Wheel Force Transducer Research and Development

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W911NF-10-1-0463

1st Interim Report.

September 2010- December 2010

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*
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1. REPORT DATE *(DD-MM-YYYY)* 16-12-2010	**2. REPORT TYPE** 1st Interim Report		**3. DATES COVERED** *(From - To)* 16 Sep 2010 - 16 Dec 2010
4. TITLE AND SUBTITLE Wheel Force Transducer Research and Development			**5a. CONTRACT NUMBER** W911NF-10-1-0463
			5b. GRANT NUMBER
			5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Prof PS Els			**5d. PROJECT NUMBER**
			5e. TASK NUMBER
			5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Pretoria, Private Bag X20, Hatfield, 0028			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) USAITC-A, Building 188, 86 Blenheim Crescent, Ruislip, Middlesex UK HA4 7HL			**10. SPONSOR/MONITOR'S ACRONYM(S)**
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT This document describes 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 the first part of a project that endeavours 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 design requirements, space envelope of the HMMWV rim and proposed transducer layout.			
15. SUBJECT TERMS Wheel, Force, Moment, Transducer, Tire			

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT UNCLASSIFIED	**b. ABSTRACT** UNCLASSIFIED	**c. THIS PAGE** UNCLASSIFIED		7	**19b. TELEPHONE NUMBER** *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

Scientific Work done during reporting period

Abstract

This document describes 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 the first 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 design requirements, space envelope of the HMMWV rim and proposed transducer layout.

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 initial concept design stage of the wheel force transducer required under point a) above. The detail design required under point a) will be covered in the next interim report.

3. Client requirements

The client requires that the forces and moments between the tire and the road must be measured on a HMMWV vehicle. There are many derivatives of the HMMWV with large differences in mass. As reference, the M1165A1 w/B3 version is used [2]. The gross weight of this vehicle is 5488 kg (12100 lbs) with 2404 kg on the front axle and 3175 kg on the rear axle. The static vertical load on a rear wheel is therefore taken as 1600 kg and the wheel load cell is designed for a maximum vertical load of 3 times the static load or 4800 kg. The main design requirements for the wheel force transducer are summarized in Table 1.

Table 1: Design requirements

Item	Parameter	Value
1	Static vertical wheel load	1600 kg (rear wheels)
2	Maximum vertical wheel load	4800 kg
3	Rim size	16.5” diameter 8.25” wide
4	Flange dimensions	8 studs on 6.5” PCD
5	Unsprung mass	Not specified, but needs to be kept as low as possible

4. Concept design

The first important step in the concept design is to determine the space envelope and therefore basic dimensions available to fit the transducer. Figure 1 indicates the basic dimensions of the standard military HMMWV split rim. Due to the suspension components on the inside of the wheel, the transducer must be mounted to the outside of the standard rim.

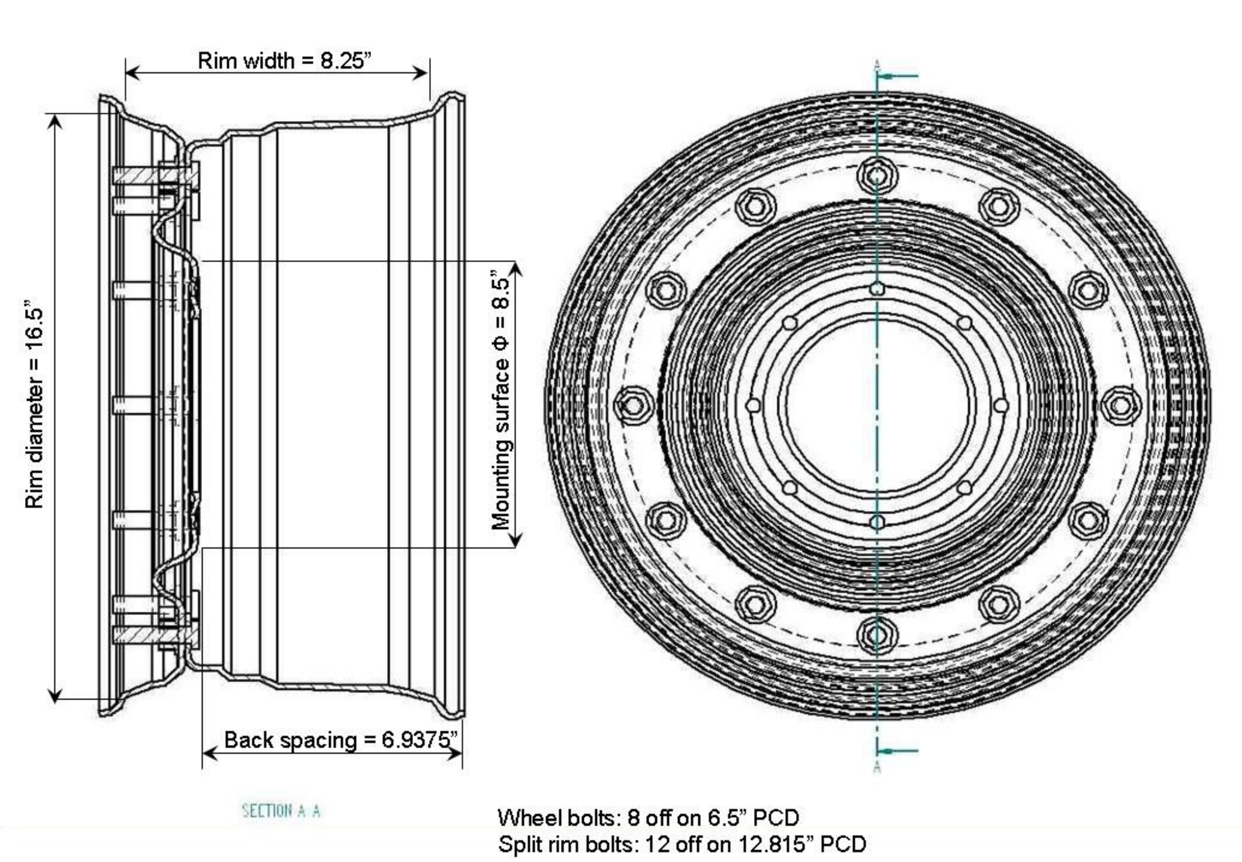

Figure 1 – Standard HMMWV rim dimensions

The wheel force transducer must replace part of the rim so that the rim is connected to the hub via the force transducer. To achieve this, the standard rim must be modified. Figure 2 indicates the standard rim on the left and the modified rim on the right. Modification is simple and involved cutting out the center portion of the outer part of the original rim to the same diameter as the unmodified inner rim.

The force transducer concept is indicated in Figure 3. The load cell inner ring is mounted to the modified rim using 12 bolts. On the unmodified rim, these 12 bolts were responsible for holding together the two parts of the split rim. These bolts were part of the inner rim. In this application the bolts are replaced and screwed in from the inside of the rim into the load cell inner ring. The nuts on the outside are not used any more as the load cell inner ring now serves this purpose.

The load cell outer ring is mounted to the hub using the hub mounting adapter. The hub mounting adapter connects the load cell outer ring to the vehicles hub with the existing 8 hub bolts and nuts. The hub mounting adapter is also bolted the load cell outer ring.

The load cell inner ring and outer ring are connected to each other via 6 individual tension-compression load cells. The design of these individual load cells are indicated in Figure 4. The exact mounting configuration needs to be finalized, but the load cells are mounted such that the 3 tire forces and 3 tire moments can be calculated from the 6 tension-compression forces measured with the individual load cells and the geometry. The mathematics behind this will be dealt with later in the project.

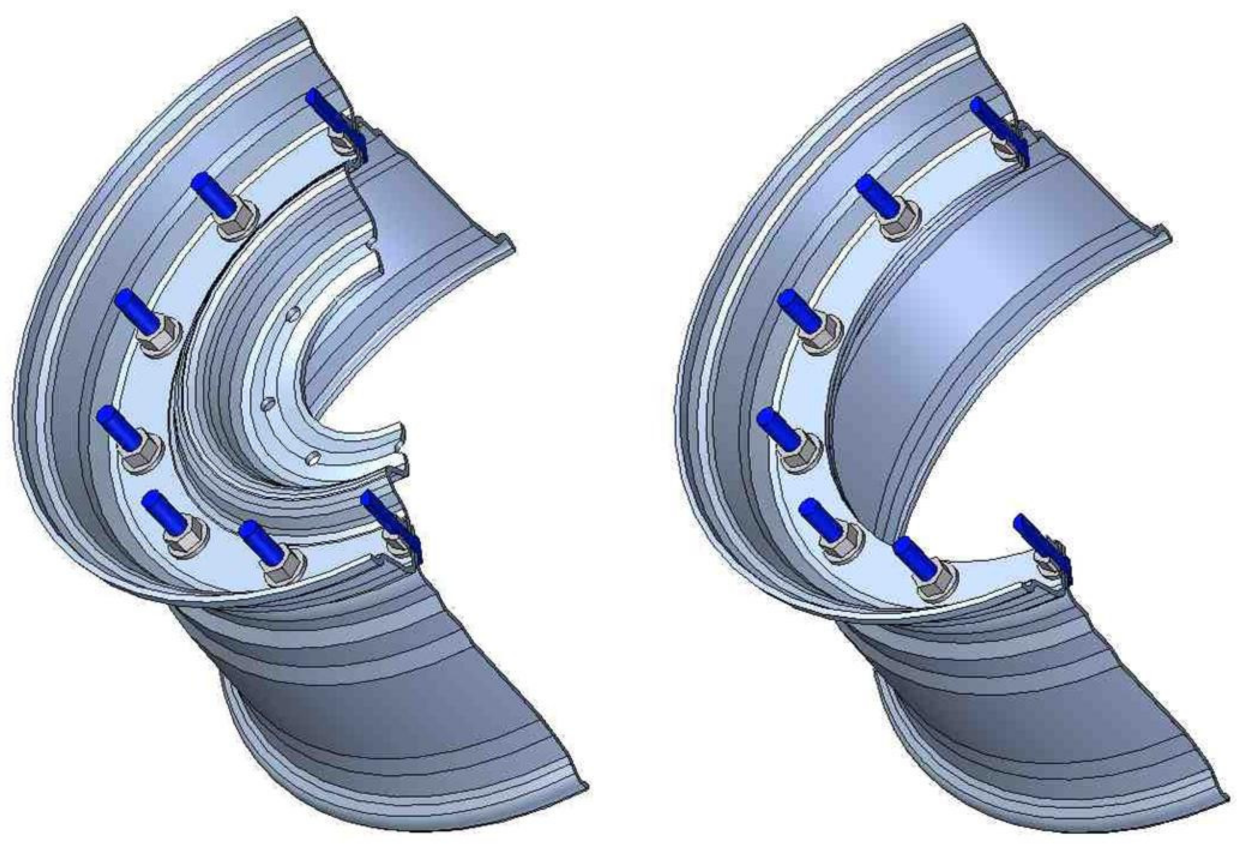

Figure 2 – Standard and modified rim

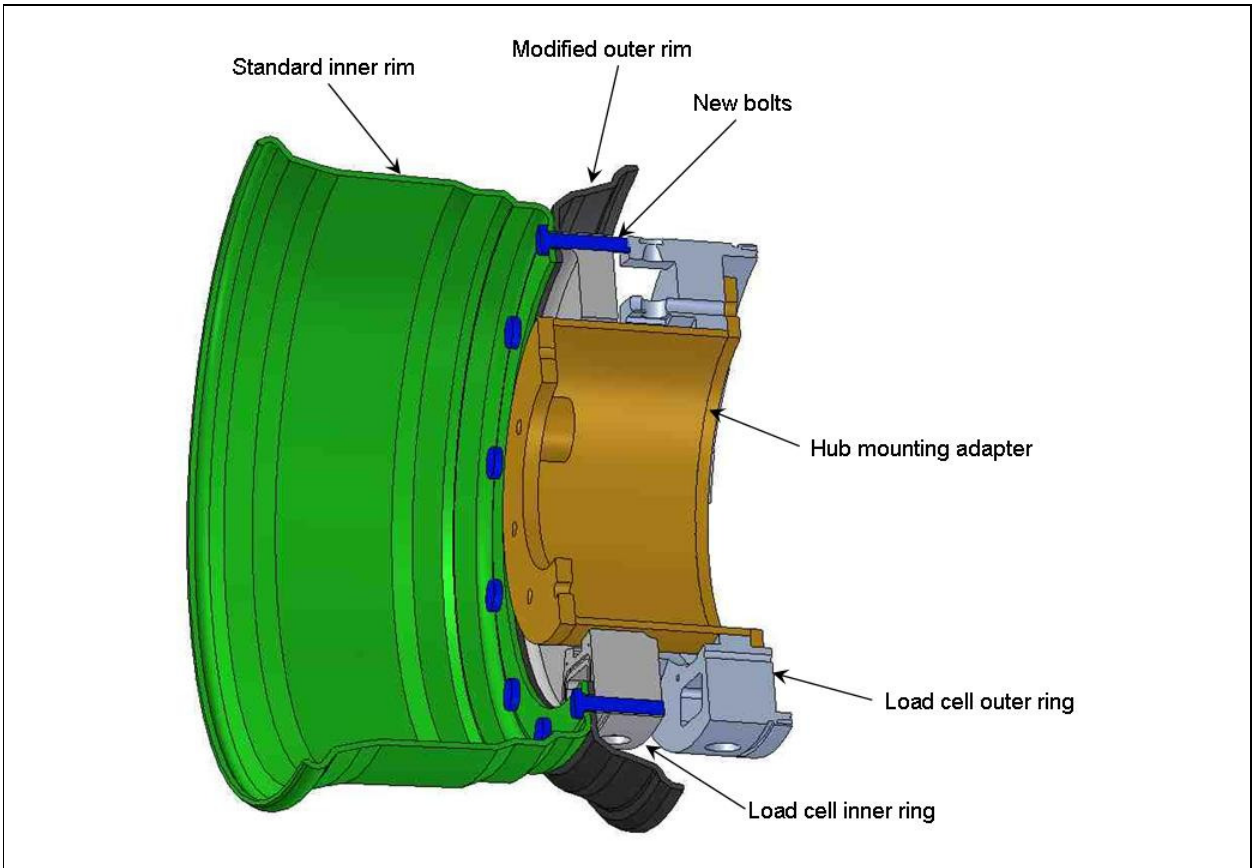

Figure 3 – Force transducer mounted to modified rim

The possibility exists to mount the wheel force transducer to other rim sizes and designs. The exact possibilities depend on the geometry of the different rims but basically entail designing and manufacturing adapters to connect the load cell inner ring to the rim and the load cell outer ring to the hub. This can also be turned around so that the load cell inner ring is mounted to the hub and the load cell outer ring is mounted to the rim.

The force transducer is however currently designed for a static load of 1600 kg (maximum load of 4800 kg). This has 2 implications when using this transducer in different applications namely:

a) If the static and dynamic loads are significantly lower, then the load cell sensitivity will be reduced

b) The strength required from the load cell influences the mass. If the load cell is used on a smaller vehicle, the increase in unsprung mass might become a problem.

Better sensitivity can be achieved fairly easily and cost-effectively by replacing the 6 load cells per rim with suitably scaled versions, but the unsprung mass increase may still be a problem.

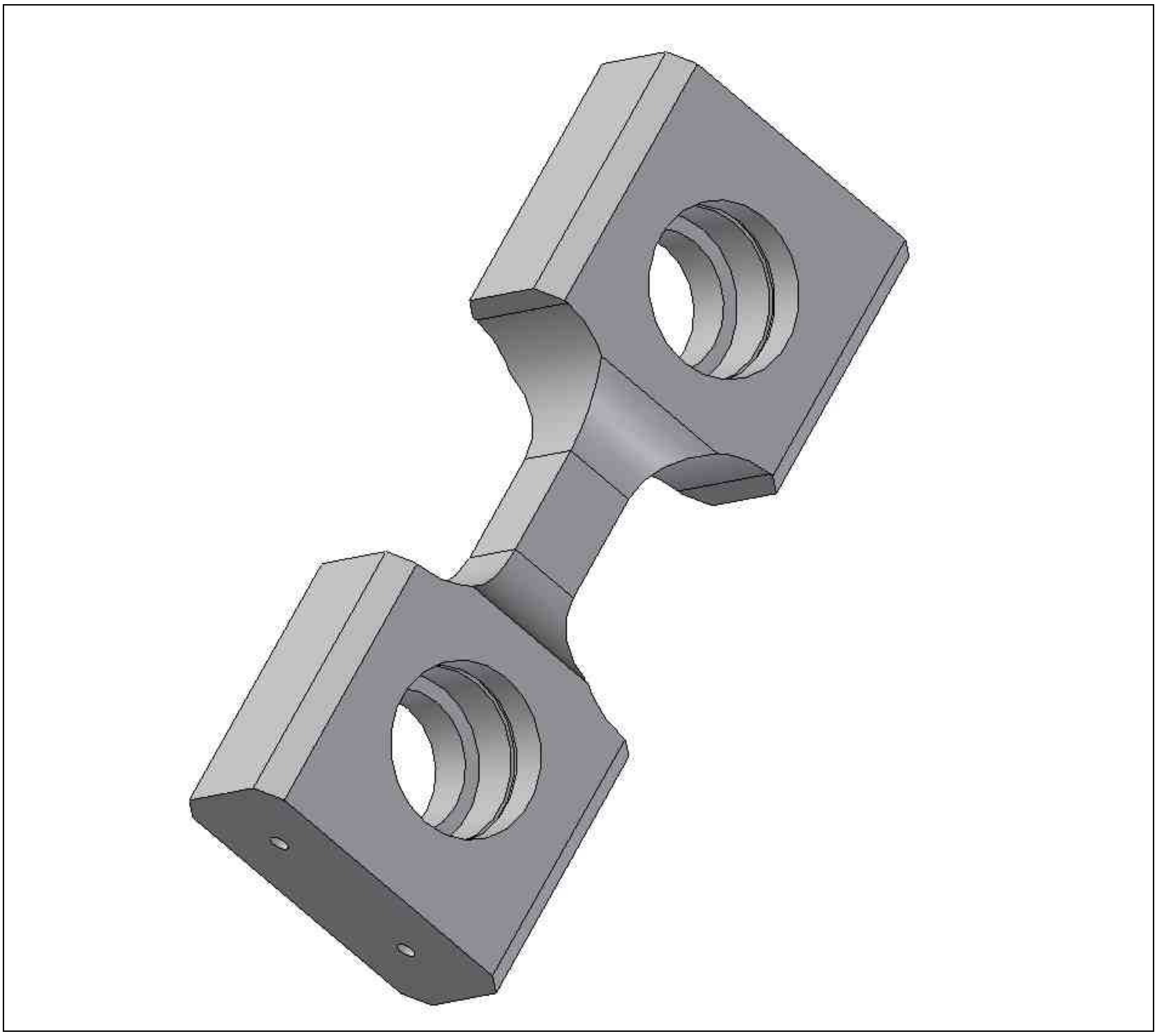

Figure 4 – Individual tension-compression load cells

5. Research plans for remainder of the contract period.

5.1. Develop wheel force transducer

The detail design will now be completed. Critical parts will be analyzed with finite element analysis to make sure that they are strong enough. During the detail design phase, special attention will be given to sealing against moisture and debris, as well as balancing. The telemetry is not included in this study and has to be procured separately. Recommendations in this regards will be made.

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 manufactured. 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. The telemetry is not included in this study and has to be procured separately.

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.

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] www.amgeneral.com/vehicles/hmmwv/expanded-capacity/details/m1165a1-with-b3, accessed 2010/11/02.

7. Administrative actions

None

8. Other important information

No other important information needs to be reported on at this stage.