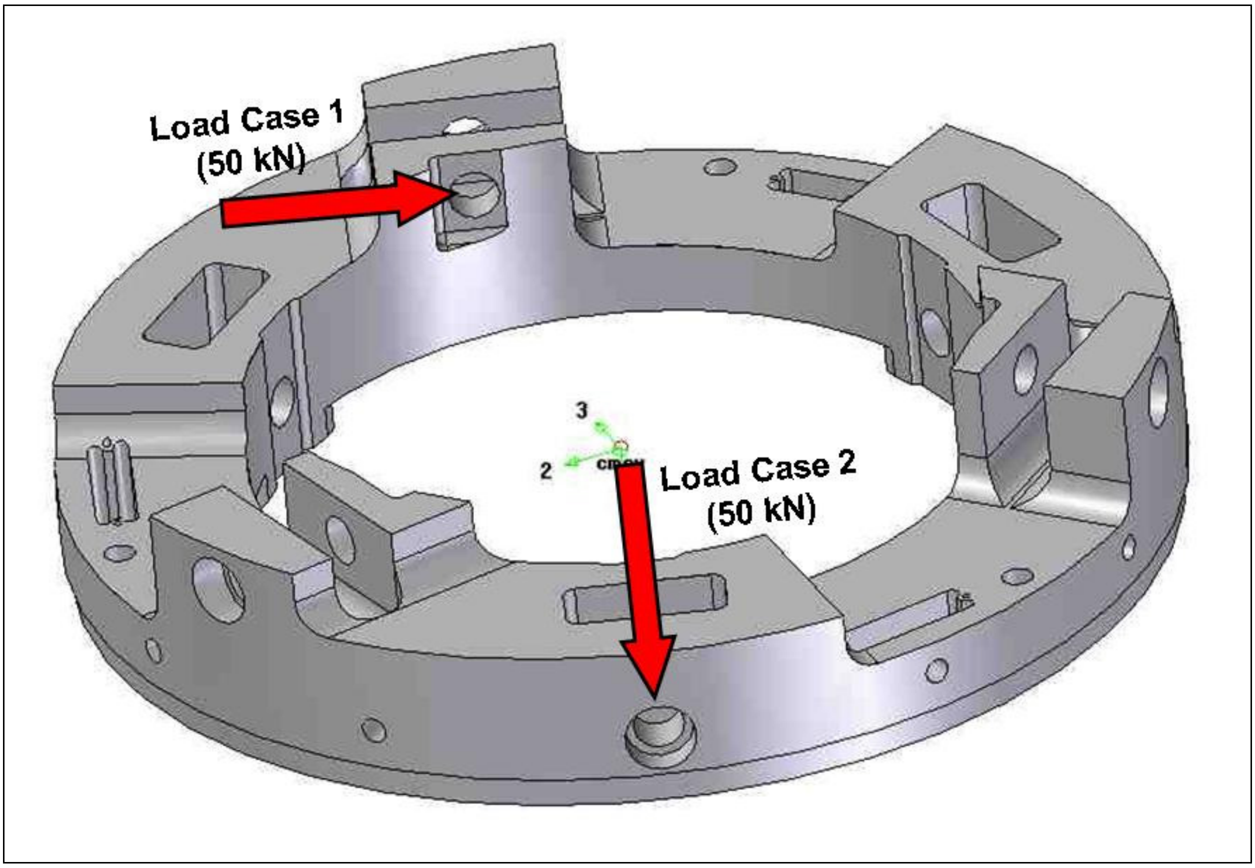

Figure 2 - Loads applied for finite element analysis

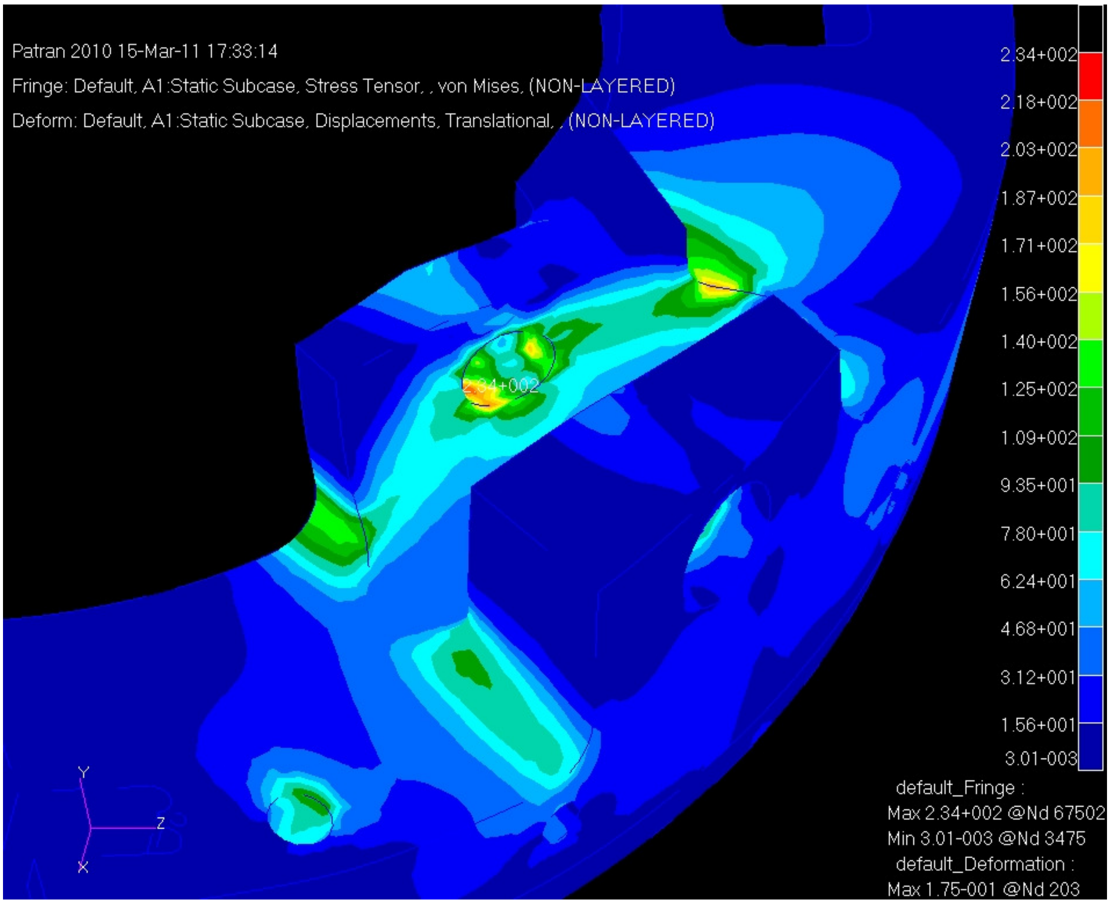

Figure 3 - Stress for Load Case 1

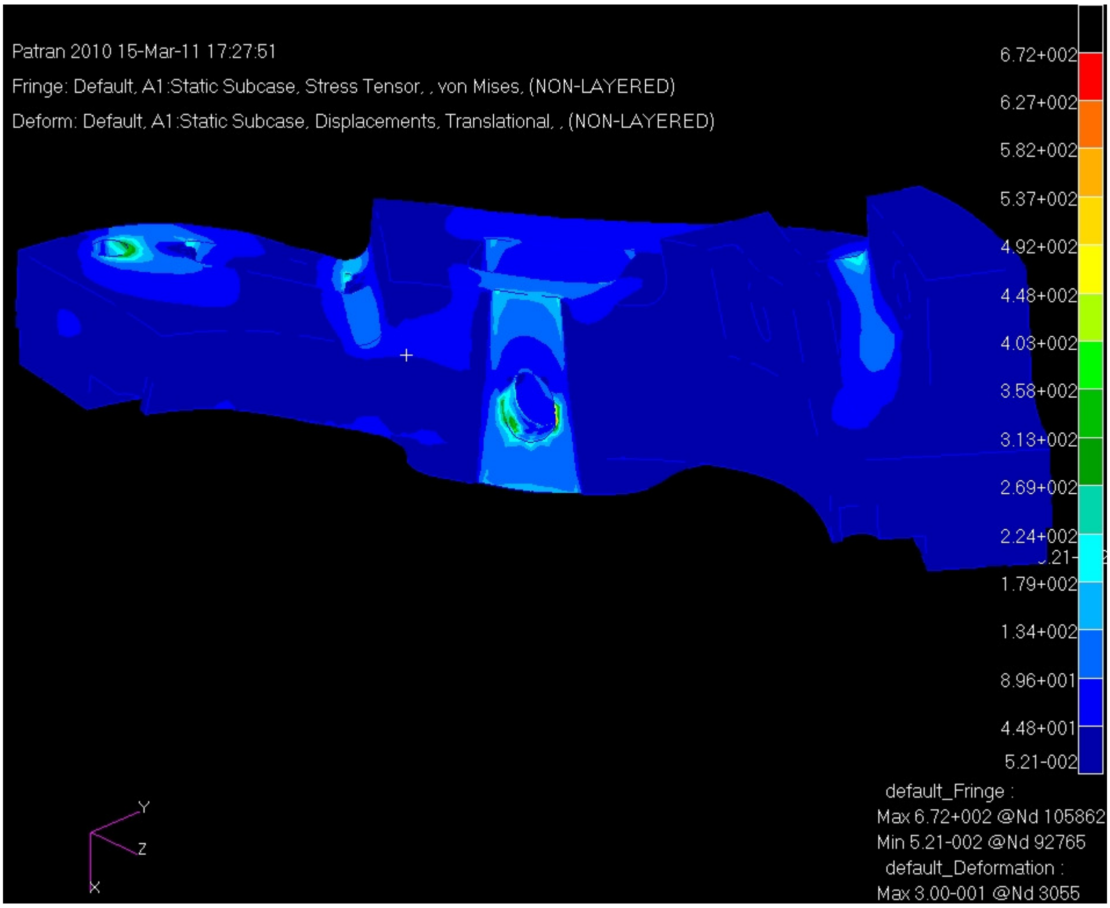

Figure 4 - Stress for Load Case 2

To confirm fatigue life, the test setup indicated in Figure 5 will be used to do a fatigue test on the aluminium flanges as well as the load cell. This test will confirm the fatigue life expectancy of the wheel force transducer.

The total mass of the wheel transducer is expected to be around 25 kg. The existing HMMWV tire and rim weighs around 70 kg. The change in unsprung mass caused by the wheel force transducer is therefore deemed acceptable.

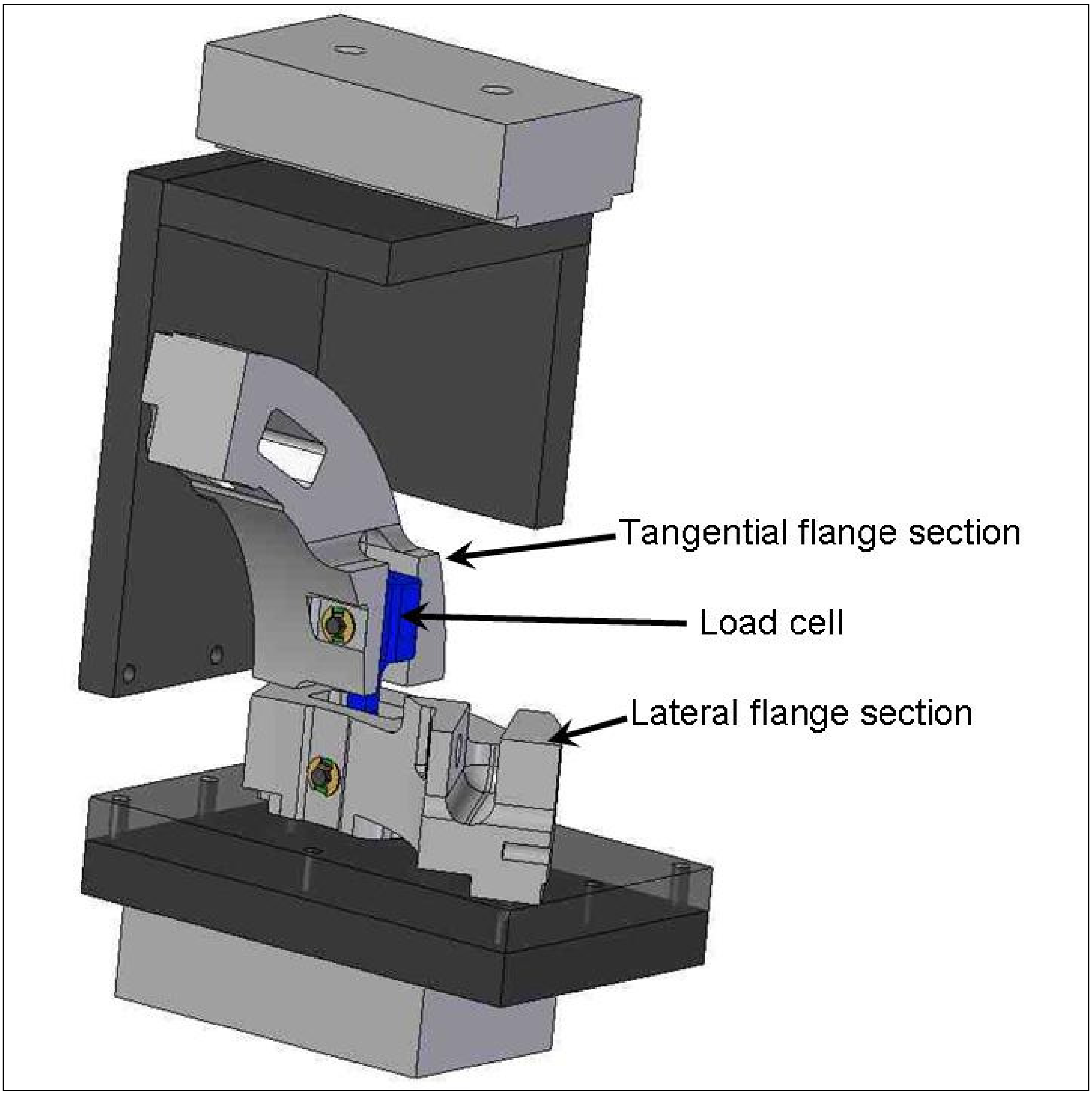

Figure 5 - Fatigue test rig

5. Research plans for remainder of the contract period.

5.1. Manufacture wheel force transducer

A prototype wheel force transducer will now be manufactured, including sections for use in fatigue testing.

5.2. Develop mathematical models of the wheel force transducer

Mathematical modeling will be performed to calculate the three forces and three moments on the tire from the load cell measurements. This model will be verified using dynamic analysis as necessary.

5.3. Validate and calibrate the wheel force transducer

A prototype wheel force transducer will be assembled. Individual load cells in the assembly will be calibrated using Schenck Hydropuls test equipment. The wheel rotational angle measurement system will also be calibrated separately. After assembly, the complete wheel force transducer measuring chain will be calibrated against known externally applied loads for all three forces as well as all three moments. The measurements will also be used to validate the mathematical models developed previously.

5.4. Manufacture a set of four wheel force transducers for fitment to a vehicle.

A set of four wheel force transducers will be manufactured, assembled, calibrated and shipped. The telemetry is not included in this study and has to be procured separately. Recommendations in this regard will be made.

A visit to CRELL is planned for 2011 to give feedback on the project progress and to discuss practical details of the project.

6. References

[1] Proposal: Wheel force transducer development, 12 August 2010.

[2] Contract W911NF-10-1-0463, awarded on 16 Sep 2010.

[3] Wheel Force Transducer Research and Development, W911NF-10-1-0463, 2nd Interim Report, September 2010 - December 2010, Prof. P.S. Els, University of Pretoria

7. Administrative actions

None

8. Other important information

The project is on schedule and within budget. No other important information needs to be reported on at this stage.