DYNAMIC BEHAVIOUR OF A BATTERY PACK FOR AGRICULTURAL APPLICATIONS

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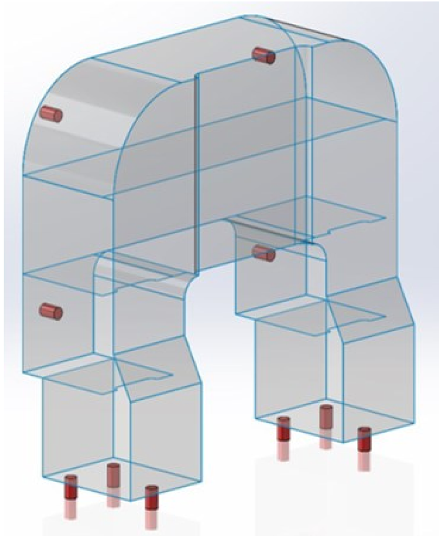
Basic Model
- Modal analysis
- Overload Test
- Achievement best combination materials used – anti-vibrating support

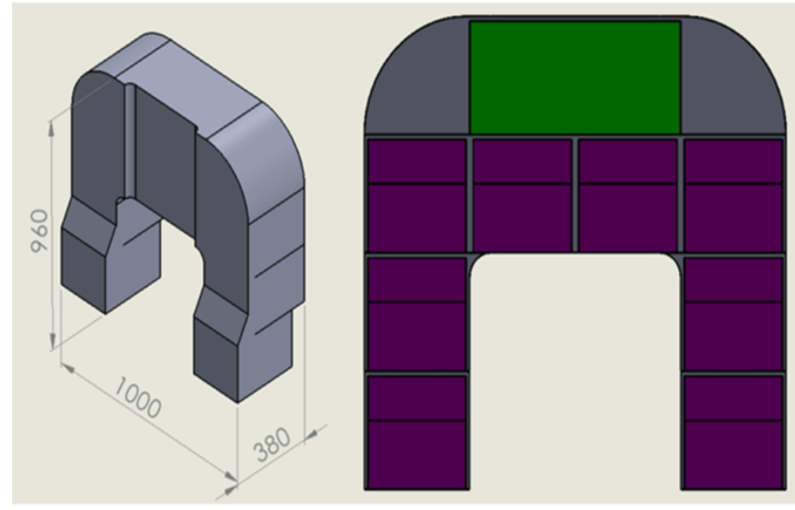
Improved model
- Geometry optimization
- Natural frequencies growth
- Improvement impulsive load response

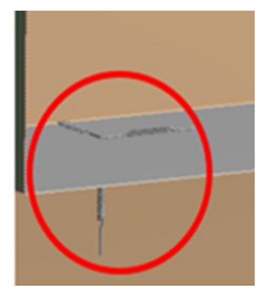
Virtual Field Test
- Multibody model
- Load profile extraction
- FEM analysis
- Dynamic behaviour during operation assessment

CASE OF STUDY

- Capacity: 16 kWh
- Nominal Voltage: 640 VDC
- 200 Li – Ion cells (200s1p)
- 8 battery modules series connected
- 1 Electronic converter (EC)
- Horseshoe BP Case shape
- 10 anti-vibrating supports
- Preserving traditional tractor shape
- Preserving vehicle functionality and visibility

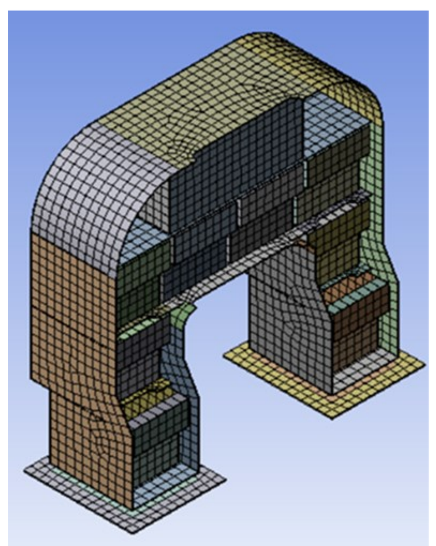






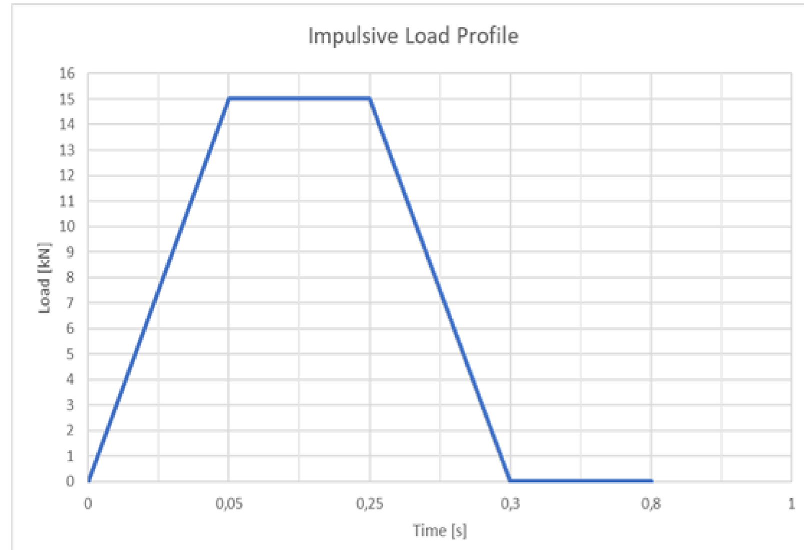
FEM MODEL

- Surface Parametric model (SHELL281 6 d.o.f.)
- "Bonded" contact constraints for welds and module fixing on the BP case.
- Presence of 30 kg distributed masses for each module and the electronic converter.
- Maximum element dimension: 30 mm.
- Anti-vibrating supports simulated through 3 orthogonal COMBIN14 spring elements.
- Presence of 2 plane surfaces, representing the chassis, upon which loads and constraints are applied.



MODAL ANALYSIS & OVERLOAD TEST

- Design goals:
  - Natural frequencies > 20 Hz;
  - Maximum allowable stress equal to 1/3 of the corresponding material yield stress;
  - Maximum vertical deformation equal to 5 mm;
  - Amplitude of oscillation of EC support plate < 2 mm in absolute value.

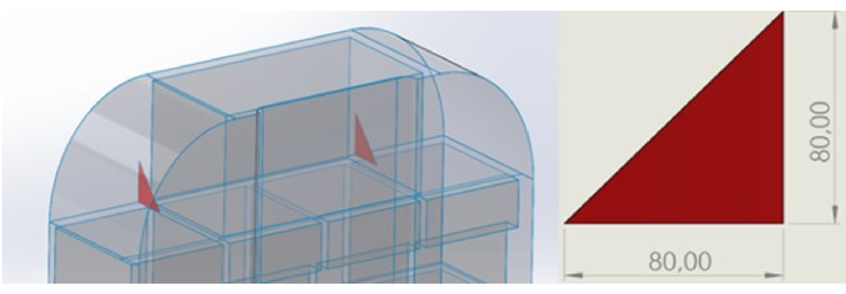


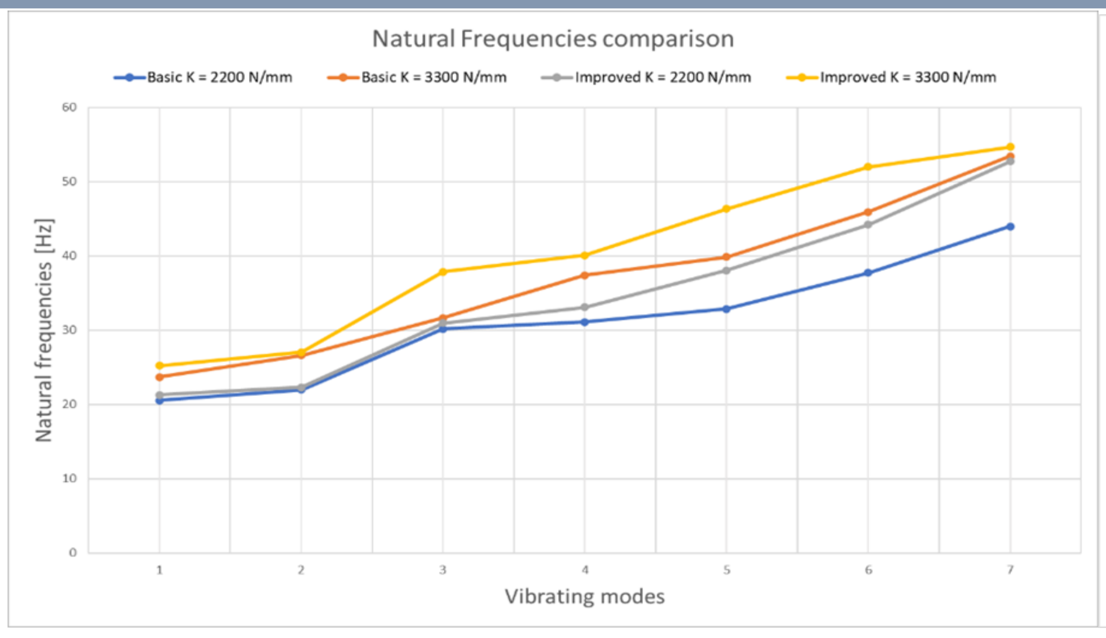
BASIC MODEL

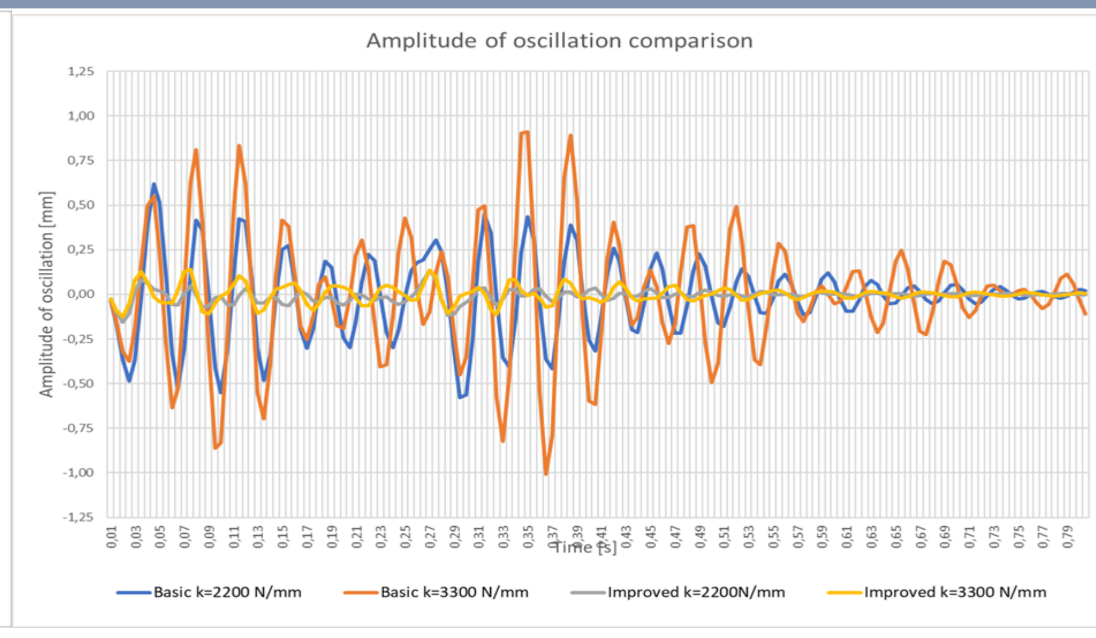
DATA	VALUE
Battery case walls thickness	4 mm
Modules/EC walls thickness	2,5 mm
Chassis plates thickness	5 mm
Damping Factor	3 %

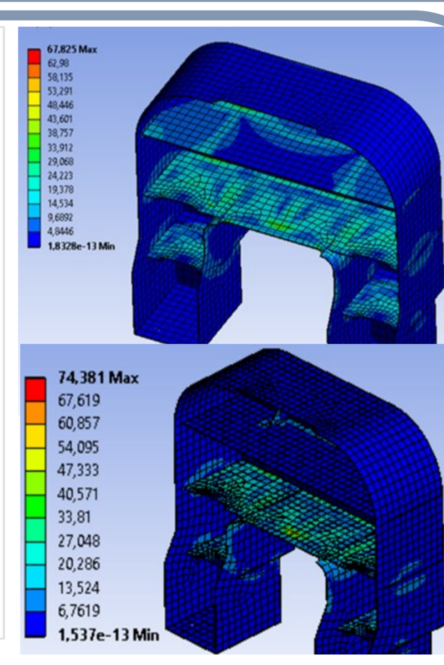
IMPROVED MODEL

Geometric model updates:
- Addition of 2 ribs on the EC support plate;
- Battery case cover thickness reduced from 4 to 3 mm.
- EC and modules walls thickness reduced from 2,5 to 2 mm.









Stiffness [N/mm]	Max. deformation [mm]
1500	5
2200	4
3300	3

Macro-case	Battery case material	Module/EC material
1	S235JR	S235JR
2	S235JR	EN-AW-3003
3	EN-AW-3003	EN-AW-3003

Support stiffness [N/mm]	σ_Case [MPa]	σ_module [MPa]	σ_EC [MPa]	SF Case	SF module/EC	V_case [mm]	V_module [mm]	V_EC [mm]
2200 Basic	67,83	19,42	12,44	3,46	8,50	3,93	3,89	3,75
3300 Basic	99,35	20,7	20,48	2,37	7,97	3,5	2,88	3,45
2200 Improved	65,26	23,5	5,64	3,6	7,02	3,68	3,7	3,55
3300 Improved	74,4	26,05	4,99	3,16	6,33	2,91	2,99	2,87

VIRTUAL FIELD TEST

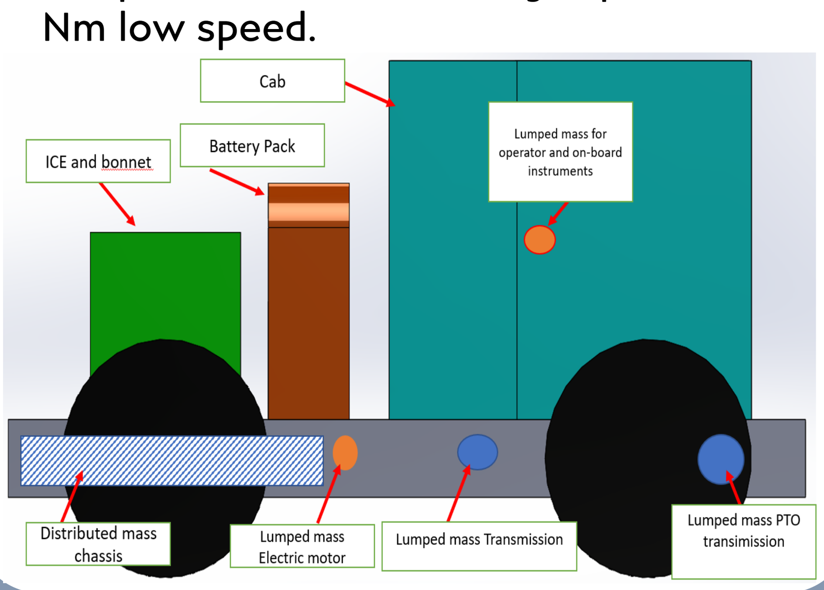
Design Goals:
- Load frequency application must not be close to system natural frequencies.
- Maximum allowable stress equal to 1/2 of the corresponding material yield stress;
- Absence of interference;
- Relative vertical deformation between BP and chassis < 2 mm;
- EC support plate amplitude of oscillation < 1 mm.

Multibody model
- Virtual Prototype
- Bumpy road
- Load profile extraction

FEM Analysis
- Load profile implementation
- Transient analysis
- Analysis results

MULTIBODY MODEL

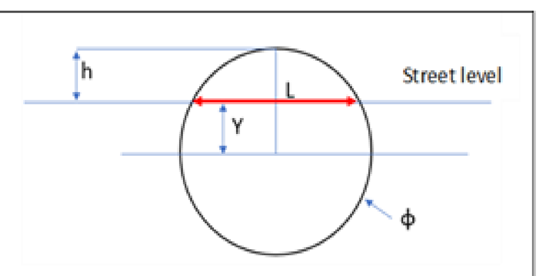
- Chassis and axles simulated with box-profile section beams.
- ICE linked to the chassis with a fixed joint.
- Wheels and cab linked to the chassis with bushing joints.
- Torque regulation based on vehicle speed and characterized by a asymptotic behaviour.
- Torque limits: 1000 Nm high speed, 2500 Nm low speed.



VIRTUAL FIELD TEST

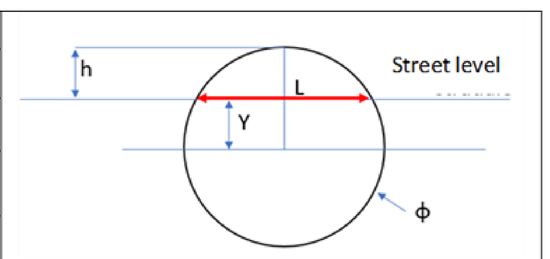
- Low-speed, vehicle speed: 10 km/h.
- 10 speed bumps distant 2 m from each other.
- Arc of circumference speed bump shape.
- Presence of a operating machine on the back PTO (1000 lumped mass)

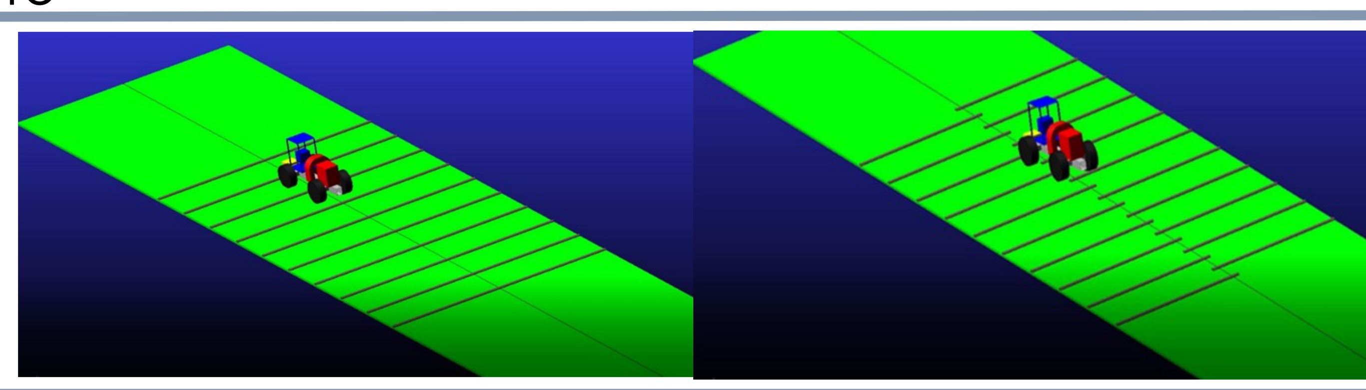
DATA
h = 70 mm
L = 150 mm
Y = 5,18 mm
ϕ = 150,36 mm



- High-speed, vehicle speed: 30 km/h.
- 10 speed bumps distant 2 m from each other.
- Arc of circumference speed bump shape.
- No presence of a operating machine on the back PTO

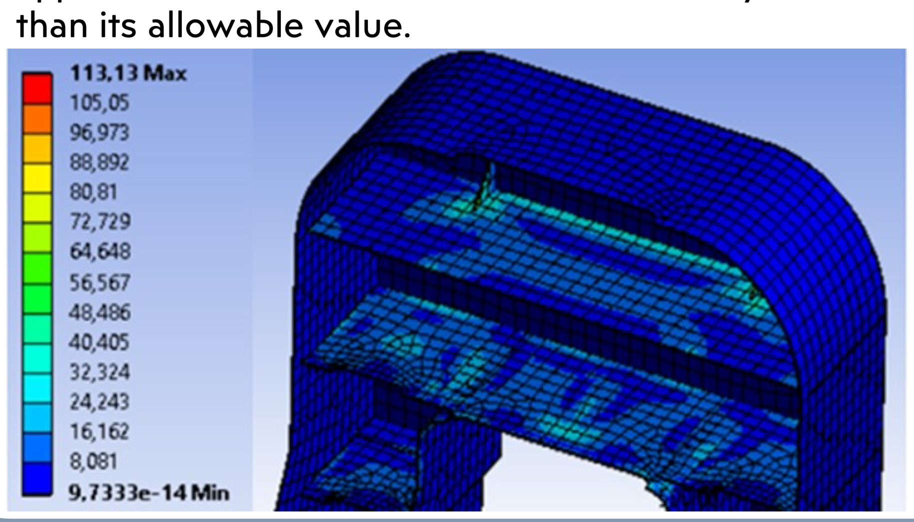
DATA
h = 40 mm
L = 300 mm
Y = 261,25 mm
ϕ = 602,5 mm

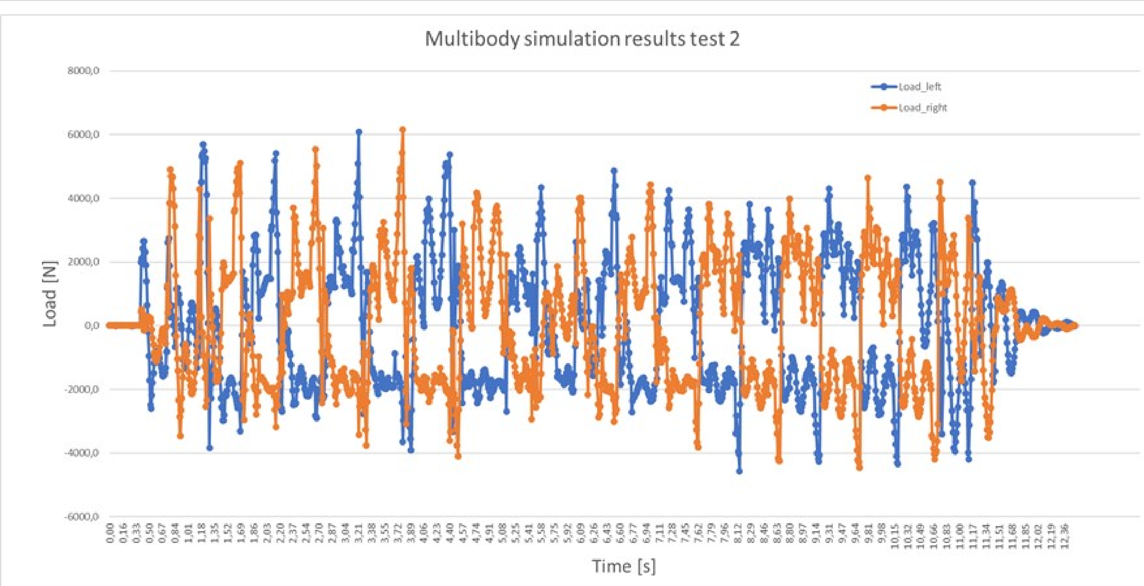




VIRTUAL FIELD TEST RESULTS

- Good dynamic behaviour of the battery pack.
- Increasing load frequency application, maximum stress increases.
- EC support plate is the most stressed zone.
- Vehicle speed represents a harder condition than the speed bump dimension.
- Almost all the load is absorbed by the battery case.
- The ribs causes a drastic reduction of the EC support plate amplitude of oscillation.
- The antivibranting supports are suitable for this application because the deformation is always smaller than its allowable value.





Field Test	1	2	3	4
Load application frequency	1,4 Hz	2,8 Hz	4,2 Hz	8,33 Hz
Minimum SF encountered	3,6	3	2,5	2,1
Relative vertical deformation between BP and chassis	1,2 mm	0,6 mm	1,6 mm	0,9 mm
Amplitude of oscillation EC support plate	0,4 mm	0,5 mm	0, 55 mm	0,8 mm
Interference	No	No	No	No

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