Design methodologies for automotive steel wheels

# PhD thesis
# Design methodologies for automotive steel wheels

Simone Venturini

Politecnico di Torino, Department of Mechanical and Aerospace Engineering
Corso Duca degli Abruzzi, 24 – 10129 Torino, Italy

Supervisors:
Prof. Elvio Bonisoli
Prof. Mauro Velardocchia

## Summary

This dissertation addresses the development of an integrated finite element model methodology for the simulation of automotive steel wheel static and dynamic behaviours in accelerated fatigue test procedure loading regimes. The methodology allows to improve the design and validation process reducing the experimental activity.
The first part of the dissertation is dedicated to the study of the production process of the wheel assembly and the operating principle of the main static and dynamic test benches used during product validation.
The analysis, carried out in conjunction with MW Italia S.p.A. and the partner Frauhnofer ITWM, made it possible to identify the lack in the state-of-the-art of a robust simulation model of fatigue test procedures where the wheel is coupled to the tyre. A wheel parametric finite element is developed by considering main residual stress mechanisms. The study of the stress state of some critical positions, and strain gauge analysis led to the choice of a multi-axial failure criterion for high-cycle fatigue with non proportional stress field components. The model was validated through several experimental test-runs on a dynamic cornering fatigue test-rig. The tyre-rim interaction was therefore introduced using a specific interface of the CDTire/3D software to simulate the behaviour of the tyre under operating conditions on the test bench. The enriched finite element model was then experimentally validated on different families of wheels and operating conditions on radial fatigue tests.
Therefore, improvements were made to the predictive model with the aim of extending the functionality to ZWeiAchsige RadPrüfung (ZWARP) tests by characterising the tyre-wheel interface. A further post-processing stage was introduced to the experimental data, affected by uncertainties in the positioning and orientation of the strain gauge sensors. The model, specific for a single type of wheel, has been generalised in a simulative approach for simplified use on different families of wheels and tyres. Furthermore, it was analysed through the development of meta-models, how the interference induced by the disc-rim fitting can affect the dynamic response of the same. Specifically, this study is closely related to the control of these systems to achieve robust diagnostics of the interference between complex geometries, dependent on the uncertainties of the system.
Finally, the research activity was dedicated to the systematic validation of the methodologies developed during the first two years. In the first part of the third year, the approach of identifying the confidence interval of the highly censored experimental fatigue data was investigated by defining reduced bias. Also, an experimental validation of the tyre-rim interface was carried out.
A strain gauge experimental test methodology was therefore developed to indirectly monitor the stress state of the contact region between tyre and rim, called flange.