

Development of Low Friction and Light Weight Wheel Hub Units to Reduce Both the Brake Corner Un-Sprung Mass and Vehicle Co2 Emission - Part 2 - Weight Reduction

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ABSTRACT

This paper will outline the technical challenges experienced and the engineering methods used to overcome them during the endeavor to reduce wheel hub units mass and friction. Results achieved by the project team are significant and have meaningful contributions both to the unsprung mass, inertia and rolling resistance reduction. These features directly enable fuel consumption reduction and related CO2 emissions as well as positively influencing vehicle dynamics.

Paper will handle two separate subjects of weight reduction and drag related power loss improvement and their combined effect at vehicle level. It will provide both simulated and test measured data as well as the validation of various features.

In the very near future every milligram of CO2 reduction will count. To achieve significant improvements engineers have to think out of the box, develop breakthrough technologies and sometimes totally rewrite the rule book. This paper will outline how the project engineers have approached the problem, used modeling techniques to simulate various solutions, conducted technology scouting, selected new technologies, prototyped and fully validated robust products.

INTRODUCTION

The wheel hub unit is a safety critical part of the brake corner. It carries the brake rotor as well as the wheel. It can influence brake noise and wear. It has been, like most other automotive products, cost and value optimized under the relentless market pressures over the last 10 years. The engineering team had to remove significant weight and friction out of this product keeping affordability within reach of the vehicle manufacturers.

The first part of this paper ([2010-01-1706](#)) focused on the drag reduction study, it introduced use of modeling techniques to conduct large number of virtual DOE's to select which parameters to combine and use for physical testing. Paper also tackled the possible conflicting effects of drag reduction and endurance, highlighting how the engineers scoped the targets, conducted the prototyping and product validation.

This second part will focus on the weight reduction challenge, the paper will outline use of alternative materials and design practices used to maintain stiffness, endurance and structural integrity under both corrosive environment and large range of operating temperatures.

Finally the paper will bring the two subjects together, proposing a modular approach to engineer for each customer specific application in order to achieve the best possible effect on both weight reduction and power loss elimination to target vehicle level CO2 reduction improvements.

VEHICLE ENVIRONMENTAL PERFORMANCE CALCULATIONS

In order to quantify the benefits of weight and friction reduction at vehicle level, a specific model has been set up with SKF Vehicle Environmental Performance Simulator (VEPS) [4]. In particular for this development a complete set of vehicle input data, including wheel bearing, was available on a medium class passenger car. As a result of friction test, friction maps both for baseline solution and optimized bearing were outlined.

The VEPS model also has the ability to estimate the influence of both static and rotating (inertia) component weight reduction on vehicle CO2 emission. [Chart 1](#) below shows the results of the calculation as individual contributions from, friction reduction, weight reduction and inertia reduction as well as their combined effects on the total vehicle CO2 emission. Values are in g/km per vehicle considering the same hub unit on all 4 corners, and the petrol engine version. Calculations are related to NEDC (New European Driving Cycle).

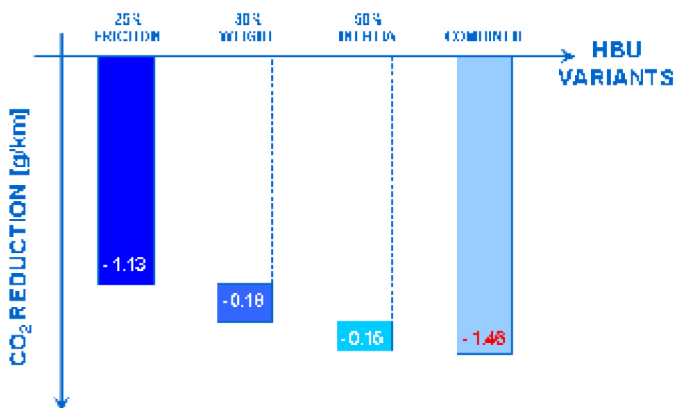


Chart 1.

FRICTION REDUCTION

The demand for energy efficiency is one of the strategic challenges that all the Automotive Manufacturers are facing now and will need to solve also in the close future. In the aim to respond to this market trend for all car segments and regions the low friction X-Tracker has been developed (SAE paper 2010-01-1706) [4]. Idea driving the friction reduction project is based on the X-Tracker asymmetric hub unit design which was presented at the 2006 Brake Colloquium (SAE paper 06BC-42) [1]; a hub bearing unit consisting of a double

row bearing arrangement in which the outboard row is at a higher pitch diameter and contains more rolling elements than the inboard row. This unique asymmetrical design significantly increases the camber stiffness compared to traditional symmetrical hub units as well as providing a higher carrying capacity and performance. By combining the asymmetric X-Tracker enhanced performance with newly optimized raceway geometry and friction optimized seals, the new product ([Figure 1](#)) provides very high stiffness to friction ratio as well as higher life to friction ratio compared to standard symmetrical hub units that would fit in the same package. The final result is a wheel bearing friction reduction of 25% and performance level equivalent to standard symmetrical solutions available in the market today. This is contributing to a reduction of CO2 emission and fuel consumption at vehicle level as shown by VEP calculations.



Figure 1.

WEIGHT REDUCTION PROJECT

INTRODUCTION

Weight and inertia reduction of chassis rotating elements enables CO2 emission reduction and fuel efficiency, as well as acceleration/deceleration performances. In particular this effect is amplified for vehicles equipped with start/stop systems.

Second generation wheel hub units are provided with one flanged ring that can be either connected to the wheel or the frame and two separate rings to be fitted onto a hub or into a knuckle bore ([Figure 2](#))



Figure 2.

Third generation wheel hubs are provided with two flanged rings (Figure 1). Flanged rings are generally built from steel forgings; material is either high carbon content steel or carburizing steel. Bearing grade steels are today well established and standardized to match process requirement and product specifications.

Many weight reduction activities on wheel hubs are today focused on optimized design towards material limits. The biggest constraints limiting optimized designs comes from machining process, rather than material strength.

- Minimum amount of material is requested for forging process
- Forging tolerances require a minimum level of stock material
- Complex geometry cannot be easily handled (thin/thick section transitions, hollowed sections)
- Milling operations are not cost efficient, turning operations are preferred. Therefore possibility of non-axial symmetric geometries is restricted.

The engineering team launched the weight reduction program setting challenging targets:

- Weight reduction of 30% at hub level, compared to standard steel design
- Minimum 90% stiffness compared to standard steel design
- The product must be affordable to the end user
- Equivalent performance to current market solutions

COMPOSITE HUB CONCEPT

Composite hub configuration can achieve targets by combining different materials to fulfill different functions.

Two main functions are provided by the flanged ring. The first function is to withstand the hertzian contacts related to rolling bearing function; the second is structural transmission of loads from rolling area to flanges and eventually connection points to wheel, brake rotor, or frame, as shown in Figure 3.

Main requirement for the rolling functional surfaces are hardness, toughness in subsurface, microstructure homogeneity, machinability of hardened surfaces to low roughness levels. Such requirements are today satisfied by use of bearing grade steel in a cost/process efficient way; alternative materials are not easily applicable. Moreover the rolling surface area has a limited extension with respect to complete flanged ring, as it is restricted around the raceways. Therefore bearing steel is the best choice for this function.

A significant weight reduction can be achieved by substituting steel with a lighter material to accomplish structural function of load transmission.

The result of integration is best utilization of materials, restricting the use of steel to specific areas of the hub unit

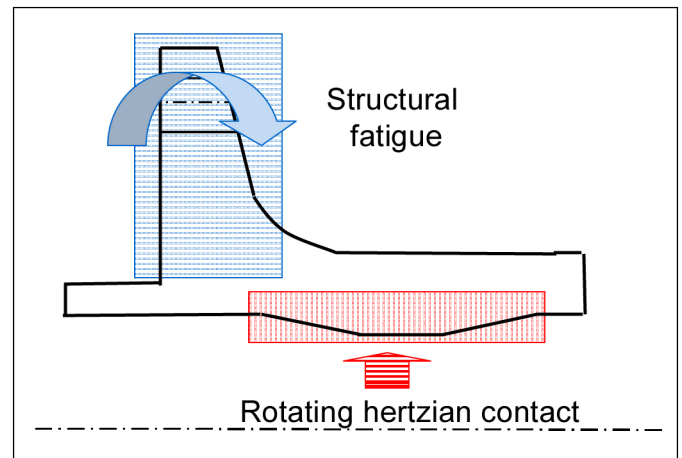


Figure 3.

Many materials and technologies have been considered in the phase of concept selection: aluminum alloys, titanium, fiber reinforced polymers, carbon fiber composites.

Three main criteria for concept selection have been considered:

- cost
- capability for volume production
- technology readiness level

Result of the analysis was selection of aluminum alloy to be integrated with steel. The integration is obtained by overmoulding process; aluminum is injected around a steel core with a casting process, as shown in Figure 4. Advanced casting techniques enable use of standard high pressure equipment providing high structural quality and heat treatable cast parts. Current development was focused on primary alloys; next development steps will include option for secondary alloys.