POLITECNICO DI TORINO

DIMEAS
Department of Mechanical and Aerospace Engineering

ScuDo
Scuola di Dottorato ~ Doctoral School
WHAT YOU ARE, TAKES YOU FAR

Aims, actual results and future plans

Design methodology for automotive steel wheels

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PoliTo scholarship without topic
for Ph.D. Mechanical Engineering XXXIV programme

MW

Fraunhofer ITWM

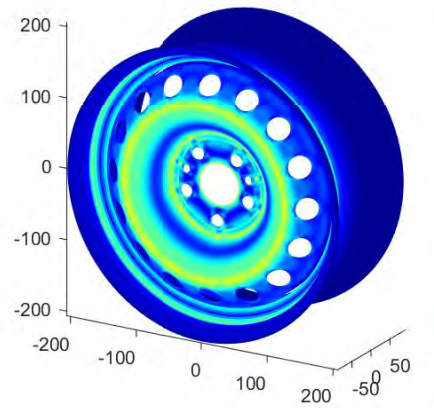
Torino, 25 September 2020

Objective

Development of predictive model for steel wheel behaviour

- failure prediction of automotive steel wheels during fatigue tests
- effect of pre-stresses
  - interference fit
  - bolt tightening
  - tyre-rim interaction

Hardware test-rig

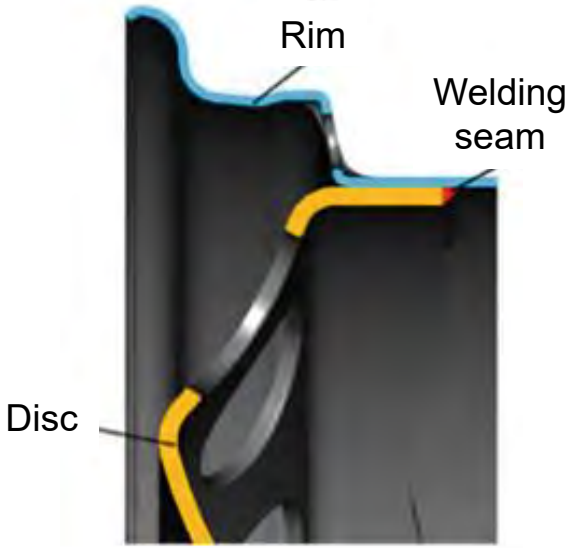


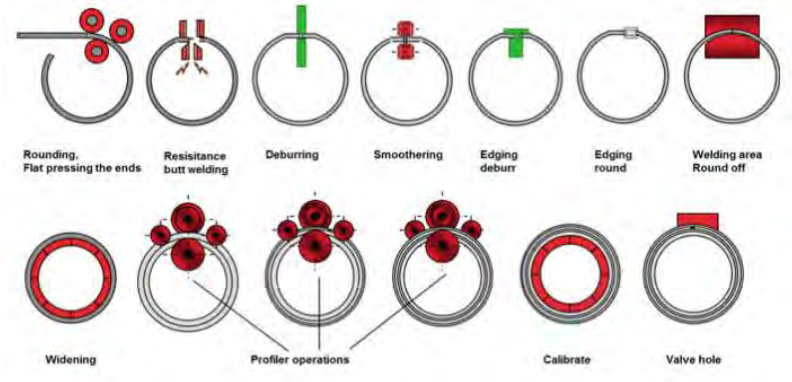
Virtual test-rig

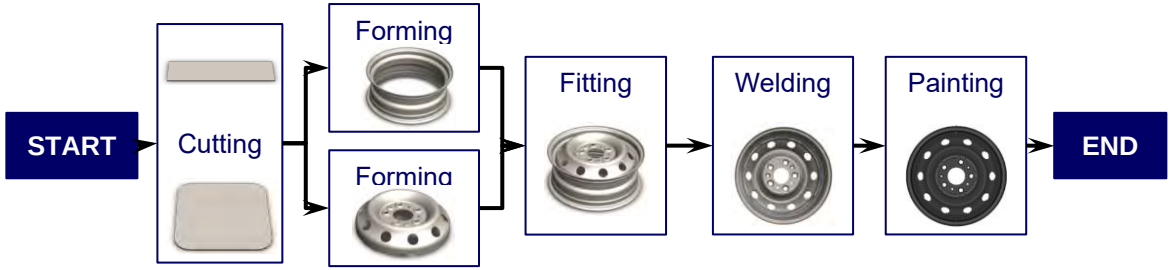
Motivation, State-of-the-art → Proposed FEM model → Testing •Extensimetry •Life cycles → Conclusions

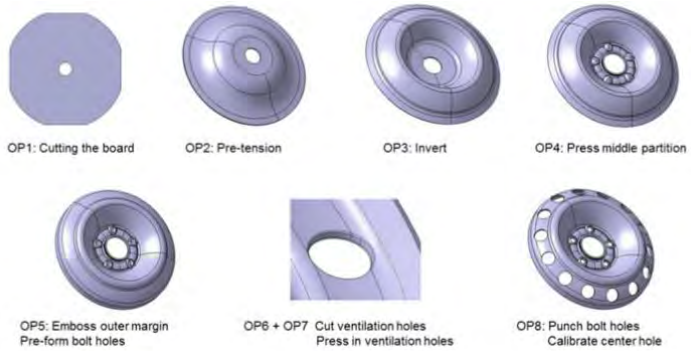
Automotive steel wheel

- Optimised but complex geometry
- Steel based (disc -> DP, rim -> HSLA)
- Lightweight (vent holes)
- Residual stresses (production, assembly by press-fit)





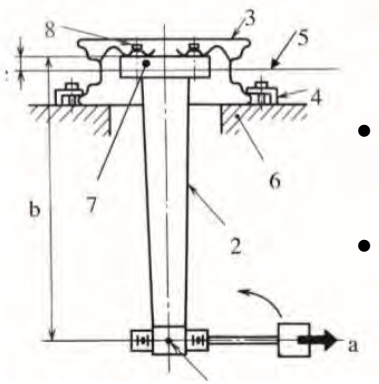




Fatigue tests

Dynamic cornering

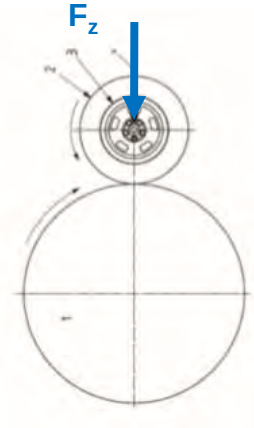
SAE J328



- Bending moment
- ~ hours

Radial

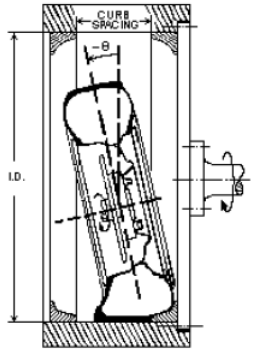
SAE J328



- Tyre contribution
- Vertical load
- (Lateral load)
- (Slip angle)
- ~ hours, days

Biaxial

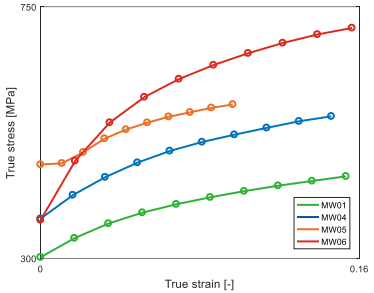
SAE J2562



- Tyre contribution
- Vertical load
- Lateral load
- Camber angle
- Overturning moment
- Definitely days

Complexity, Level of details, Industrial demand, …

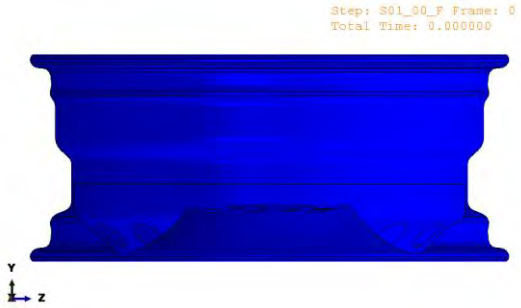
Virtual test-rig

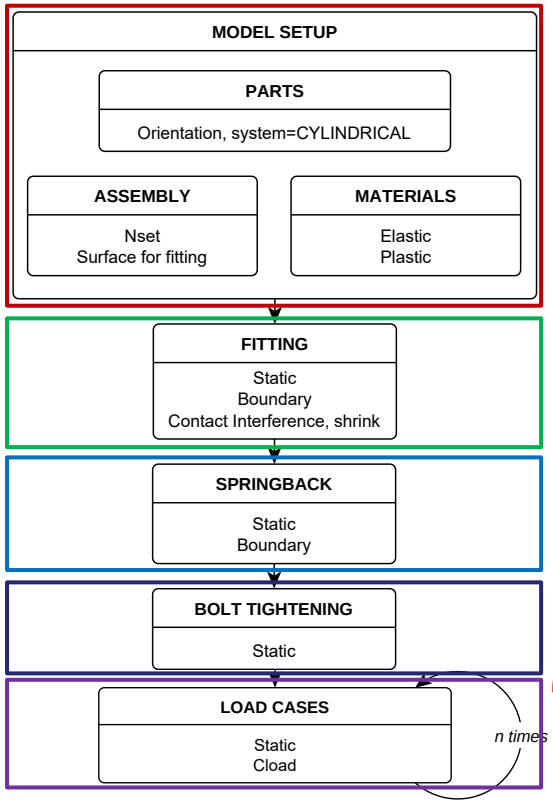


Abaqus® FE model
- shell elements
- elasto/plastic behaviour

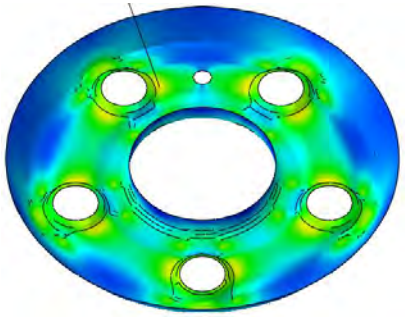
Interference by strain-free geometry deformation
- overclosure solved by minimum strain
- correct disc offset

Springback
- remove residual elastic stresses

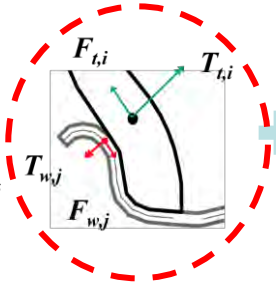


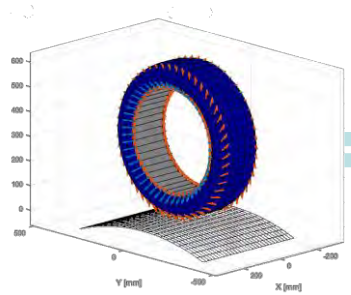


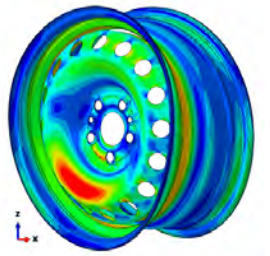
Bolt tightening
- add pre-stress
- bolt hole plastic behaviour



Load cases
- quasi-static simulations
- loads acting on flange nodes
- ITWM WheelTestRig reactions to the rim





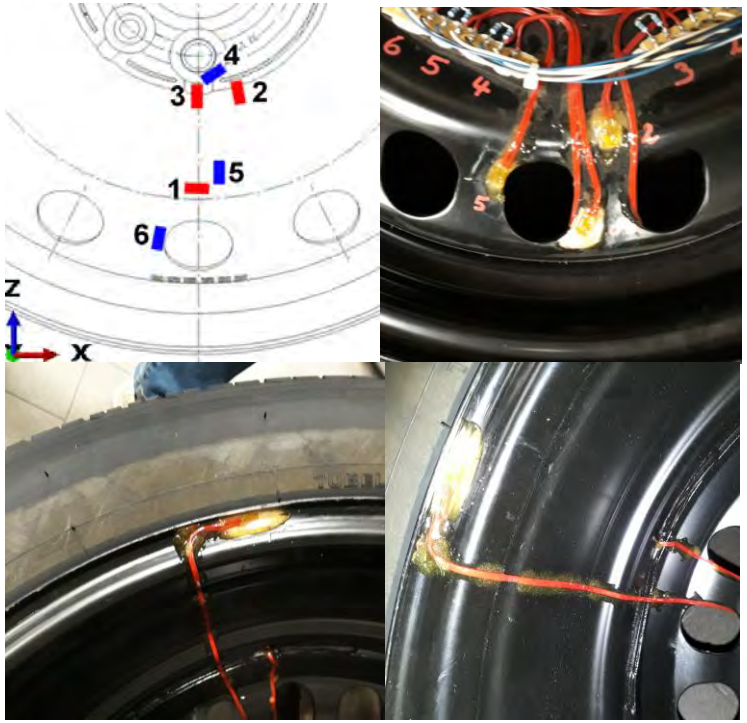


Life assessment
- McDiarmid criterion (Damage Factor)
- extensimetry

CRITICAL

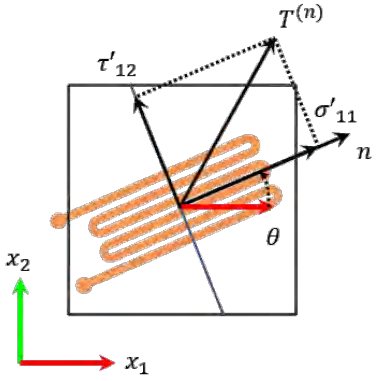
Post-processing

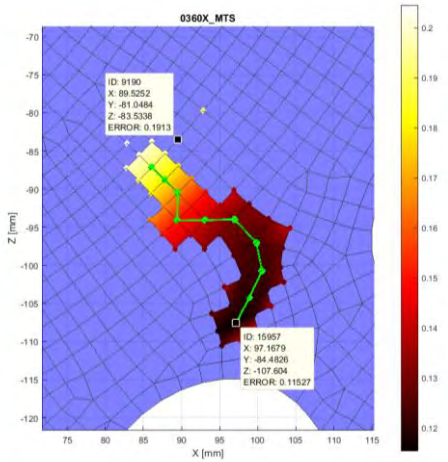
- Uncertain strain gages location and orientation
- Experimental data not synchronised

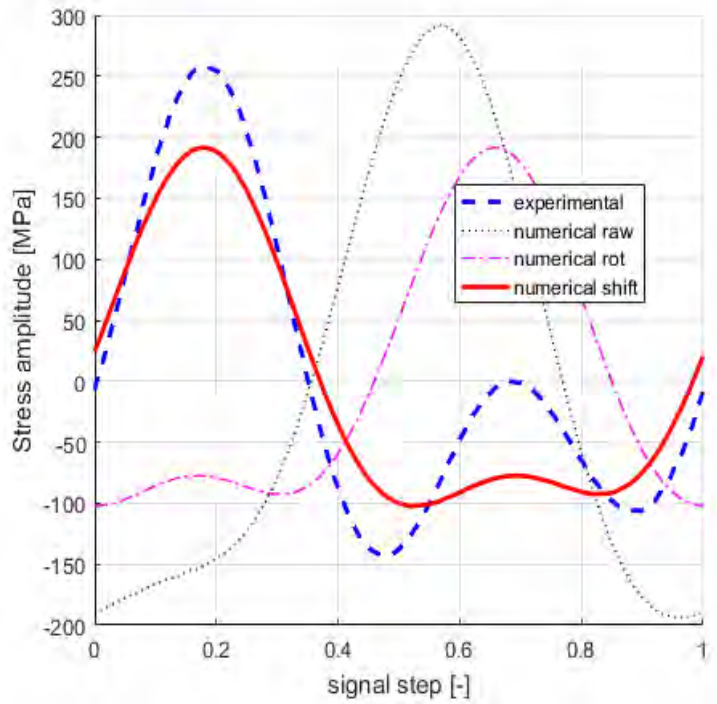


Minimisation problem:
- Strain gage orientation
- delay between exp. and num. stress history

Gradient method:
- Strain gage location



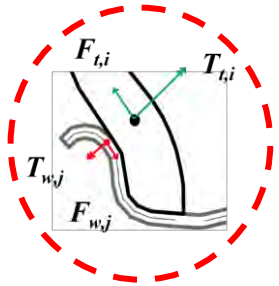


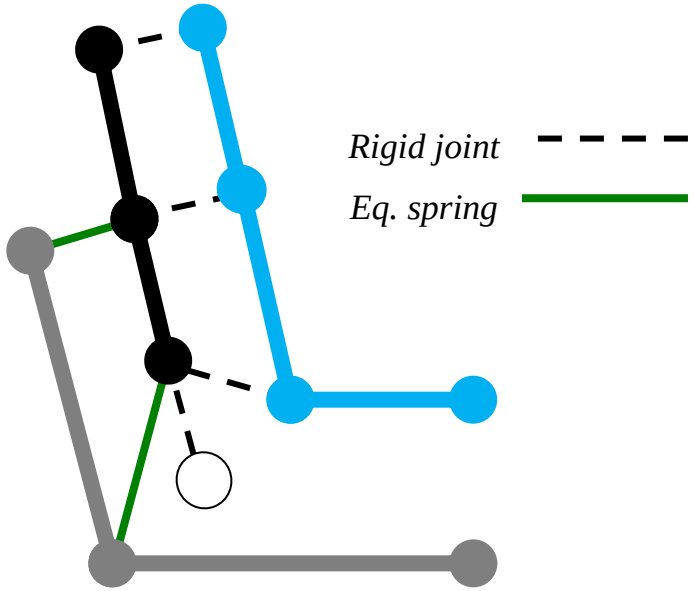


Tyre-rim interface

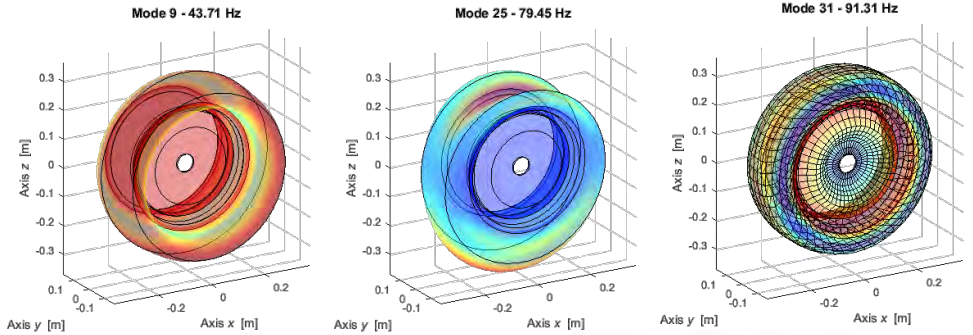
Stiff instead of a rigid interface

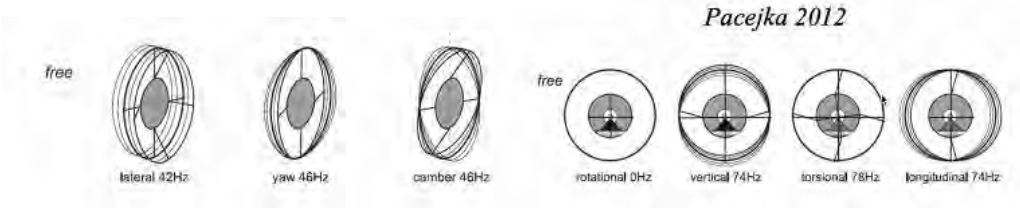
- Coincident non collapsed nodes
- 3D Air volume
- 1D elastic elements at tyre-rim interface
- 1D Tire bead pretension
- Contact -> equivalent stiffness (Hertz)



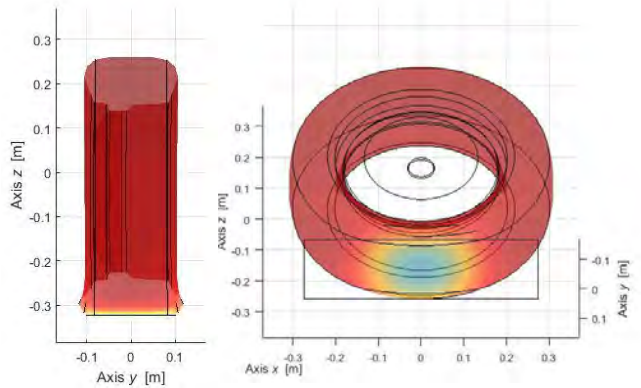


Free-Free / Clamped hub

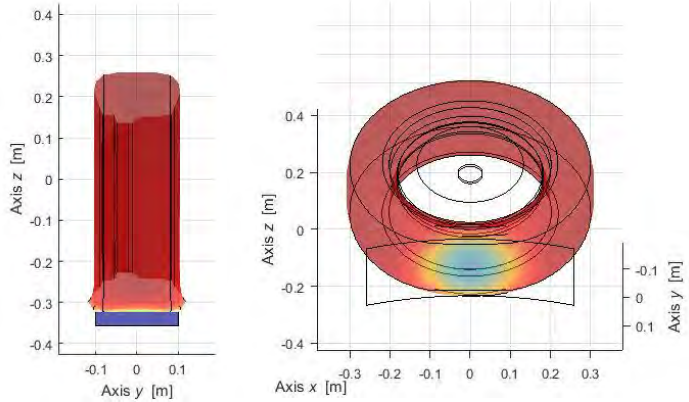




Planar contact

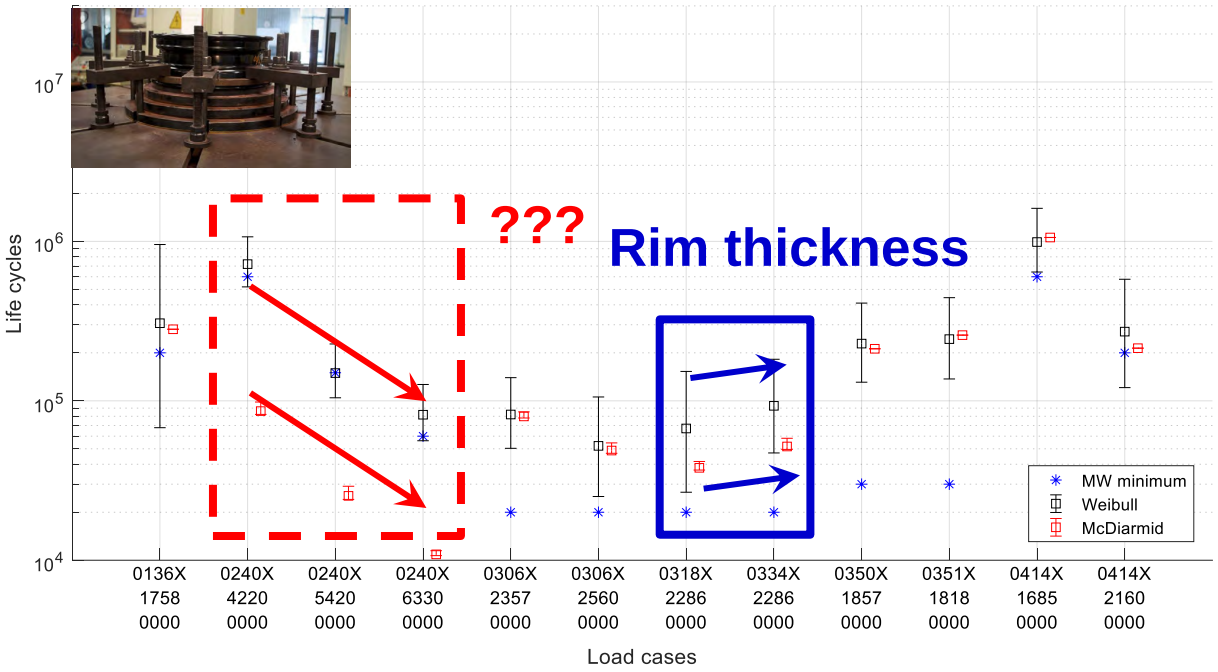


Drum contact

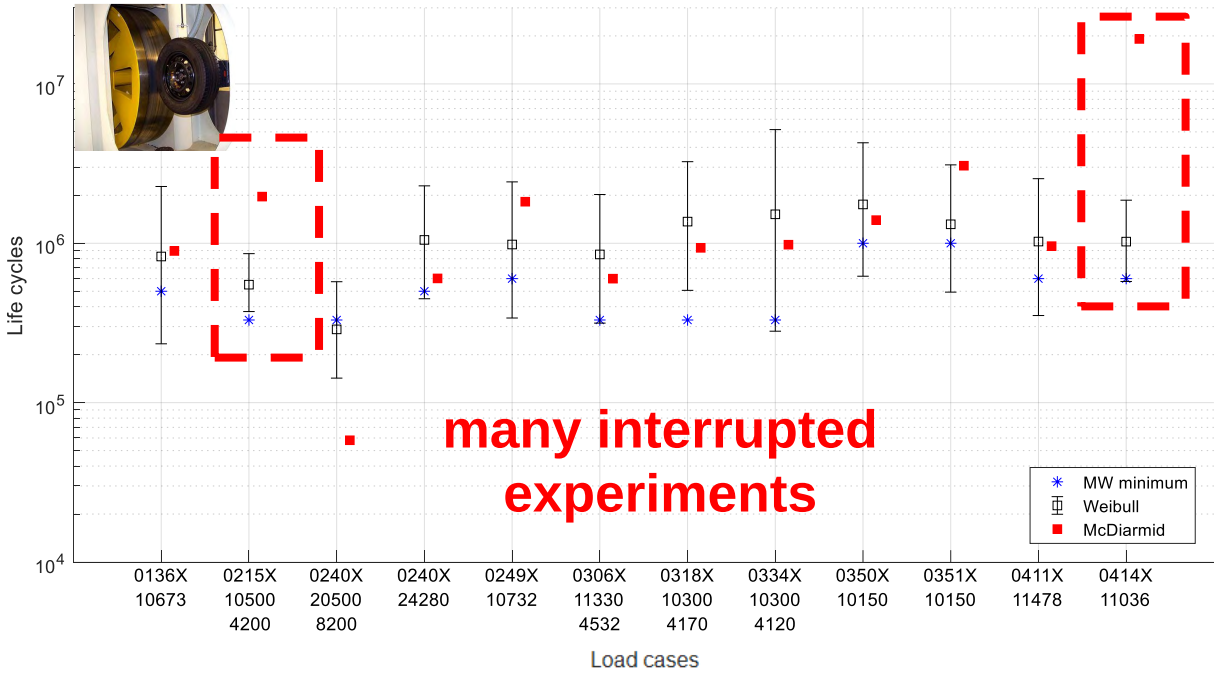


Dynamic cornering and radial tests

Dynamic cornering



Radial



ZWARP biaxial fatigue tests

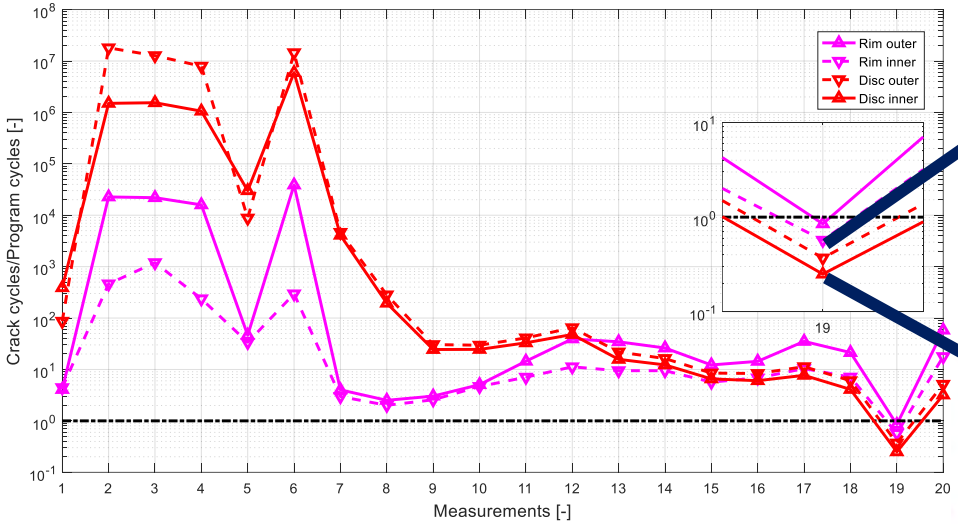
Normal production

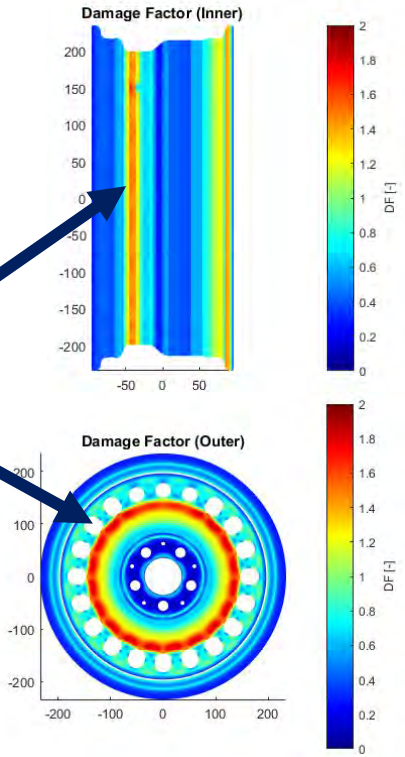
Test end: ZWARP Test (AK349)			
Final Cycles	Final km	End test data	
623'515	1'300	15/06/2019	
Time test [h]	%	Repet. no.	Step no.
18	26%	44	12
Description			
Cracks on disc starting from vent holes ("crusts" are visible on the trimmed surfaces; coining radii are almost absent).			

Reworked vent holes

Test end: ZWARP Test (AK349)			
Final Cycles	Final km	End test data	
1'211'401	2'550	28/06/2019	
Time test [h]	%	Repet. no.	Step no.
34	51%	86	4
Description			
Crack on rim with air leakage (in correspondance to welding seam); no cracks on disc.			

Non-cumulative damage





Cumulative damage

	CDTire + Abaqus	Experimental
Final repetition	31	44
Final cycles	447540	623515
Completion	18.80%	26%

Conclusions

Steel wheel FEM model to simulate effects on fatigue of:

- Prestress during assembly and manufacturing
- Major industrial fatigue tests
- Good crack site identification and life estimation

Next steps

- Stiff tyre-rim parametric mockup embedded in the methodology
- Experimental extensimetry campaign to characterise different flange geometries

Publications (in the year)

- **Venturini S.**, Bonisoli E., Rosso C., Rovarino D., Velardocchia M., "Modal analyses and meta-models for fatigue assessment of automotive steel wheels", *Model Validation and Uncertainty Quantification Vol. 3, Proceedings of the 38th IMAC, A Conference and Exposition on Structural Dynamics, Conference Proceedings of the Society for Experimental Mechanics Series*, 520 pp., Ch. 17, 2020, Springer, ISSN: 2191-5644.
- Rovarino D., Actis Comino L., Bonisoli E., Rosso C., **Venturini S.**, Velardocchia M, Baecker M., Gallrein A., "A methodology for automotive steel wheel life assessment", *SAE Technical Paper*, 2020-01-1240, 2020, pp. 1-10, DOI: 10.4271/2020-01-1240.
- Rovarino D., Actis Comino L., Bonisoli E., Rosso C., **Venturini S**., Velardocchia M, Baecker M., Gallrein A., "Hardware and virtual test-rigs for automotive steel wheels design", *SAE Technical Paper*, 2020-01-1231, 2020, pp. 1-19, DOI: 10.4271/2020-01-1231.