Optimal design of a heat dissipating wheel for a 2CV race car

Nick Van Kelecom* and Tom Wellens†
Faculty of engineering technology, Campus Group T, Leuven, Vesaliusstraat 13, 3000 Leuven, Belgium

Yann Caniou‡ and Maximilien Landrain§
Noesis Solutions NV, Gaston Geenslaan 11 B4, 3001 Leuven, Belgium

and

Maarten Vaniershot**
Faculty of engineering technology, Campus Group T, Leuven, Vesaliusstraat 13, 3000 Leuven, Belgium

The field of race cars is the ideal place for innovation that will be later proposed to the public vehicles. This work deals with the issue of the need of a race car engine to be able to dissipate the heat create by the fuel combustion in order to increase its level of performance. The solution proposed here consists in developing competition turbine shaped rims that would be able to extract the air from under the bonnet of the car. A numerical model is created in order to simulate both the air flow and the mechanical behavior of the rim. The initial design is finally optimized in order to maximize the air extraction and to minimize the weight of the rim.

Nomenclature

CFD	=	Computational Fluid Dynamic
FEA	=	amplitude of oscillation

I. Abstract

The CQS Group Racing Team recently came up with a problem: their engine needs to work in optimal conditions to deliver its best performance during the competition. One of these conditions is to reduce as much as possible the amount of hot air under the bonnet so that the engine is able to dissipate its heat with fresh air.

This research work investigates the possibility of designing a rim that is able to extract the hot air from underneath the hood of a 2CV race car. The main advantage of this kind of rims is that the engine is able to cool down faster than with a natural extraction of the hot air. In order to make it possible, the spokes of the rim are designed like the blades of a turbine so that the air can be extracted. The mass flow was determined by Computational Fluid Dynamics (CFD) modelling on the extracted air.

For safety reasons, another feature that has required a lot of attention alongside the CFD is a Finite Element Analysis (FEA) structural analysis of the rim. The objective of this second analysis was to assess the resistance of the rim design to mechanical loads. The structural loads that are applied on the rim are the centrifugal force, the pressure of the tire and the weight of the car. Afterwards, a parametric numerical model was created and used in an optimization process whose objective was to maximize the air extraction and minimize the mass of the rim with respect to structural constraints.

The optimization strategy that has been implemented is a classical approach. An adjustable full factorial design of experiments is run in order to capture the behavior of the model with metamodel, also referred to as response surface, namely a polynomial representation here. After the accuracy metamodel has been assessed using cross validation, a two-step optimization strategy has been applied. First a global optimization method,

Communicating Author: yann.caniou@noesissolutions.com.
* Master of industrial science, KU Leuven, Vesaliusstraat 13, 3000 Leuven, Belgium.
† Master of industrial science, KU Leuven, Vesaliusstraat 13, 3000 Leuven, Belgium.
‡ Application Engineer, Noesis Solutions, Gaston Geenslaan 11 B4, 3001 Leuven, Belgium.
§ Application Engineer, Noesis Solutions, Gaston Geenslaan 11 B4, 3001 Leuven, Belgium.
** Professor, KU Leuven, Vesaliusstraat 13, 3000 Leuven, Belgium.

namely an evolutionary algorithm (EA), has been run to identify a region of interest. An EA is an optimization algorithm that mimics biological phenomena: starting from an initial population of individuals, it iteratively applies mechanisms such as selection, mutation, recombination and reproduction to propose new candidates that are evaluated using a fitness function. Then a local optimization method, namely a gradient-based algorithm has followed to reach an optimal design point. Finally, this possibly global optimum has been validated by a CFD and a structural analysis to confirm the results. This entire strategy has been carried out inside the Optimus® platform. This tool allows the practitioner to capture the process, here both the structural and CFD analyses, in a workflow and to automate all the above-mentioned steps of the strategy.

The results show that it is possible to develop such a rim that is light but string enough to withstand the solicitations of a race car and that is able to extract the hot air from the engine bay of the 2CV. The results obtained through the structural analysis are comparable with those obtained with the previously run manual calculations. The boundary conditions that were placed on the model for the flow analysis were “moving frame of reference”, “static pressure type” and “boundary flow surface”. The flow analysis has shown good velocity and pressure results. Future improvements could be further enhanced by decreasing the mesh size.