LEON-T project: airless truck tires – first prototype

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vti
FINDING A BETTER WAY

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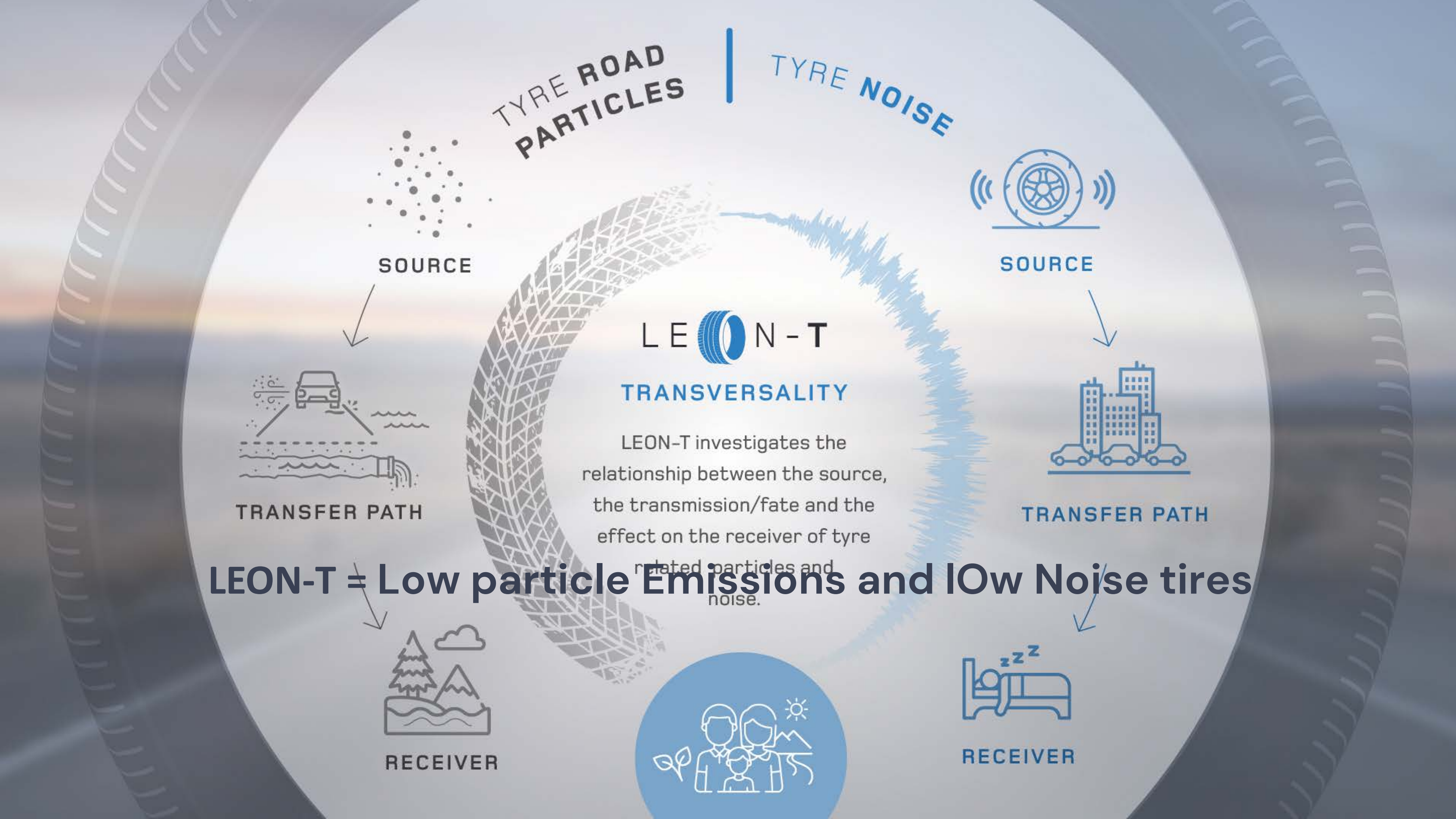
LEON-T

tire TECHNOLOGY EXPO 2024
DEUTSCHE MESSE, HANNOVER, GERMANY
March 19, 20 & 21, 2024 - Exhibition and Conference
March 18, 19, 20 & 21, 2024 - Short Courses

LEON-T = Low particle Emissions and lOw Noise tires

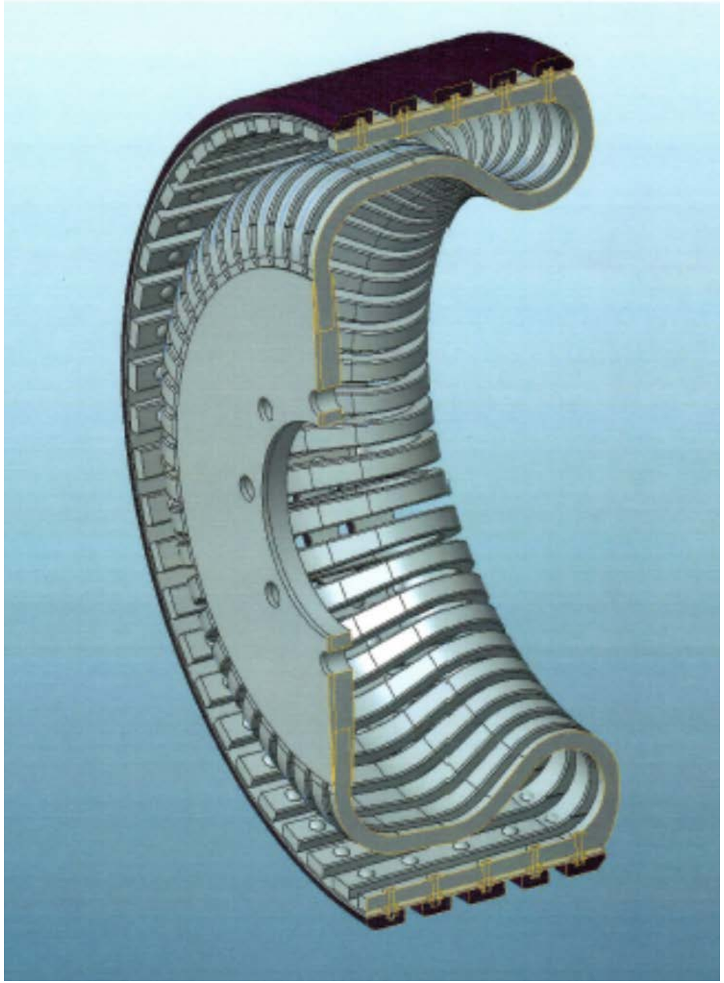


LEON-T, Work Package 5:
Development of airless tires for heavy goods vehicles

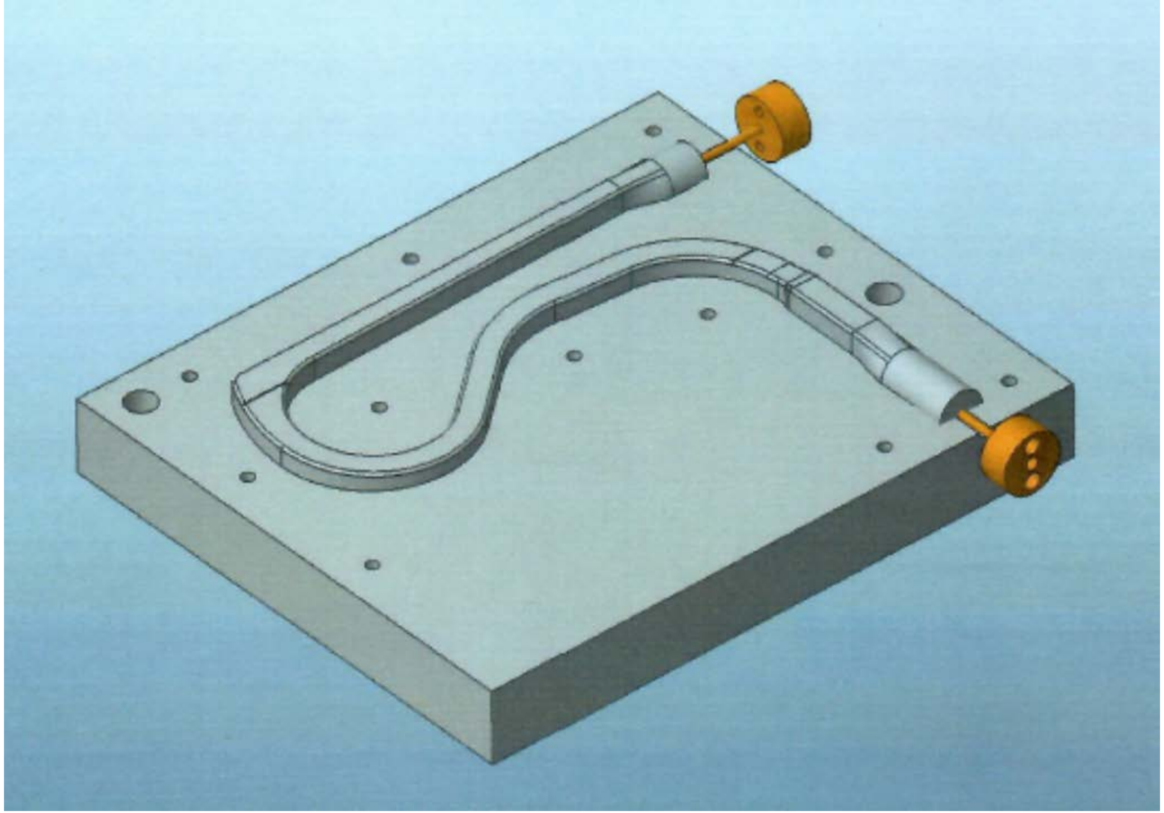
Partners:
VTI (Sweden – WP Leader)
Euroturbine (Sweden)
Idiada (Spain)
Audi (Germany)
LingLong tires (China)

We planned to scale-up the car ”composite wheel” from 2008 to HGV size:
285/70R19.5
LI = 145/143

Calculations for spokes (springs) in composite material

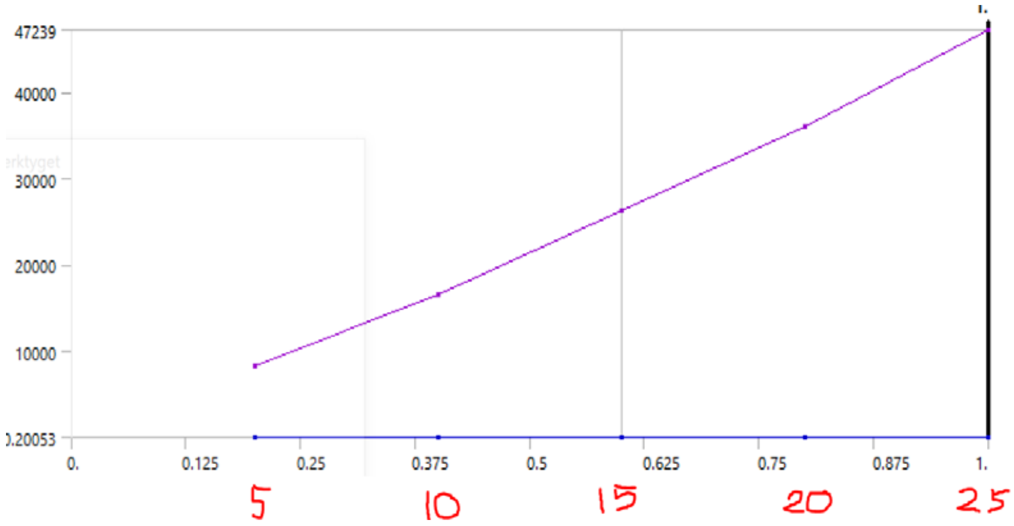


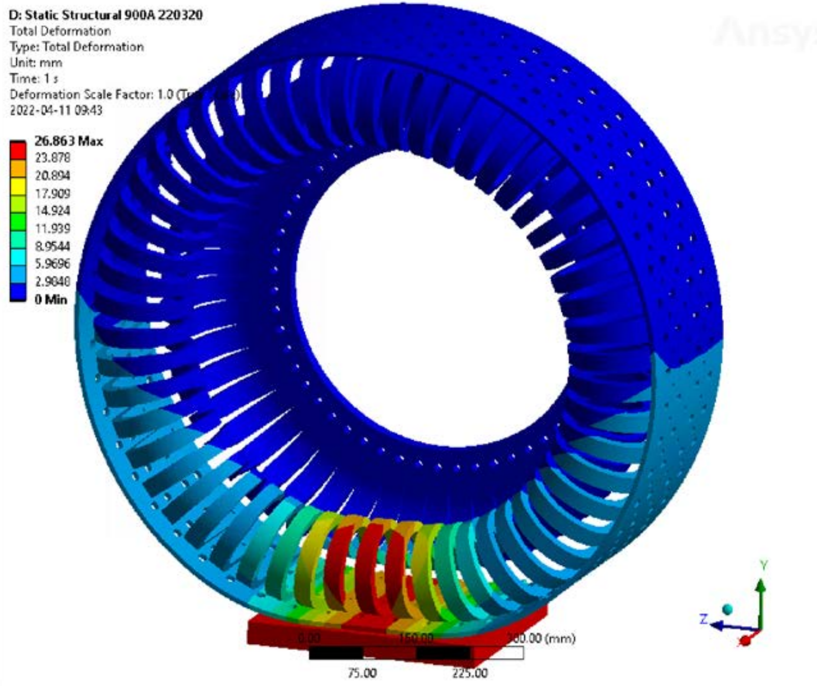
Spokes in (unidirectional) carbon fiber-reinforced plastic laminate
Appeared to be too weak to carry a mass of 2800 kg (LI 145/143)



Calculations/modelling for spokes made of high-strength steel (fossil-free) showed acceptable performance

The steel spring and assembled wheel has been analysed for static loads in ANSYS. Target was a reaction force of 40 kN at 25 mm displacement and as low stresses in the springs as possible.





Made by Lightness by Design AB (Dr Fagerberg)

Calculations/modelling further by Idiada gave promising results

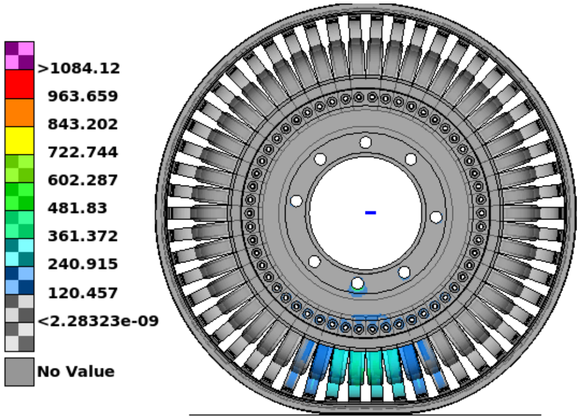
FE model setup

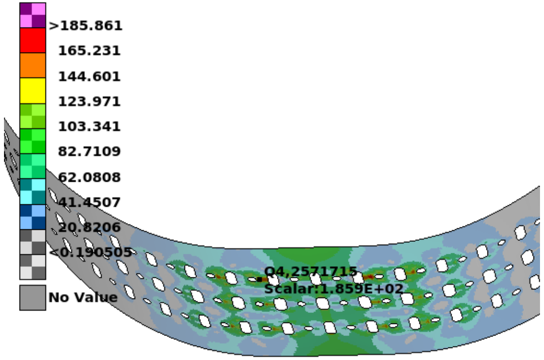
Material property definitions

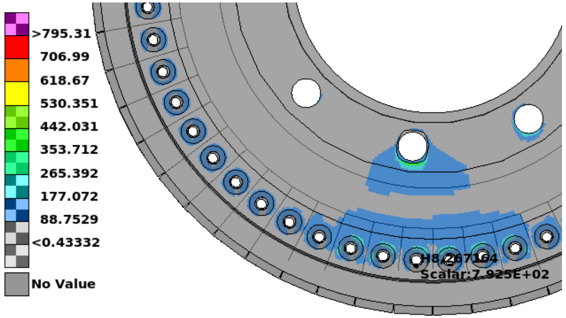
tire loading and stiffness calculations

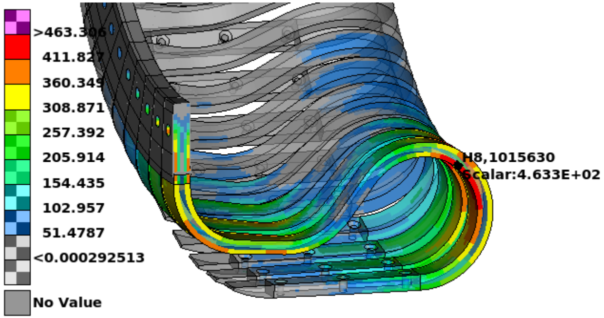
➡ Stresses in the models

Rubber behaviour





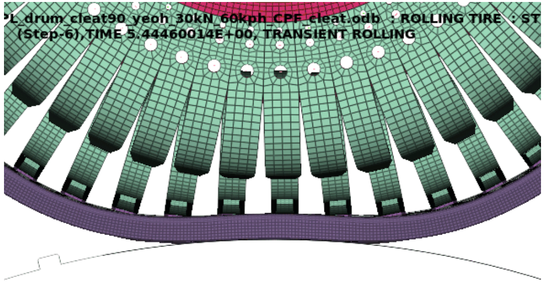


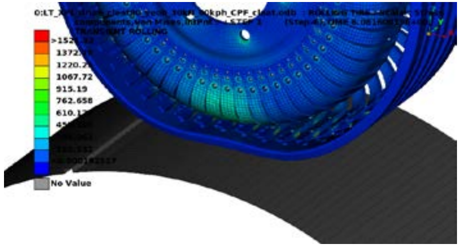


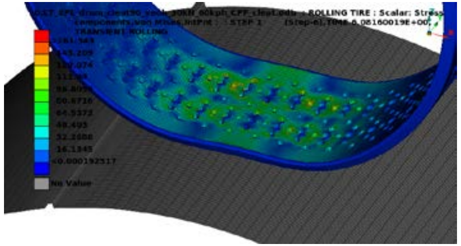
Dynamic behaviour modelling by Idiada

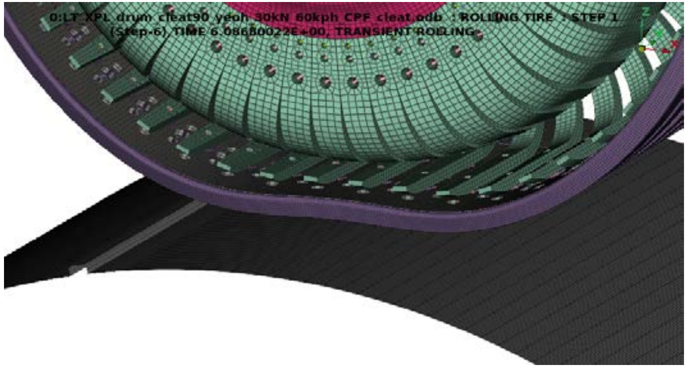
- FE model setup
- Material property definitions
- Tire loading and stiffness estimation
- Composite damping investigation
- Modal analysis model
- Modal analysis results
- ➡ Tire roll over cleat

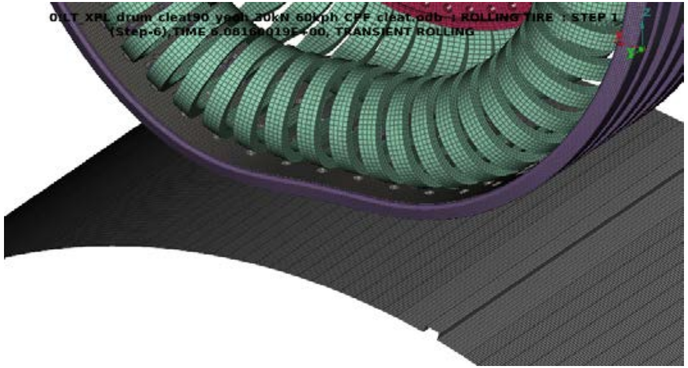
Tire rolling speed – 60 km/h











Manufacturing of spokes is a challenge

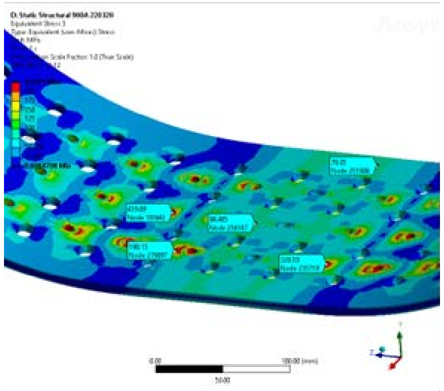
Spokes must meet strict tolerances in order for tire to be round and not to be unbalanced

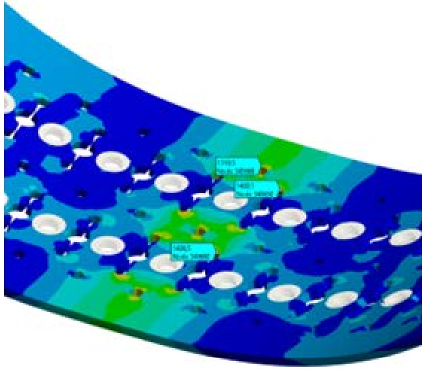
Belt in composite material (CFRP)

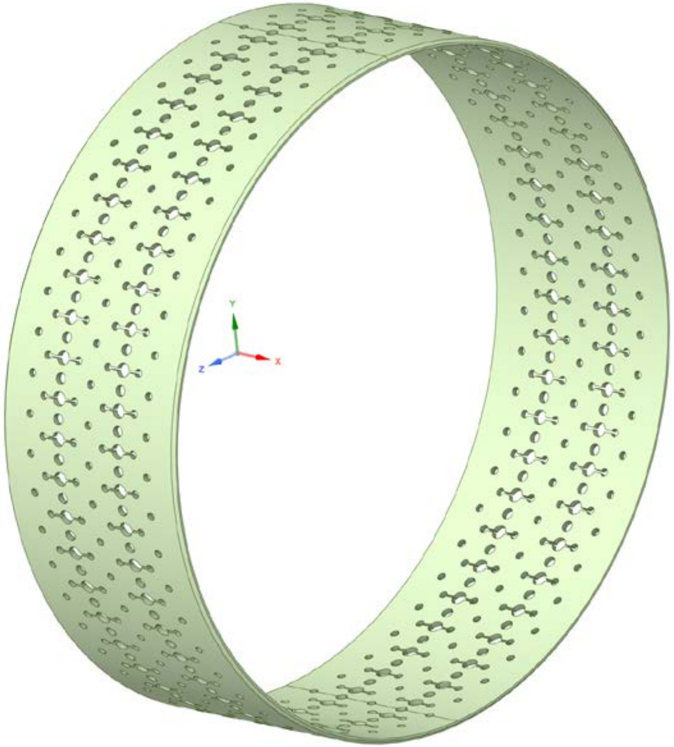
Belt in (quasi-isotropic) carbon fiber-reinforced plastic (CFRP) laminate

The belt was modified with stress-reducing holes between the spokes. Also, air- and water-ventilating holes were drilled to improve noise and wet grip properties.

The improved belt design was included in the stress analysis.





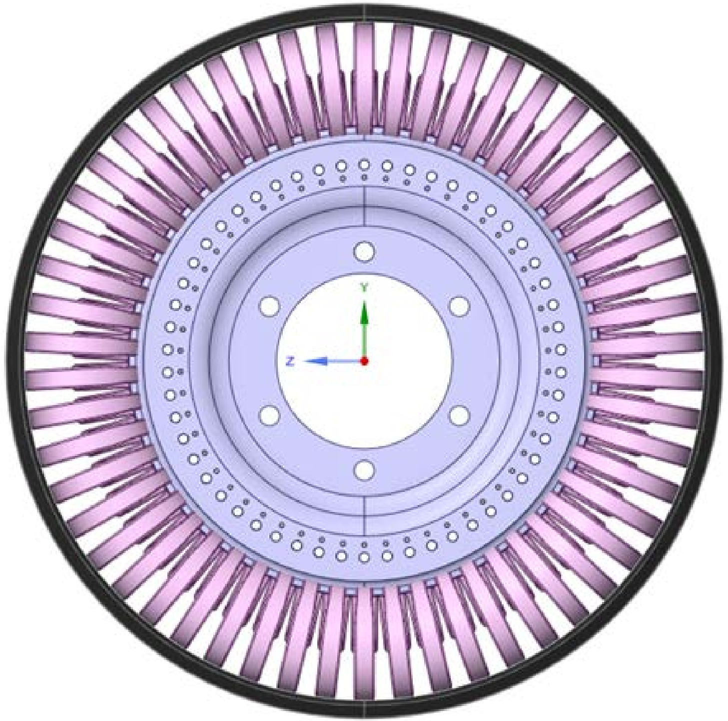


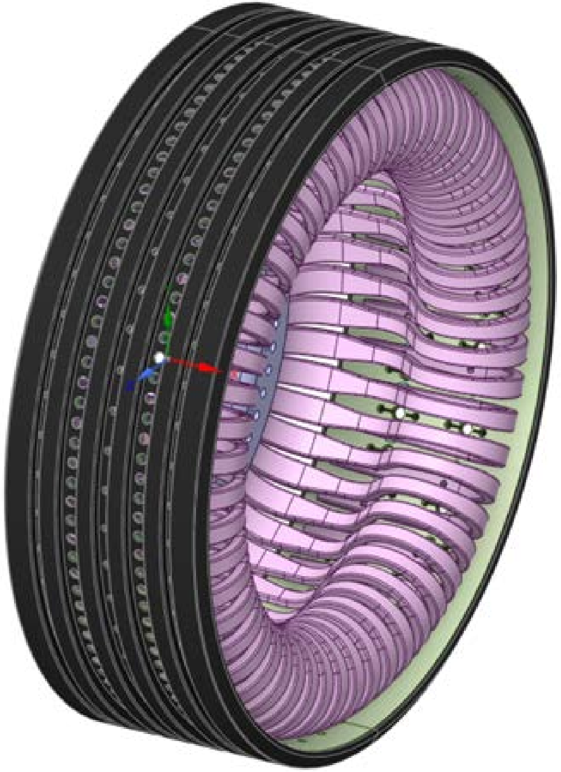
Manufacturing of belt and rubber tread

The composite belt is prepared in an autoclave using a quasi-isotropic lay-up of glass-fiber prepregs. Thickness is approx. 7 mm. The belt is machined and dressed with a rubber tread from Linglong Tires (China). Longitudinal grooves are made and then the rubber and belt system is vulcanized in an autoclave.

Vulcanization is made at conditions similar to those at re-treading

To first prototype, available in September 2023





Weight is an issue

The weight is 150 kg, which is 50 kg more than desired.

But weight can be reduced by replacing bolts and nuts with other means of fastening, and using a lighter rim

With more advanced resources, composite material could replace steel and a lot of weight can be saved

Outside

Inside

First assessment of the prototypes’ performance: Part 1

We needed a suitable host truck on which the prototype could be mounted as the outer tire on a drive axle with double-mounted tires.

We were allowed to use a Volvo FL Electric truck having ”our” tire dimension (285/70R19.5), and to run it on a large asphalt area and on a 2 km long local asphalt road.

Test were conducted in November 2023.

First assessment of the prototypes’ performance: Part 2

Cruise-by at 75 km/h with a tire load of appr. 2000 kg

First assessment of the prototypes’ performance: Part 3

Results and observations of the first test:

Tire had appr. 30 mm larger overall diameter than the pneumatic tire it is intended to replace

Tire/road contact length was approx. 170 mm

The truck was unloaded, in which case it had a total weight of approx 11 500 kg

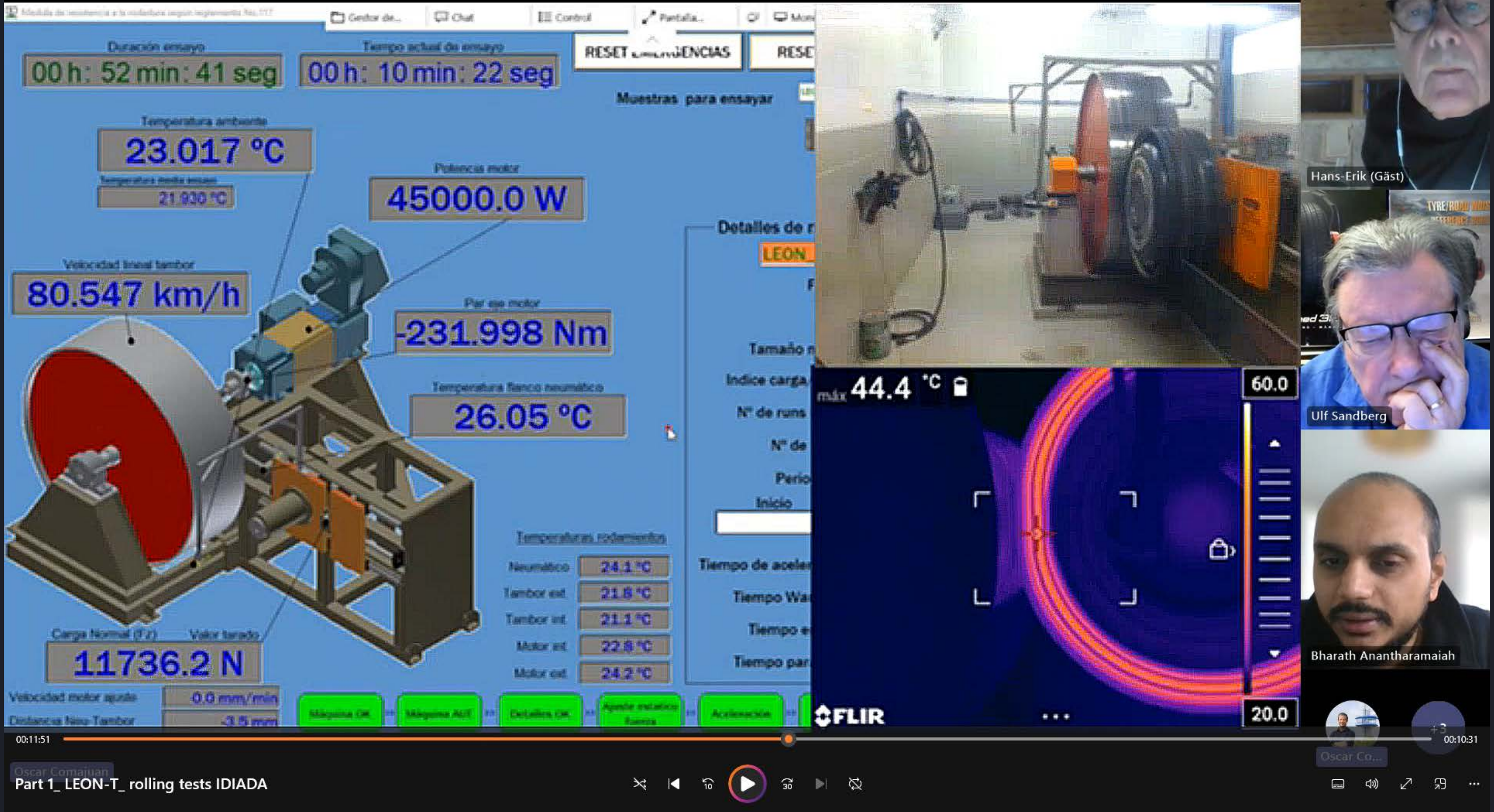
The airless tire load was 1946 kg (the pneumatic one 1195 kg)

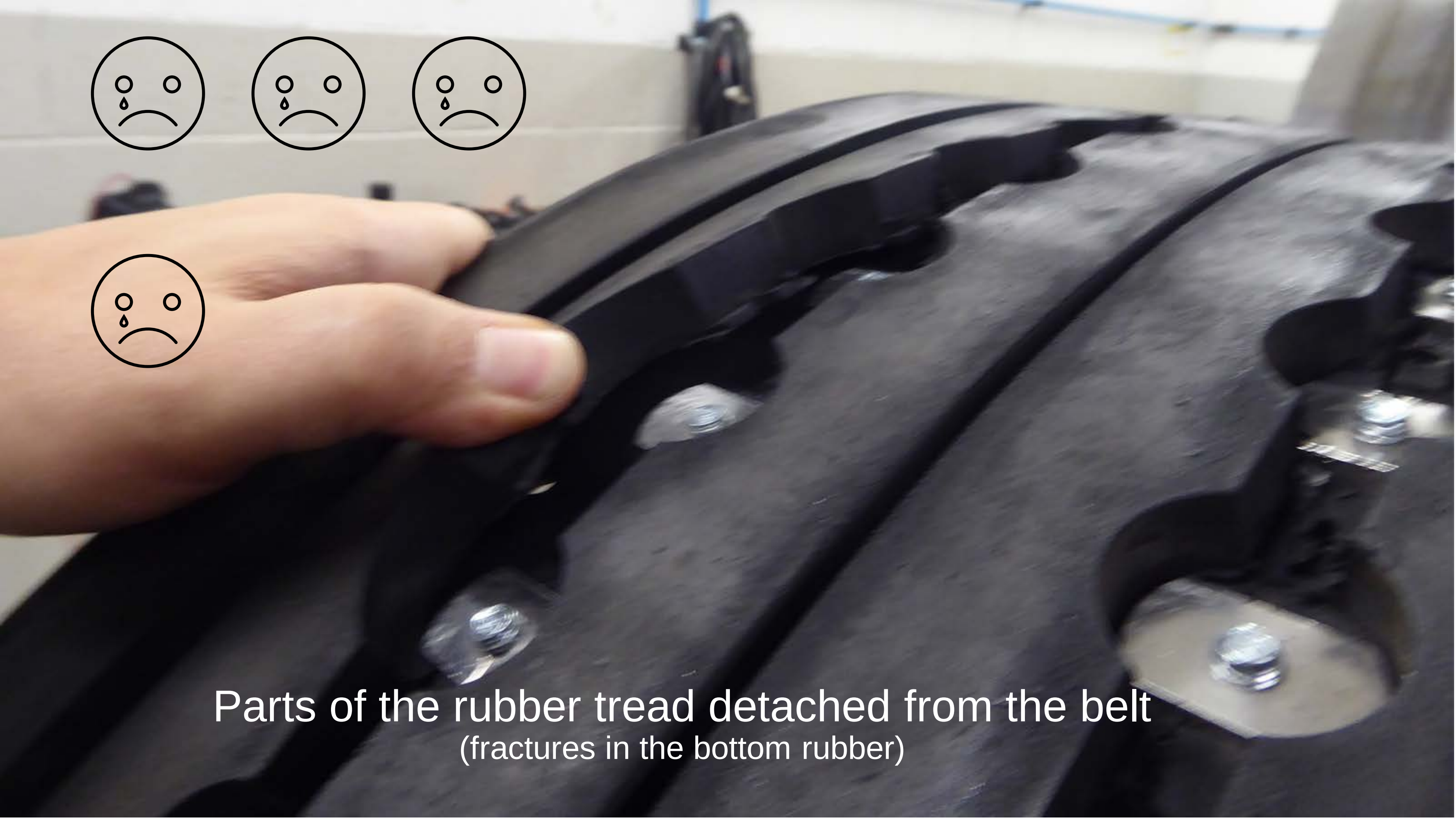
The tire was driven a total of 10 km at speeds 0 – 75 km/h, including light accelerations, braking and turning

No disturbing tone could be heard at pass-by

No roundness problem could be seen, no damages or signs of fatigue were seen

Next step: Running on laboratory drum at Idiada





Parts of the rubber tread detached from the belt

(fractures in the bottom rubber)

First prototype: Second version

A second version now ready for new drum test at Idiada. It is improved as follows:

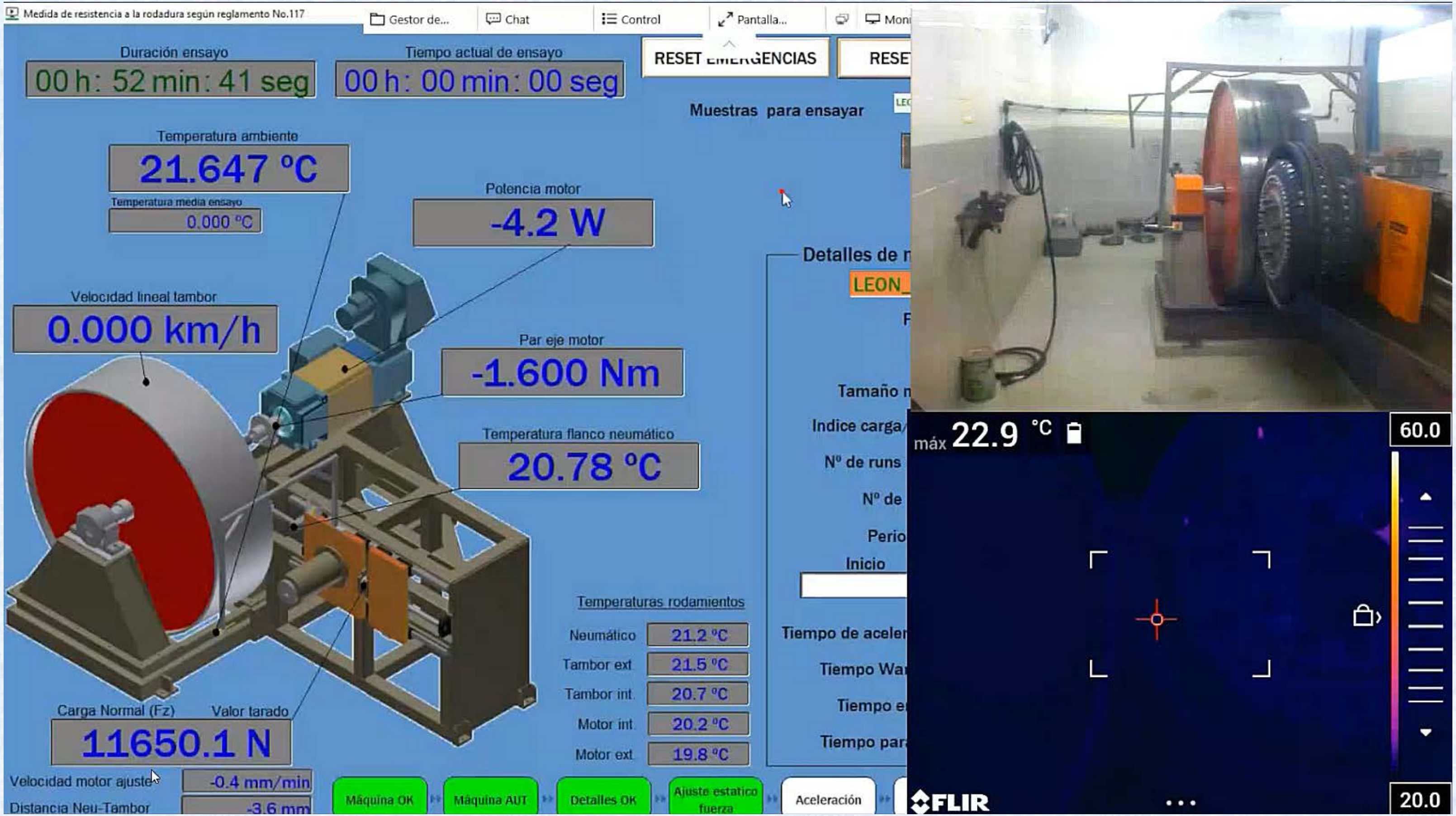
- New belt, this time made of carbon fibers
- New type of rubber
- Sipes cut on the ribs (at about 30º)

Question: Are the vulcanization conditions typical of retreading fine in this case, or should one use the conditions of full-tire vulcanization?

The strength of the bond between belt and rubber has thus increased by a factor 7.5 (from 1.4 to 10.6 N/mm).

New test to be made at Idiada, in two weeks

If endurance is ok, then rolling resistance will be tested, to be followed by noise tests



Potential advantages

- Structure may live as long as the vehicle: only treads replaced (retreading)
- No punctures
- Production by additive manufacturing (3D printing) easier than for pneumatic tires
- Reduction in rolling resistance
- Water in the contact patch is easily escaping through holes in tread/belt
- Exterior noise reduced with appropriate construction
- Noise from the air cavity resonance is no issue any more
- There is no air inflation that can vary and cause higher rolling resistance
- More eco-friendly materials and less raw material needed (less rubber needed, steel may be fossil-free)
- Flatter (rectangular) tire/road contact patch, may reduce rubber wear
- May have more space for brakes, or for integrated electric motors
- Particular interest: Conti’s concept ”The Zipper” on easy changing of tread

Potential disadvantages and risks

- Can we avoid increasing weight, or maybe even reduce it, compared to conv. tires?
- Can we get sufficient endurance and avoid fatigue problems?
- How to get a durable connection between spoke and belt (no heavy bolts and nuts)?
- Debris in the structure?
- Exterior noise from the spoke impact (??)
- In-cabin noise from the spoke impact, when no sidewalls are there to reduce it
- One cannot play with air inflation to adapt to varying loads
- Conicity; if a problem, one can turn every second spoke 180 degrees
- New factories required (except for treads)

Major challenge

Project ends 30 November 2024

A project with a duration of only 3½ years and a budget of appr. ¼ of a typical EU Horizon project is too short for this kind of innovative work, where setbacks may (will) occur and remedies must be found and tested

Acknowledgements

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The content of this report reflects only the author´s view CINEA is not reponsible for any use that may be made of the information it contains.

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- Mr Hans-Erik Hansson at Euroturbine, for being the inventor of this airless tire construction and also has led the construction phases
- Dr Linus Fagerberg at Lightness by Design, for making advanced calculations of the strength of especially the spokes, for various materials
- Dr Bharath Anantharamaiah, at Applus+Idiada, for modelling several aspects of the construction
- Dr Juan Jesus Garcia, at Applus+Idiada, for coordinating the LEON-T project and his deep interest in the airless tire

The end