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Design optimization through Weight Reduction of Forged Parts via Innovative Geometrical Change

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Abstract - The Wheel Hub of a rally cross car is analyzed to reduce the unsprung mass of the car. The problem statement is to mainly focus on the unsprung mass related to the suspension, and more specifically on the Wheel Hub. One of the objectives of the suspension system of a car is to damping the movement of the car. This is an important area when designing a vehicle, and especially a race car due to the extreme conditions that may result in reduced traction and loose of confidence for the driver. A theoretical model is performed to demonstrate the importance of a low unsprung mass and to illustrate how it affects the vehicle-handling. A process to evaluate the current Wheel Hub and decision to re-design the Wheel Hub is performed, and the parts are analyzed using the Finite Element Method to verify the design and material selection. Vehicle dynamics of the car is analyzed to calculate the acting forces. Optimization of the design is performed by using Computer Aided Engineering. The re-designed Wheel Hub presented as the result of this project with a Brake Disk Adapter integrated in Hub. This design reduces the number of parts, and the unsprung mass up to 25% without any effects on suspension geometry or other parts of the car.

Key Words: *Wheel Hub, vehicle dynamics, optimization, Finite Element Analysis*

1. INTRODUCTION

In rallycross only one thing counts - to be fastest. Everything need to be in harmony. A driver has to be such comfortable with the behaviour of the car that he, or she can set the limits of its performance.
Engineers all over the world still fascinated of the topic Sir Isaac Newton (1642-1727) presents in "Principia Mathematica Philosophiae Naturalis" in 1686, and his three laws of motions. Newton shown that the "*The force is equal to the change in momentum per change in time. For a constant mass, force equal mass times acceleration*". The force F acting on a body is related to its mass M and the acceleration a. see Equation (1.1) (Jansson & Grahn, 2013), (NASA, 2018).

$$F=Ma=Mdvdt$$

1.1 Technology, Society and Environment

Sustainable development is commonly described as "*development that meets present needs without compromising the ability of future generations to meet their own needs*" (The International Institute for Sustainable Development (IISD), 2018). Everything engineered and manufactured need to be carefully considered due to the TSE - Technology, Society and Environment effects. The objectives of this project are to reduce the total mass of the car. In the rallycross car, this is made to perform a better acceleration, braking and cornering. In road or passenger cars a low mass will reduce the amount of energy, or fuel used to transport the car a desired distance. The knowledge in motorsport and thought this project will be applied in performance cars, but also normal passenger cars. Car manufacturer trying to reduce the fuel consumption to increase the number of sold cars because of reduced exhaust emissions. By using new technology, the amount of material with retained strength can reduce the need of both experimental testing of physical models and the raw material to produce the product. With increased computational capabilities the possibilities to perform simulations that realizes the physical model, which reduces the time in both engineering development and manufacturing processes.

1.2 About EKSRX/EKS

From the web site of EKS:

(1.1) "*To most people, Mattias is best known as a champion of the Deutsche Tourenwagen Masters (DTM). He won the championship for Audi in 2004 and 2007 and he was overall first runner-up in 2014 and 2017. Apart from driving in DTM, Mattias has won race titles all over the world. The idea of creating a privately-owned rallycross team was put to paper in late 2013. The plan was to compete in the FIA World Rallycross Championship in*

2014. People in the business said it would take one and a half to two years to build a rallycross car. And even then, it wouldn't be enough time to have a ready-to-race car with top-level performance. To say it was a challenge would be an understatement. The team signed up as EKS, three-letter code of Mattias Ekström in DTM. After having the engine flown in by helicopter from Sweden, the mechanics completed the last finishing details just in time for the start – the first Audi S1 EKSRX car was ready to race. A month later, Mattias ended up at the top of the podium in Höljes, Sweden. It had only been six months since the team started working in an empty garage in Fagersta, Sweden. The perception that it was an "impossible project" just added fuel to the desire to show the know-it-all the opposite. In late 2016, three years into the project, Mattias could call himself World Champion and - as if that hadn't been enough already - EKS won the Team's Championship" (EKSRX, 2018).

Aims for the project

- • Estimation of acting loads

Based on previous real data from the car, calculate the forces applied on the Wheel Hub. Forces and moments from chassis, drivetrain and suspension need to be analysed to make an accurate simulation.

- • **Comparative Design Analysis**

Compare two types of Wheel Hub designs, regarding the advantages, and disadvantages of the designs.

- • Optimization

The current Wheel Hub can be optimized with knowledge from the other designs. This should be performed with CAD-models, CAD means Computer Aided Design. EKS will provide CAD-models including drawings of all interesting parts. Finite Element Analysis will be performed, mathematical analysis and optimization to find an optimal design with reduced mass, required strength, and usability during service of the car. EKS can contribute with examples of other solutions, contact with peoples that have knowledge and data from previous experiences and tests.

- • New design

Perform a design concept of a new Wheel Hub or present what changes can be done with the current Hub to obtain the desired improvement. The design need to be optimized with respect to total mass and fulfils the requirements of function.
Targets in the project is mass loss gain vs. performance, and the advantages of making a new Wheel Hub. The design shall be evaluated due to the performance, mass (economic is not considered in this project) and what types of changes are worth implementing.

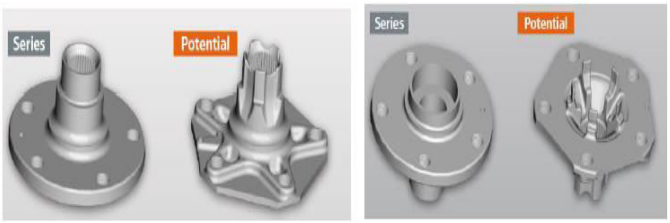

Fig -1: Figure

3. CONCLUSIONS

The conclusions made while working through this project is that the possibilities to improve the Wheel Hub is large. The design developed in this project is a big step forward to reduce the unsprung mass of the car. The design will not affect the geometry of the suspension and therefore the behaviour of the car in that aspect. The advantages of change to the re-designed Hub will increase the acceleration of the car and improve the traction between tire and road. The limitations set in this project makes it difficult to make the changes needed to find the optimal design. Even if the design will improve the car by making small changes can an advantage in changing the upright and suspension geometry an even more innovative design with less unsprung mass and advantages in suspension geometry, heat flux etc.
The design (optimized current Wheel Hub) presented in Figure 5.12 reduces the mass with 15% and can be performed with small changes and new parts. This design is not fully optimized but will reduce the total mass of the Wheel Hub which was the objectives. Recommendations to EKS is to evaluate the re-designed Hub and compare the result of this project to find their best decision the best way to improve the unsprung mass of the car.

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