The Liberty Wheel project: Part 6: Design of the Liberty Wheel

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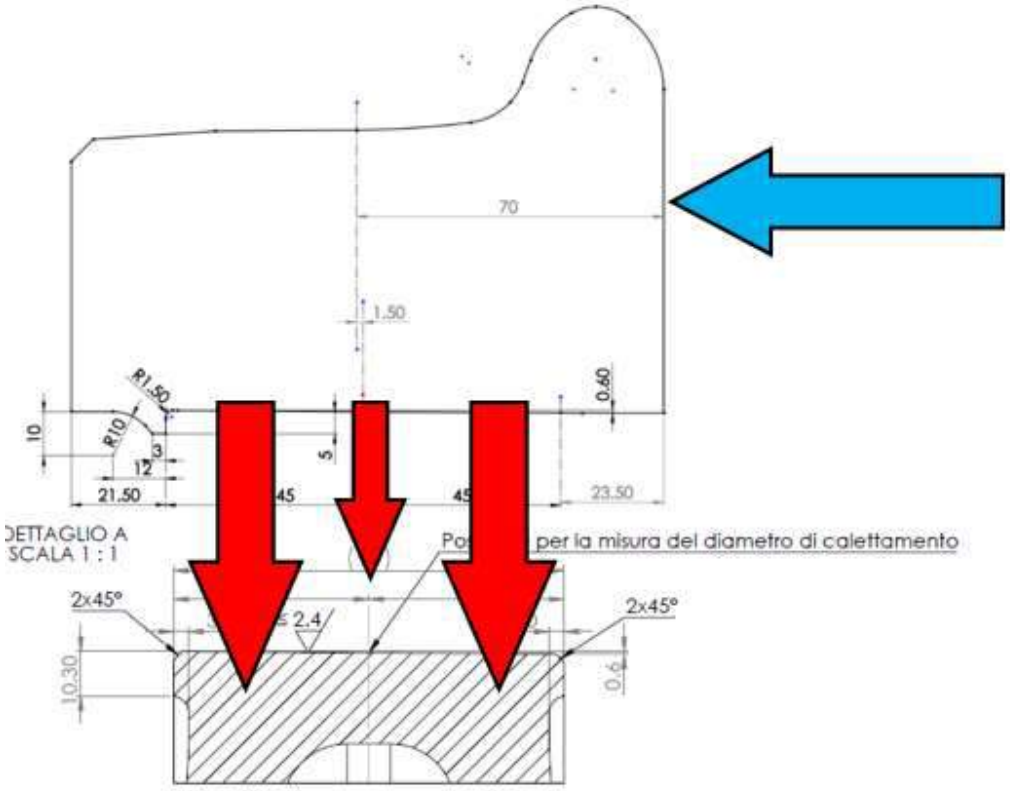
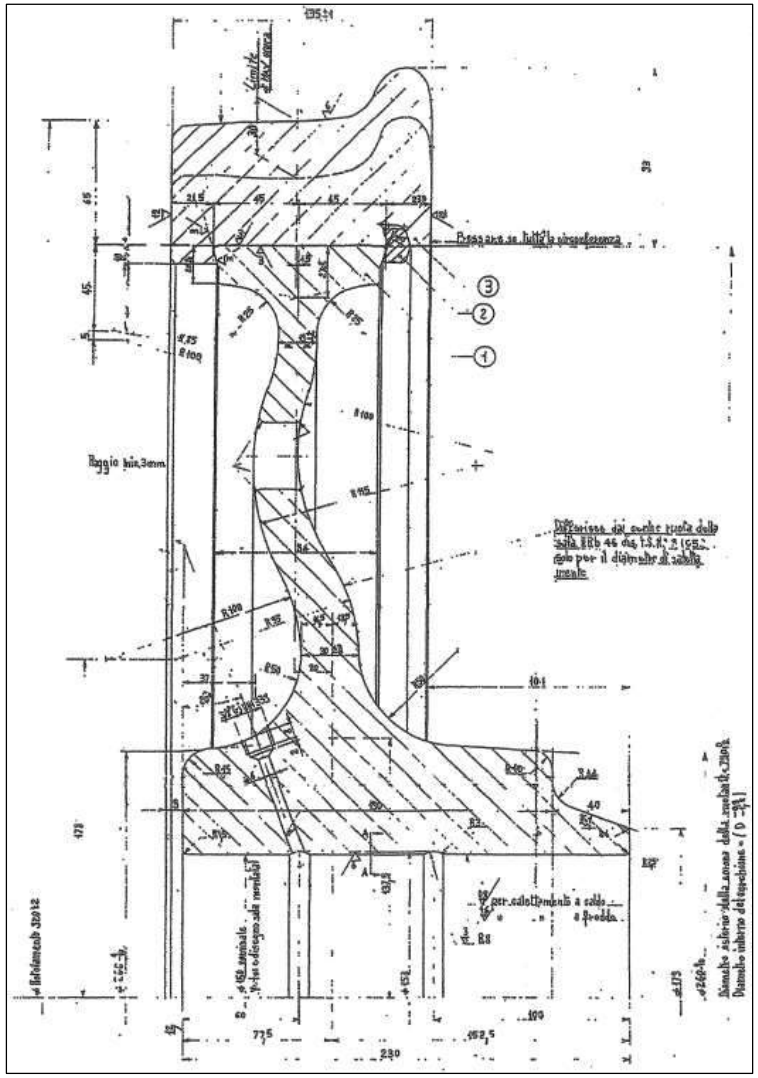
The new wheel centre for a new tyred wheel

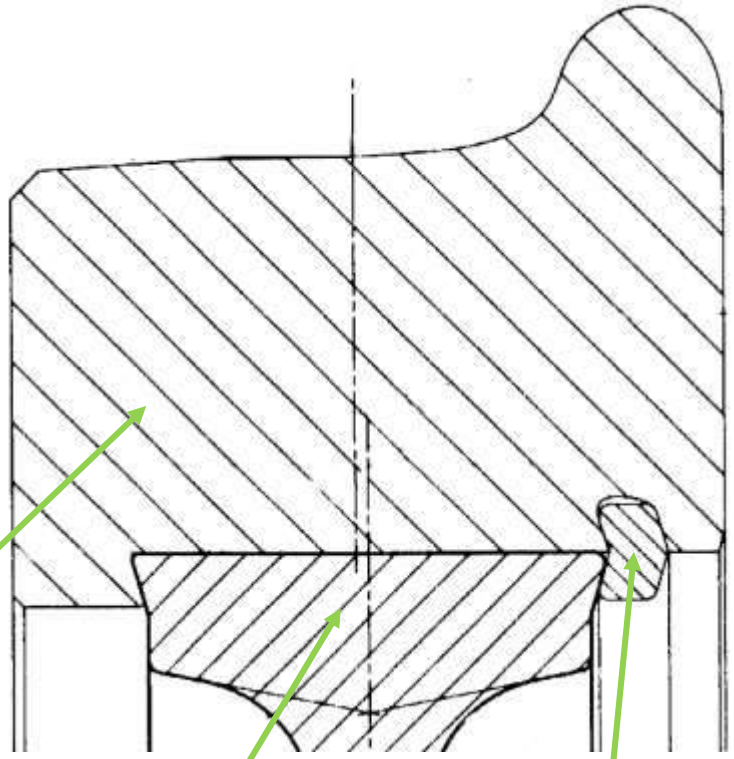


- **Wheel centre design is central for a good tyred wheel**
- **Low radial stiffness is preferable for lower stresses on the tyre**
- **Straight web is preferable for lower stress in the wheel centre and lower lateral displacement**

ALn668 original drawings (1957!)



Materials

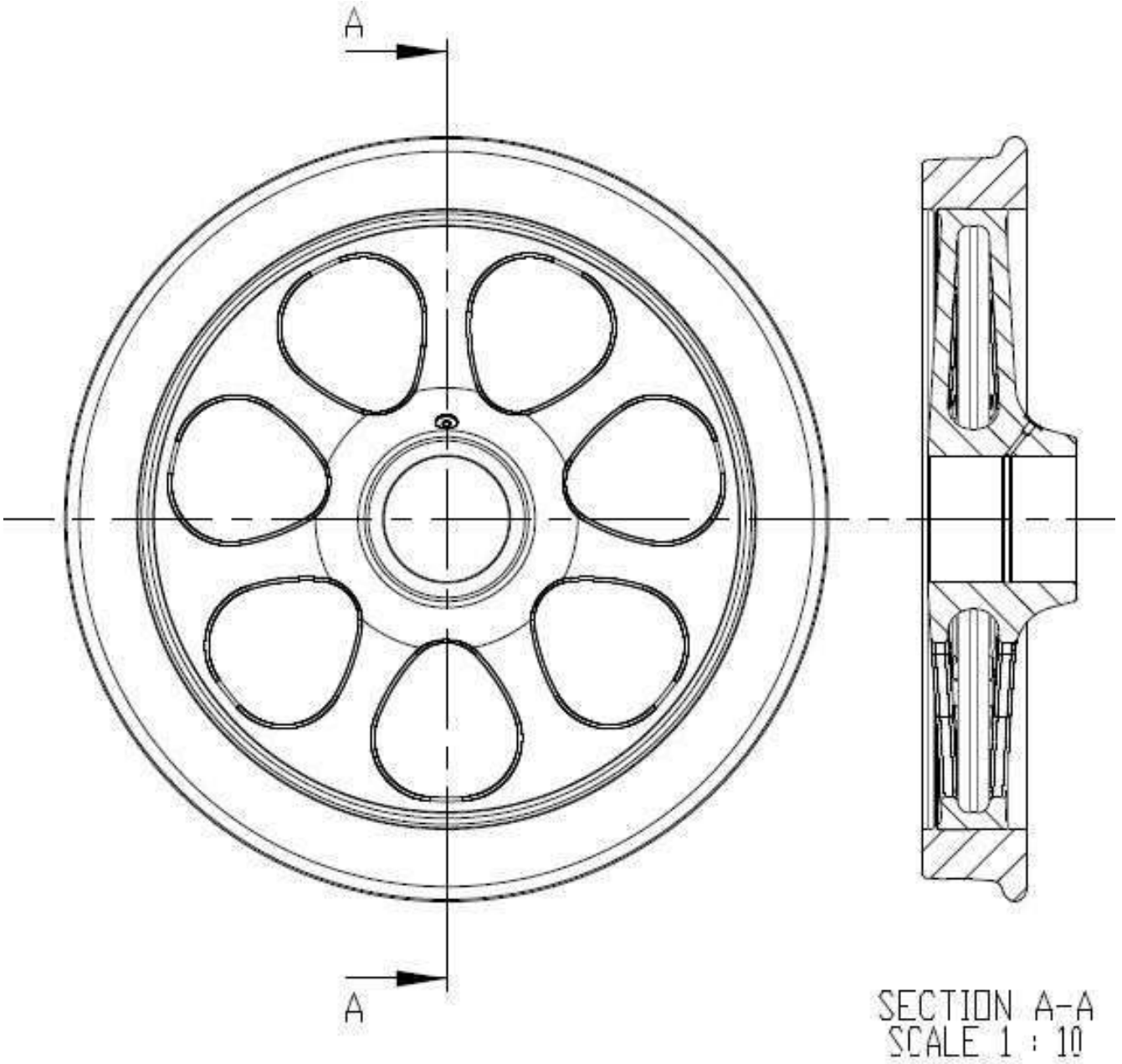


Tyre
Fe740
UNI 6102-90
$R_{p0,2}$ = 410 MPa

~~Wheel centre~~
~~**Fe42**~~
~~**UNI 7175-73**~~
~~**$R_{p0,2}$ = 235 MPa**~~

~~Retaining ring~~
~~**Fe37C**~~
~~**UNI 7162-72**~~
~~**$R_{p0,2}$ = 235 MPa**~~

Modified wheel centre



Modified wheel centre

180 kg

130 kg

-30% of unsprung mass

-50 % of lateral emitting surface

Casting simulations

NovaFlow&Solid r1
Centro ruota raff 5 e cromite.psp
Date : 07/01/2019
YZ plane, mm

Box dimension,casting position and number of cells					
along X, mm	1164.000	581.406	293	Size of cells, mm	4.000
along Y, mm	1008.000	504.702	254	Total cells:	9 686 492
along Z, mm	524.000	292.500	133	Casting cells:	593 907

Boundary conditions

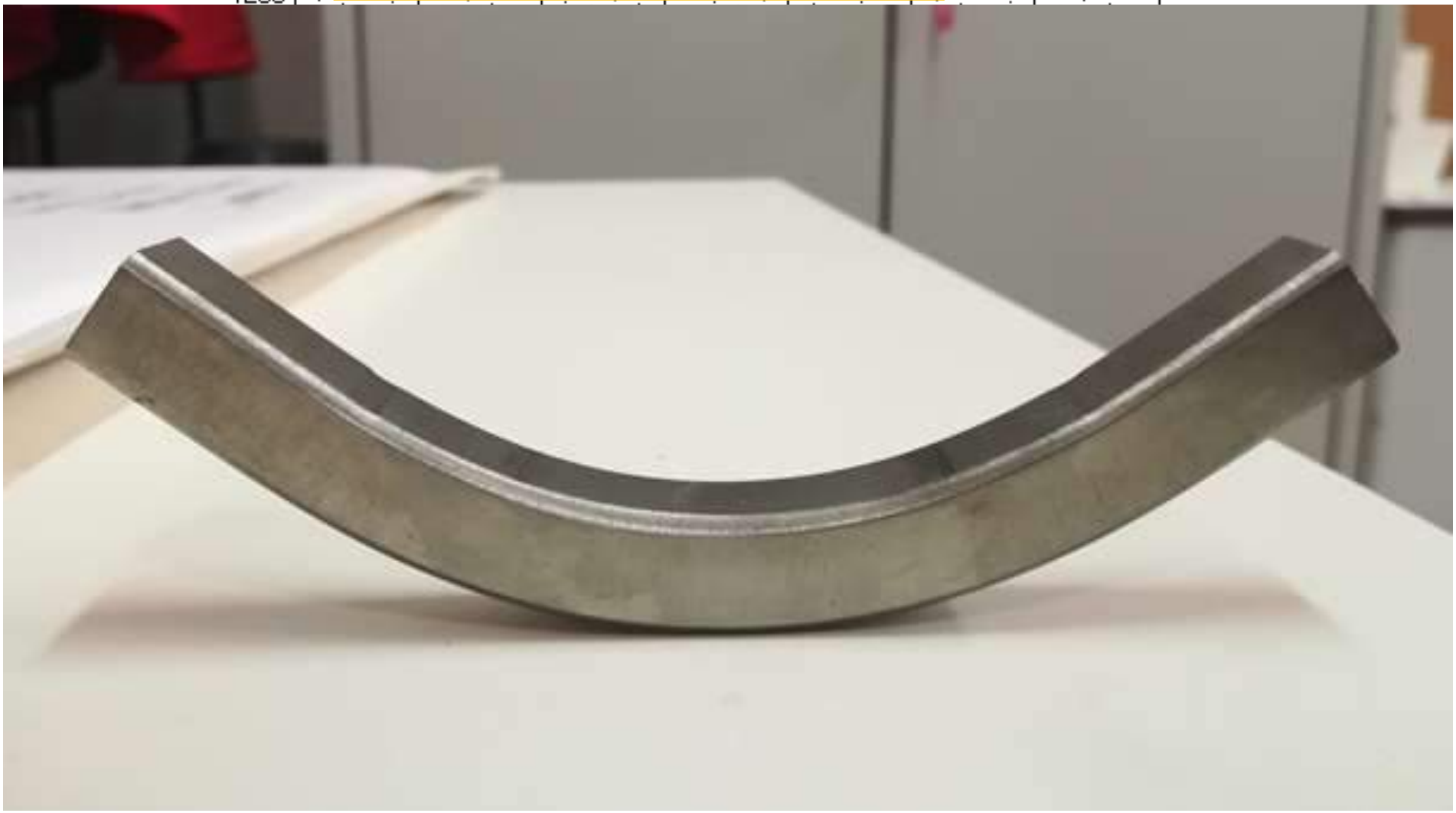
	Low	High
YZ plane	Normal conditions	Normal conditions
XZ plane	Normal conditions	Normal conditions
XY plane	Normal conditions	Normal conditions

0 - quasi-equilibrium model calculation, without segregation
Without convection
Aggressive AMG

Mould materials	T, °C
EN-GJS-500 [S]	1390.0
EN-GJS-500 [S]	1390.0
EN-GJS-500 [S]	1390.0
EN-GJS-500 [S]	1390.0
EN-GJS-500 [S]	1390.0
EN-GJS-500 [S]	1390.0
Filter - 10 PPI	25.0
Exothermic - High	20.0
Core - Cromite Sand	20.0
Core - Cold Box	20.0
Chill - Grey Iron	20.0
Mold - Green SandHPM	20.0
Air - In mold	20.0

Austempered Ductile Iron

Work hardening plastic behavior

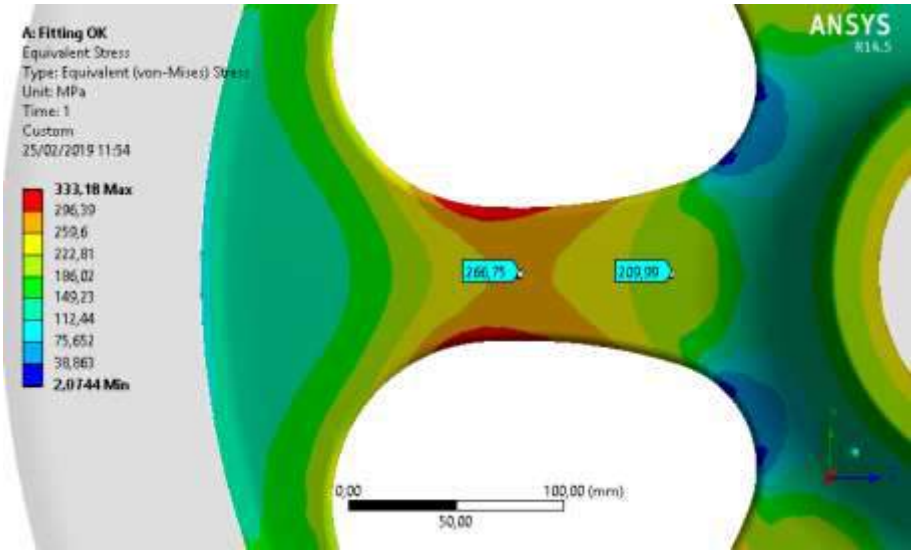


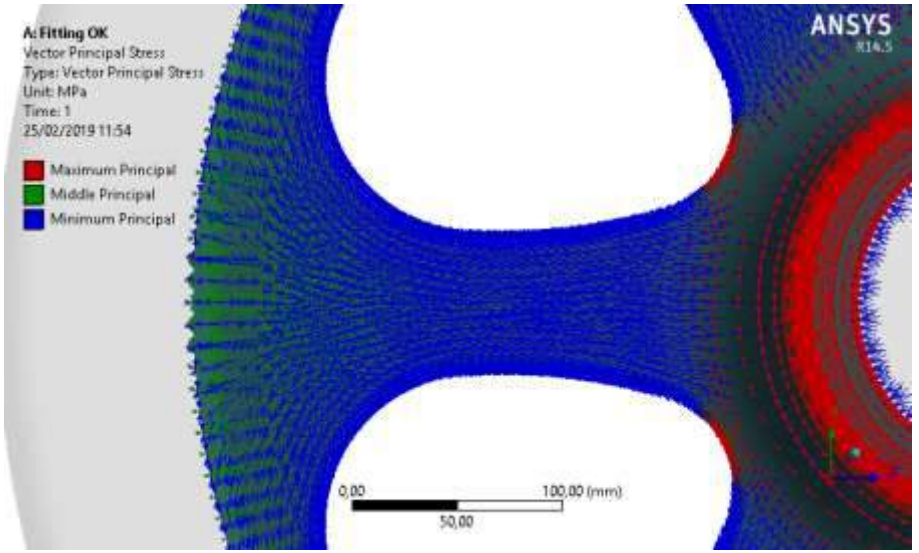
Austempered Ductile Iron - comparison

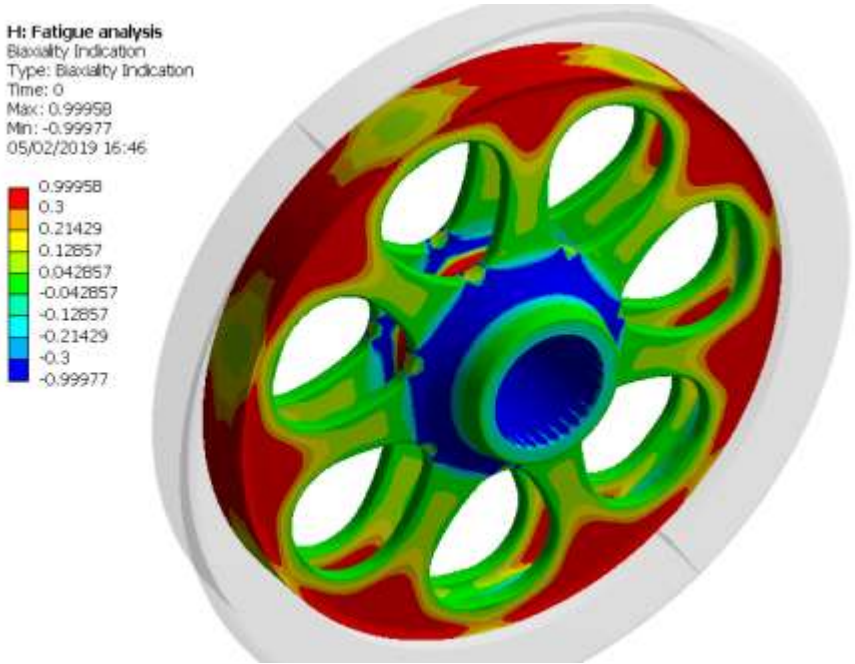
	ADI800	EA1N	30NiCrMoV12	ER7*	SUPERLOS*
R_m [MPa]	670	370	860	560/380	640/500
$R_{p0,2}$ [MPa]	920	600	975	890/730	980/850
A_5 [%]	13	27	20	18/21	18/21
HB	250	-	-	265	290
K_u (20°C) [J]	-	55	70	27	24
K_v (20°C) [J]	10	-	-	11 a)	9 a)
σ_a (50%) [MPa]	400	274	510	-	-
σ_a (90%) [MPa]	327	195 b)	363 b)	315/260	370/320
K_f [-]	1.67	1.61	1.67	-	-
K_{IC} [MPa$\sqrt{m}$]	62	52	117	88	82
ΔK_{th} [MPa$\sqrt{m}$] (R = -1)	16.8	17	10	-	-

* Rim/Web
a) Values for -20°C
b) 95% survival probability
c) 99.7% survival probability

Fitting assessement

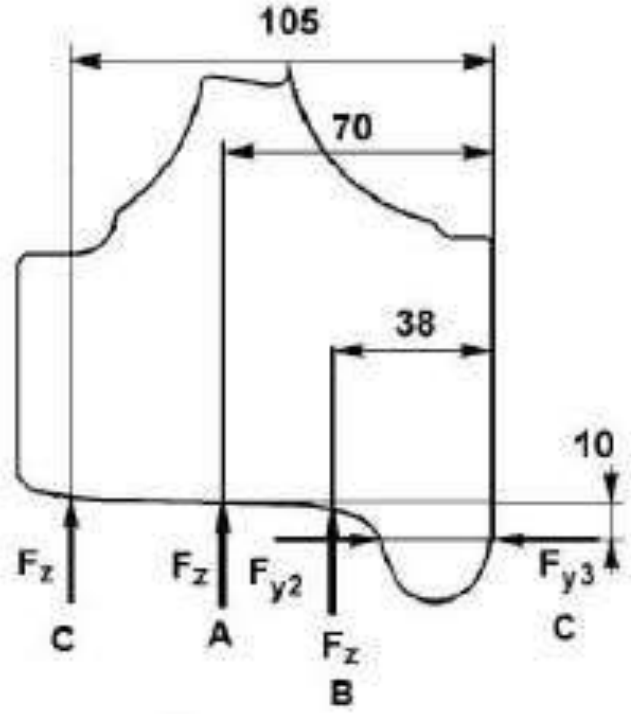


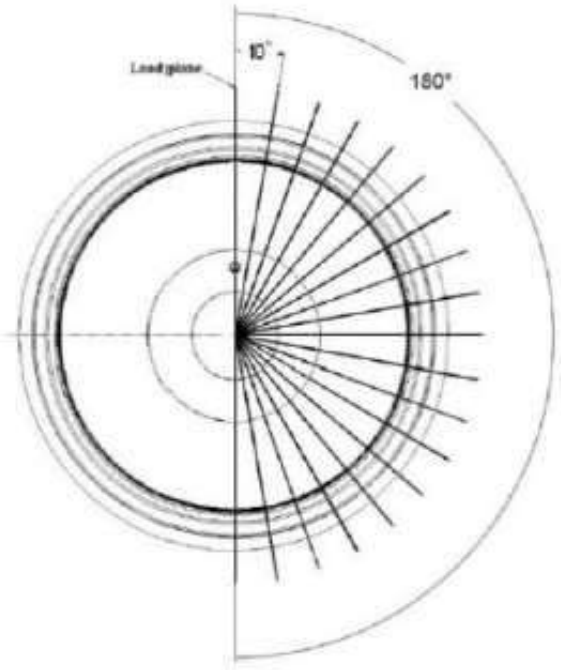




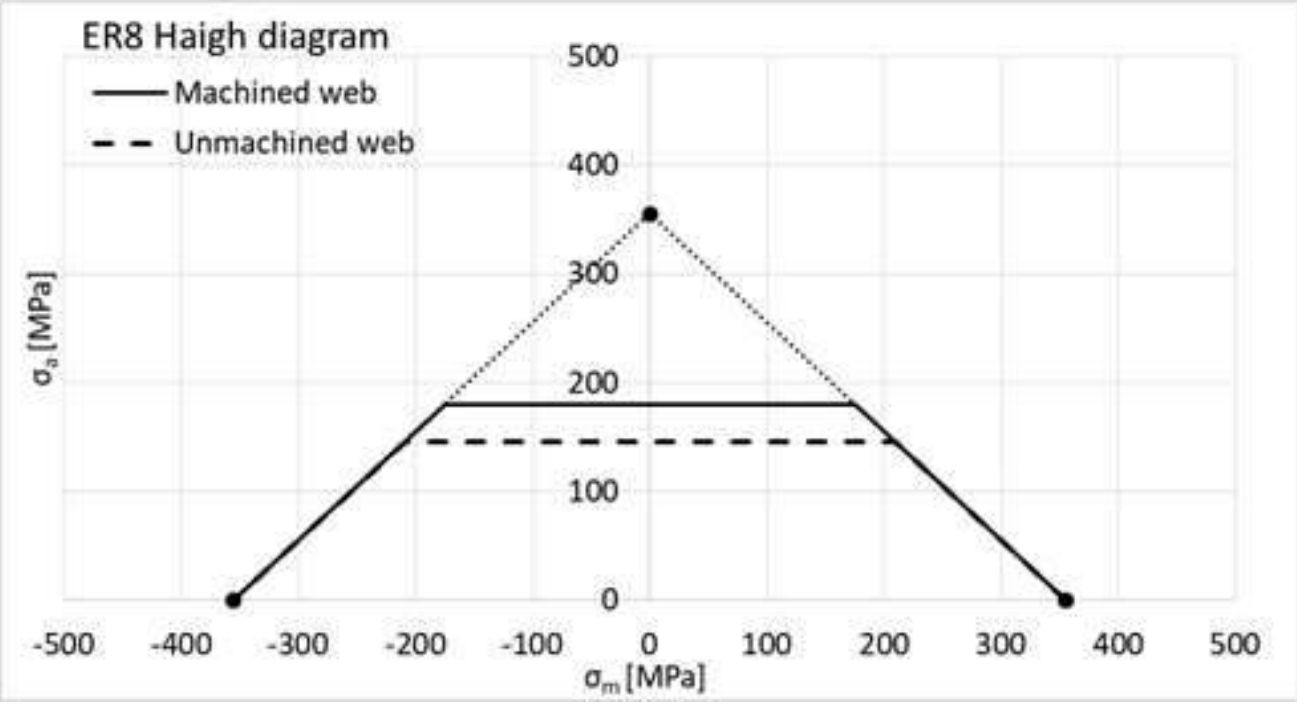
Fatigue assessment – Monobloc wheels

- Loads from *EN13979* are applied on N positions along the circumference of the tyre
- MPSM (*Maximum Principal Stress Method*) is used to reduce the stress distribution due to the 3xN load cases, is reduced to a uniaxial load case to be compared with the permissible stress.
- Applicable only to axisymmetric wheels



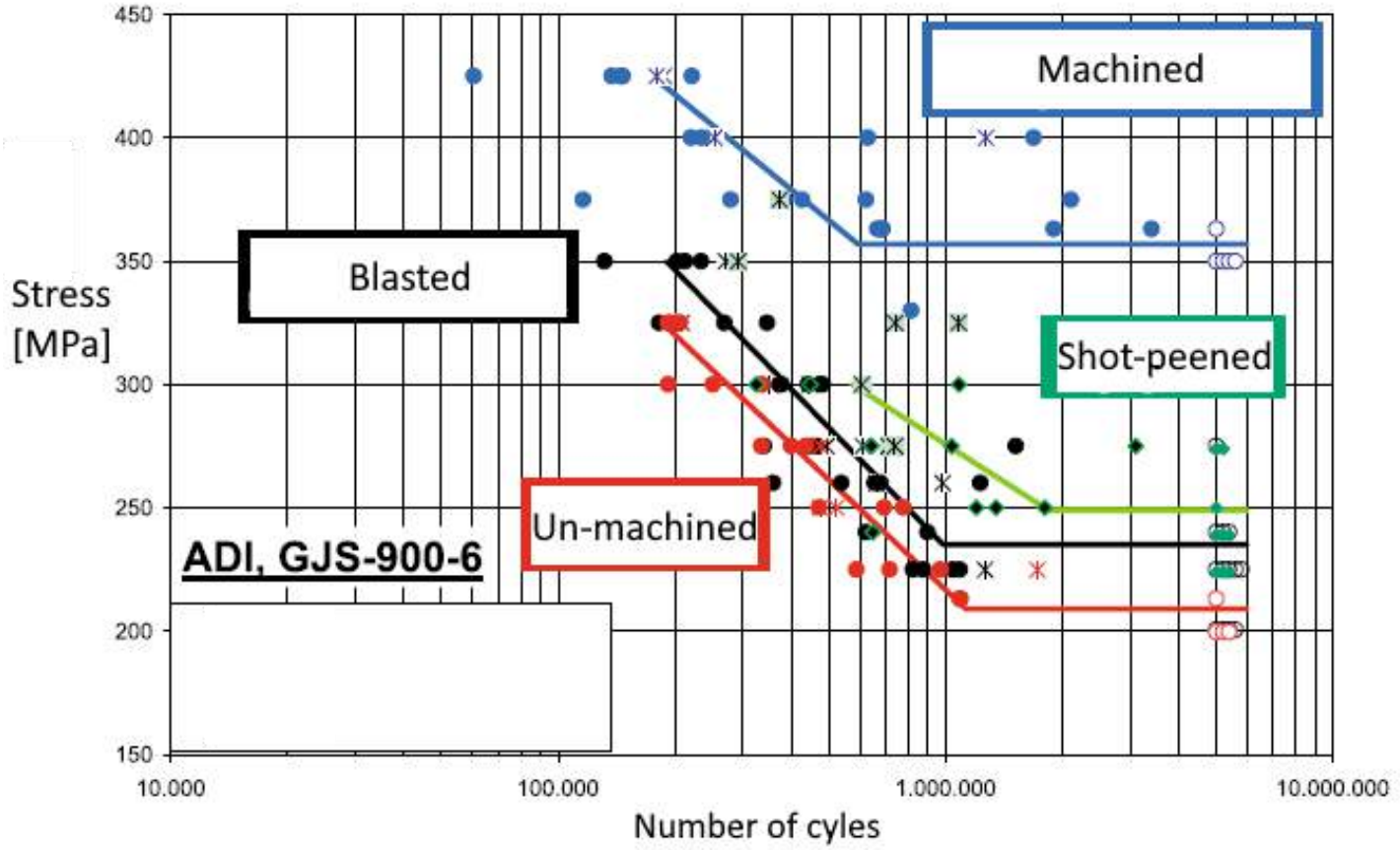


Fatigue assessment – Haigh diagram



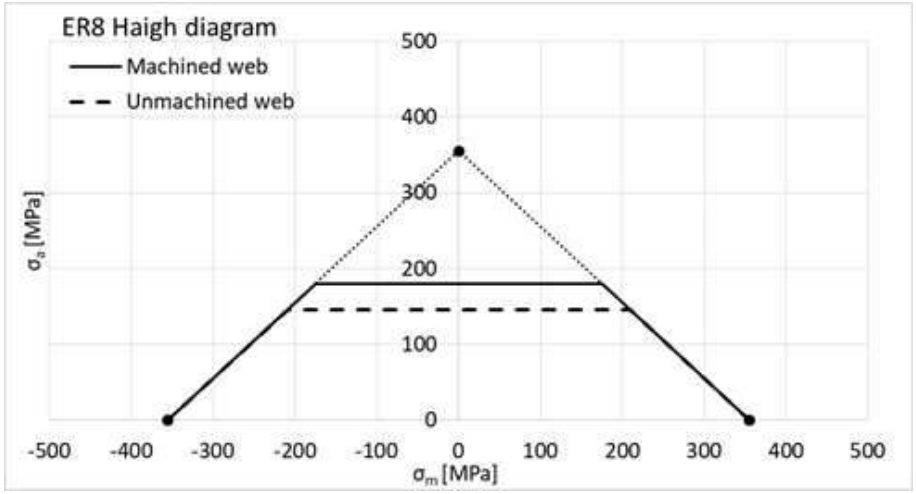
- No effect of the mean stress due to the absence of notches
- Obtained by several full-scale tests
- Proven in service

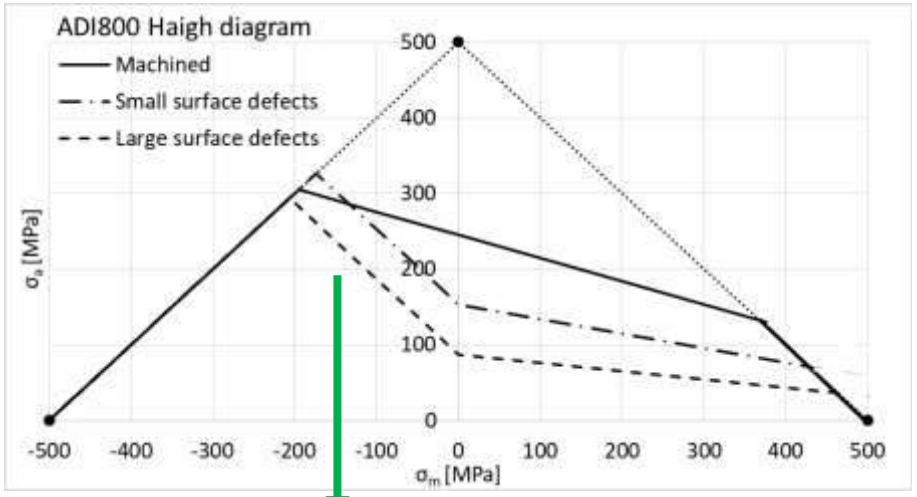
Fatigue assessment – Effect of casted skin



- Presence of surface defects reduces fatigue limit
- Fatigue limit is reduced if compressive stresses are not introduced (machining, shot-peening, shot-blasting)
- **Compressive stress introduced by the tyre fitting**

Fatigue assessment – Haigh diagram comparison



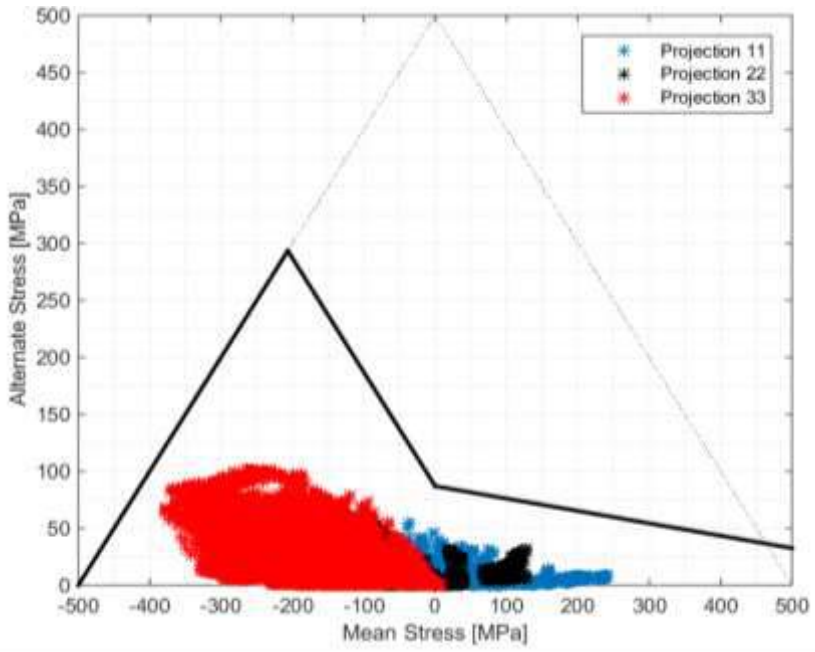


- **<u>Notches can not grow if compressive mean stress is not recovered</u>**
- **<u>Increase of fatigue life</u>**

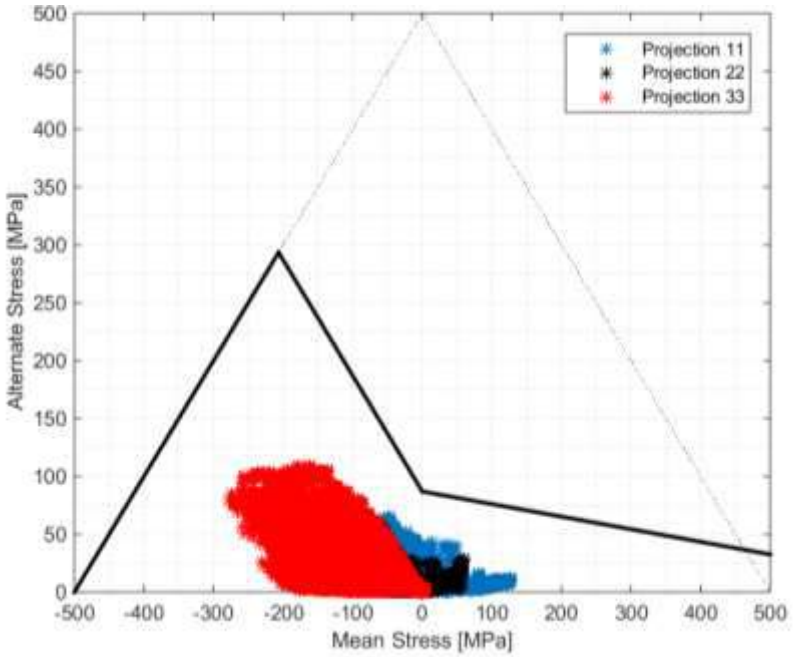
Fatigue assessment – Results

- Spokes are subjected only subjected to radial stress and the **MPSM of EN13979 is applicable**
- **Only compressive mean stresses are present**
- **Maximum alternate stress is 100 MPa**

NEW TYRE



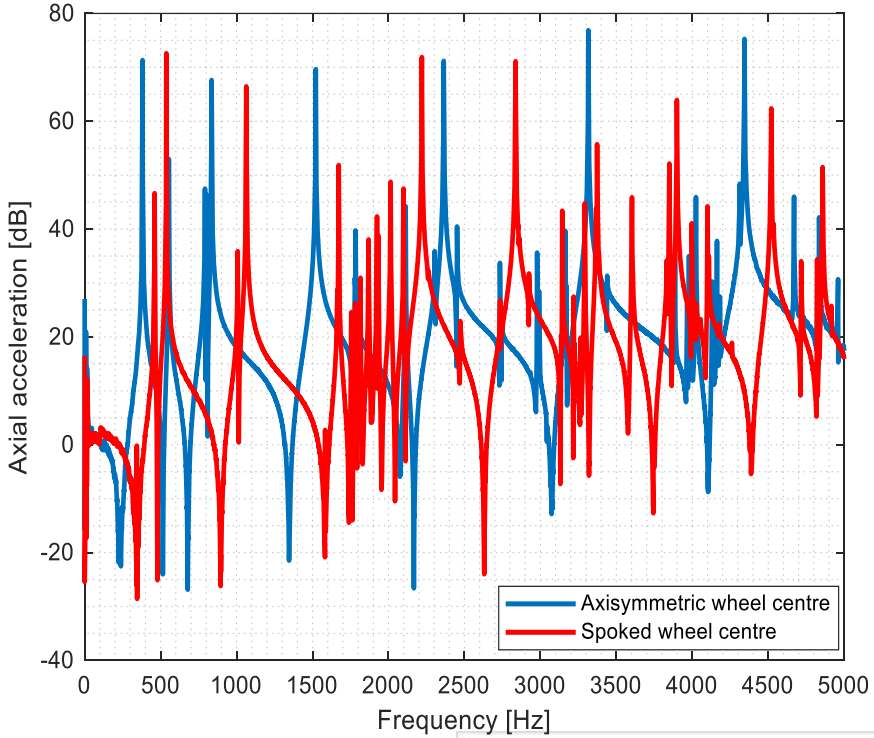
WORN TYRE

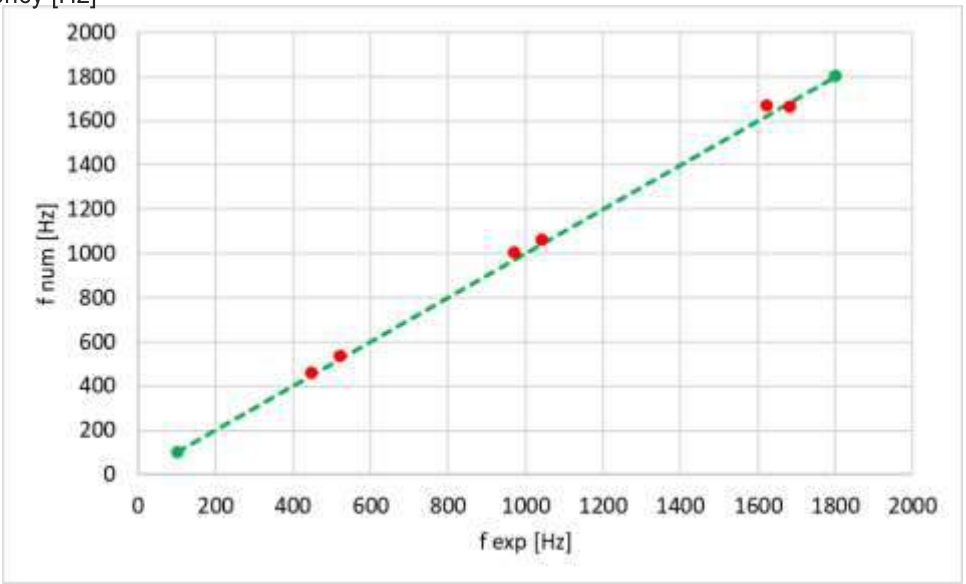


The Liberty Wheel

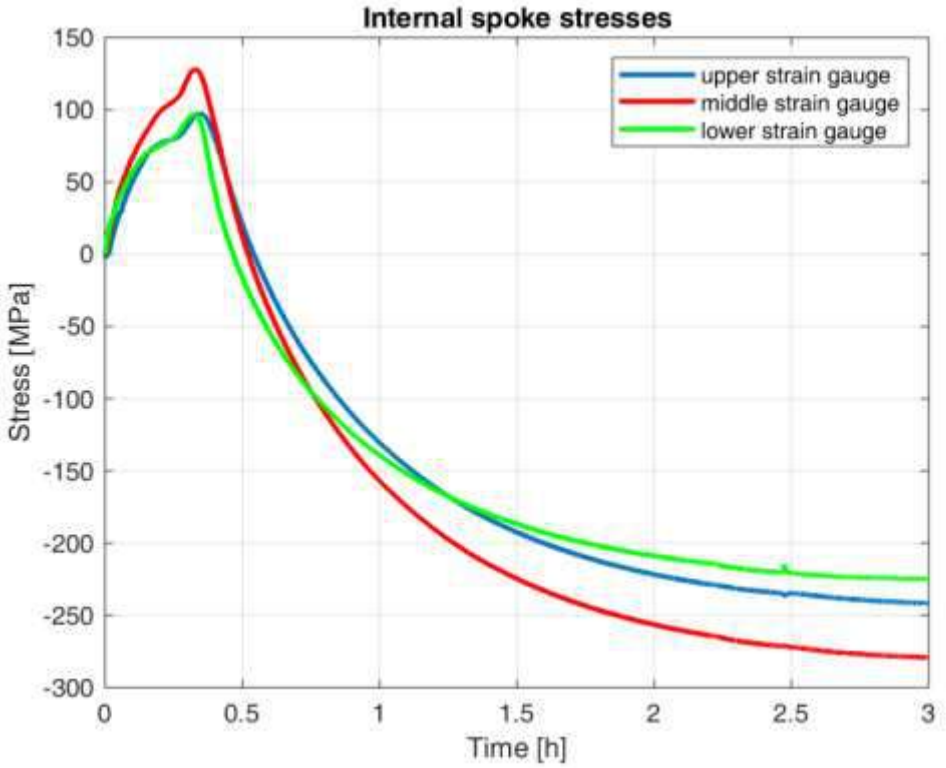
This is NOT the Liberty Wheel

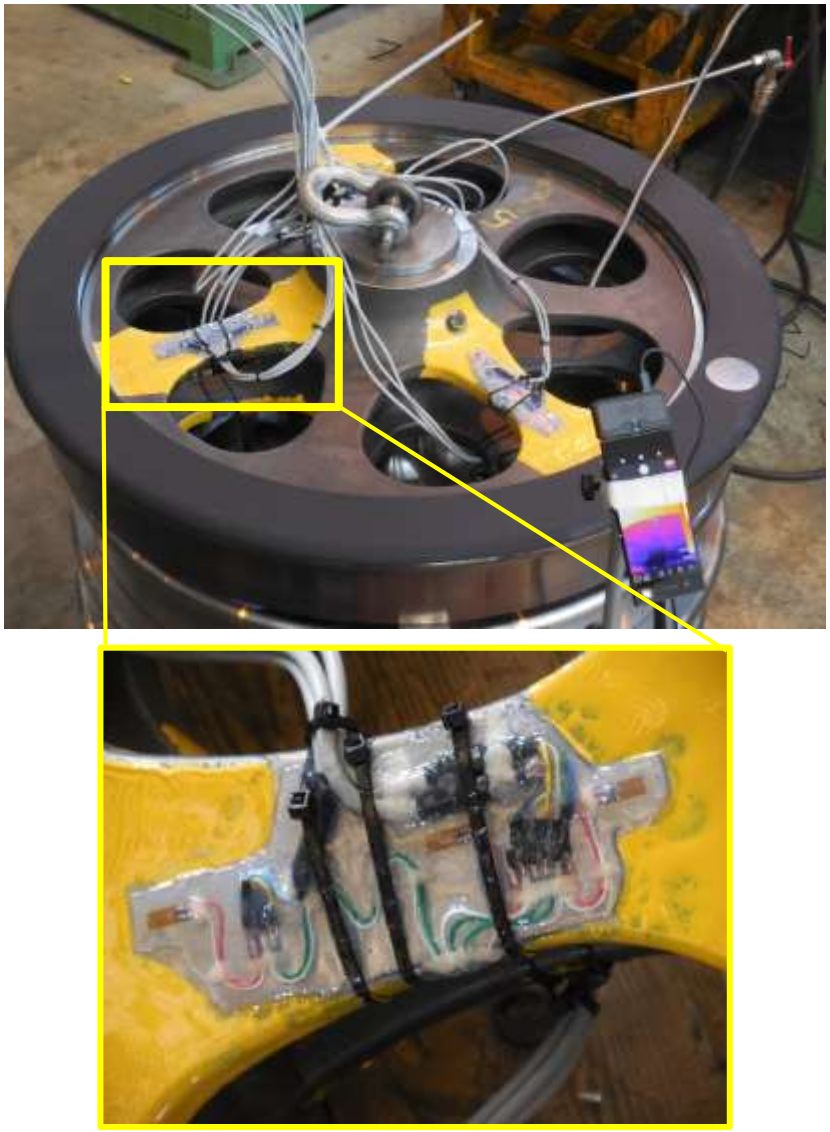
FEM vs EXPERIMENTAL





Measuring the compressive mean stresses





Full scale fatigue test

1 MILLION CYCLES REACHED AT 300 MPa!!

Conclusions

- **Austempered Ductile Iron** allows shape optimization of the wheel centre
- Tyred wheel **mass is noticeably reduced**
- **Compressive mean stress** due to tyre fitting increases fatigue life even on rough casted surface
- An innovative tyred wheel ***«The Liberty Wheel»*** has been proposed, designed, manufactured and tested