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Maschinenprüfplattform: Rollover stability of agricultural machines

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Outline

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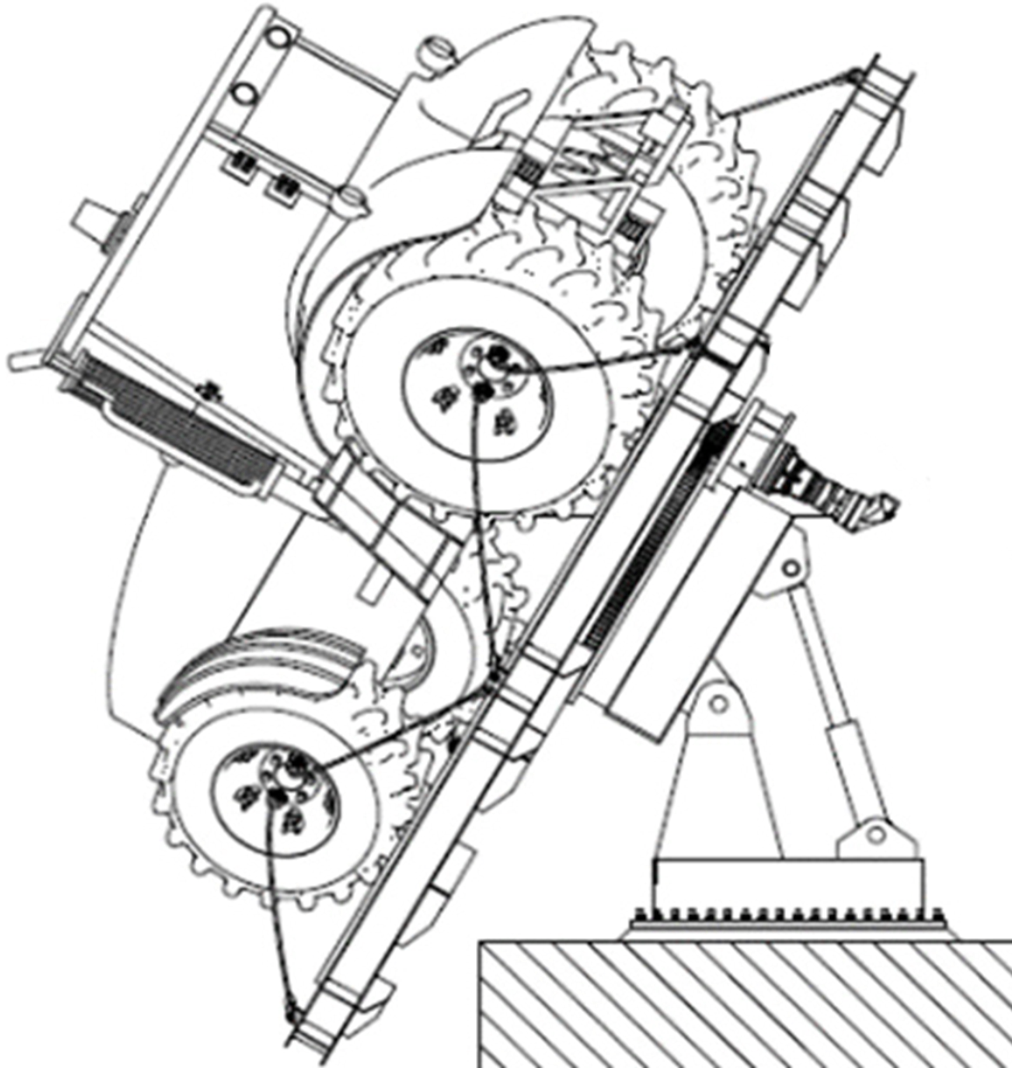
- Rollover stability model
- Stability test-rig
- Stability test-rig test
- Conclusions and Future Works



Introduction

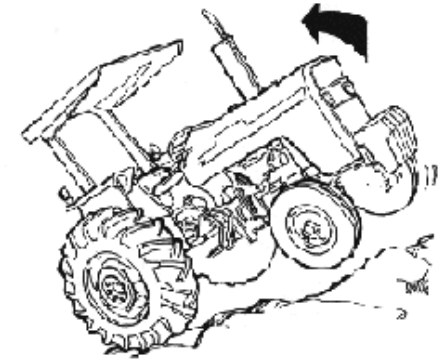
- The Italian National Institute for Insurance Against Accidents at Work (INAIL) recorded:

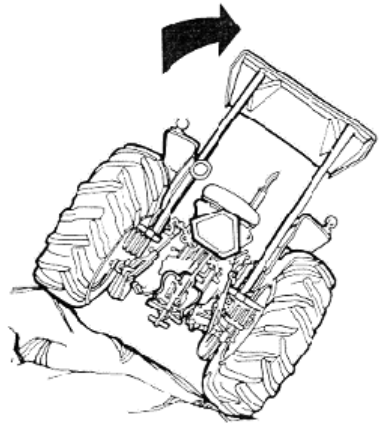
735 fatalities in agriculture over the period 2018-2022

Machinery operations, notably tractor usage (22%)

Tractor rollover fatalities (about 50%)

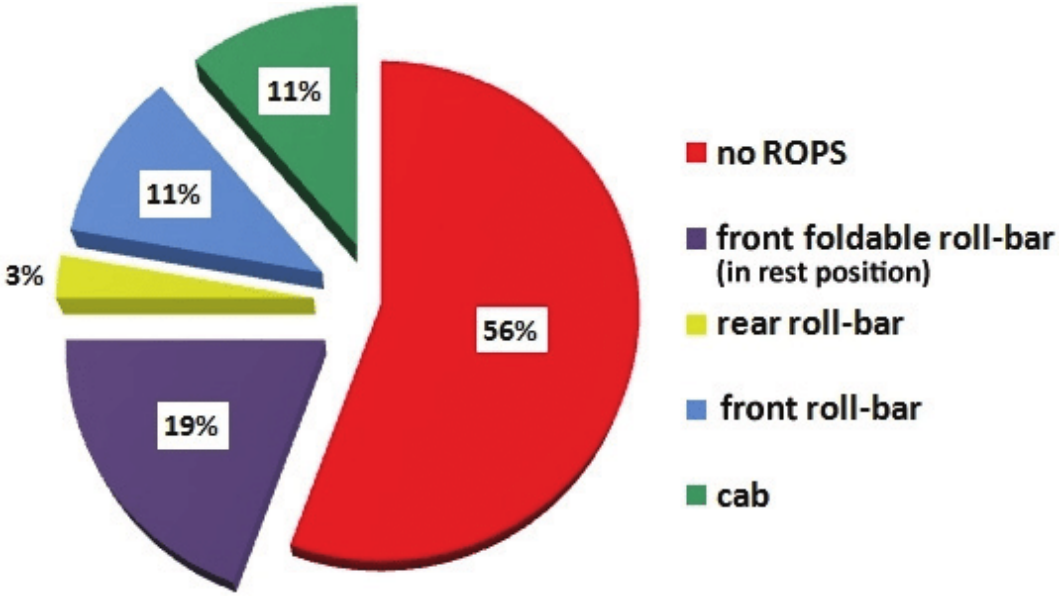
100-140 fatal overturning accidents per year in Italy.





- Many incidents go unrecorded or are inaccurately and incompletely reported.
- Similar trends have been observed in Switzerland and Austria.

Introduction

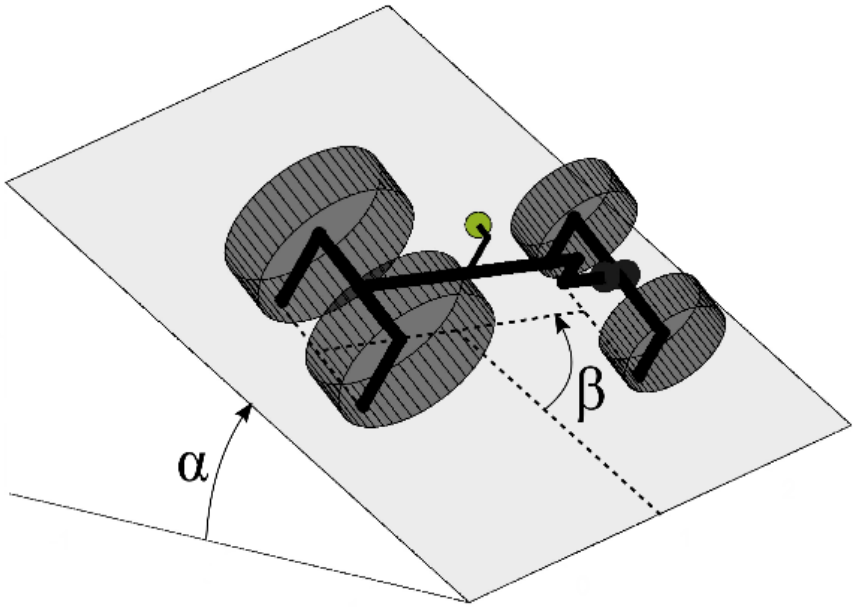


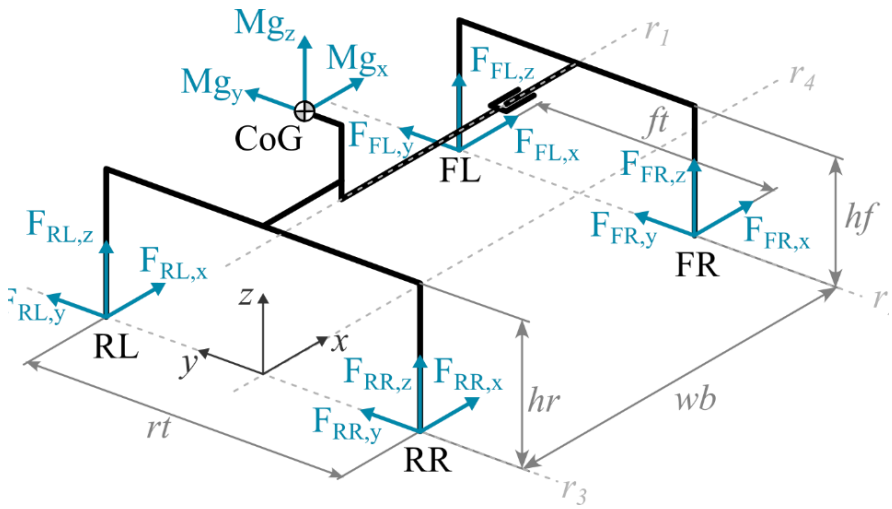
Types of ROPS fitted on agricultural tractors involved in fatal overturn accidents in Italy during the period 2008-2014 (Pessina et al., 2015).

- Old and worn tractors, often **lacking Rollover Protective Structures** (ROPS) and seat belts, contribute significantly to fatal accidents.
- Even when **ROPS** are present, they are frequently either **removed** or left in the **rest position**.
- Understanding the **stability behaviour** of machines operating on slopes is crucial for accident prevention.

Rollover stability model

- Simplified tractor **kinematic and dynamic models** of the tractor (i.e., wheels as rigid bodies).
- Used to compute the tractor configuration and thus the **position of the four wheel-terrain contact points**.
- Computation of the **wheel-ground contact forces** as the **tilting angle changes**.
- The **instability** is detected as soon as at least **one of the contact forces becomes null or negative**.
- **Experimental test** on real machine are needed to tune and evaluate the model.





Stability test-rig

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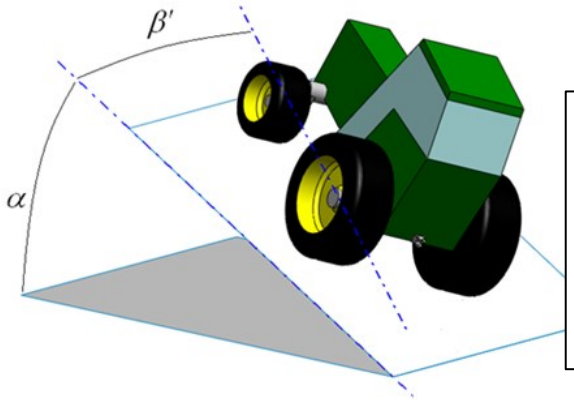
- **Tilting** and **rotating supporting plane** to orientate a tested machines in any direction.
- Support plane divided in **4 plates** (i.e., each one supports one wheel).
  - Each plate can move up and down independently to simulate **bumps or potholes**.
  - Each plate integrates a series of **load cells** to measure the wheel-terrain **contact force**.
- Support plane covered by a **special grid** to prevent the tractor sliding during the test.

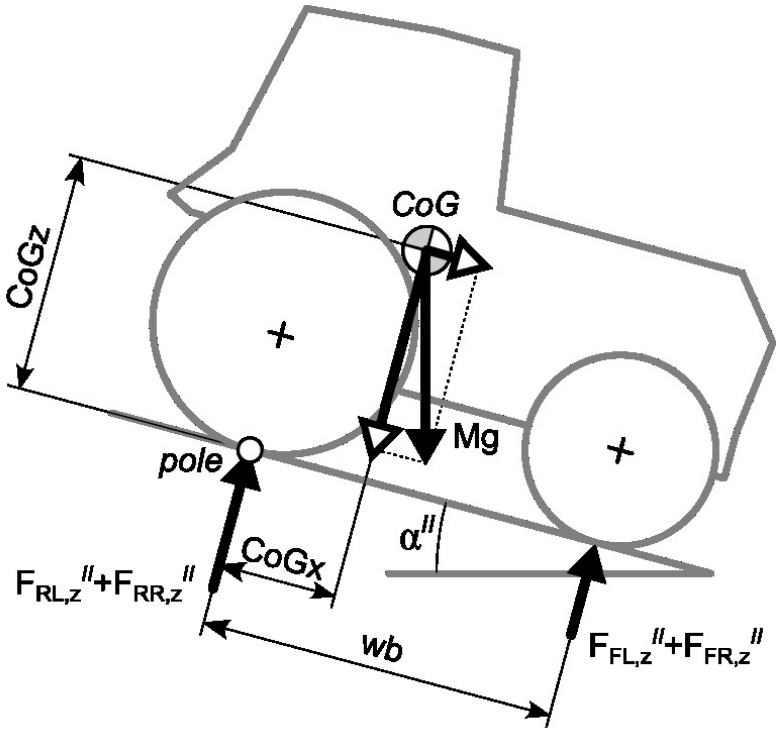


- Tilting (α): up to 55°
- Rotation (β): ±180°
- Plate vertical displacement: 0÷300mm
- Max testing dimension: 6x4m
- Max testing weight: 10t

Stability test-rig test

Indirect measure of the Centre of Gravity (CoG) position.

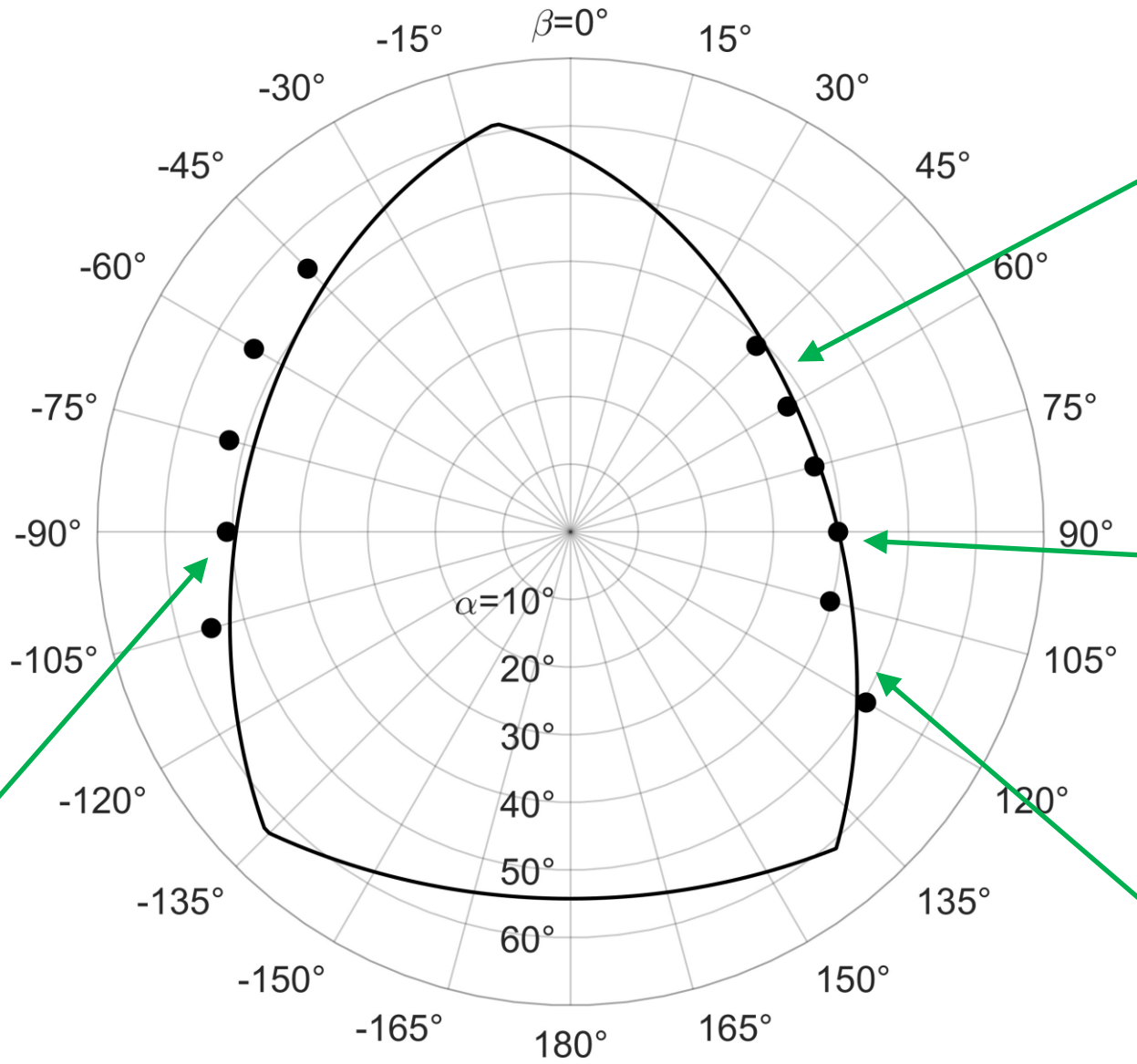
- Based on the measurement of the 4 components of the contact forces.
- Different orientation of the machine to minimize errors (e.g. fuel displacement inside the tank).



Stability test-rig test

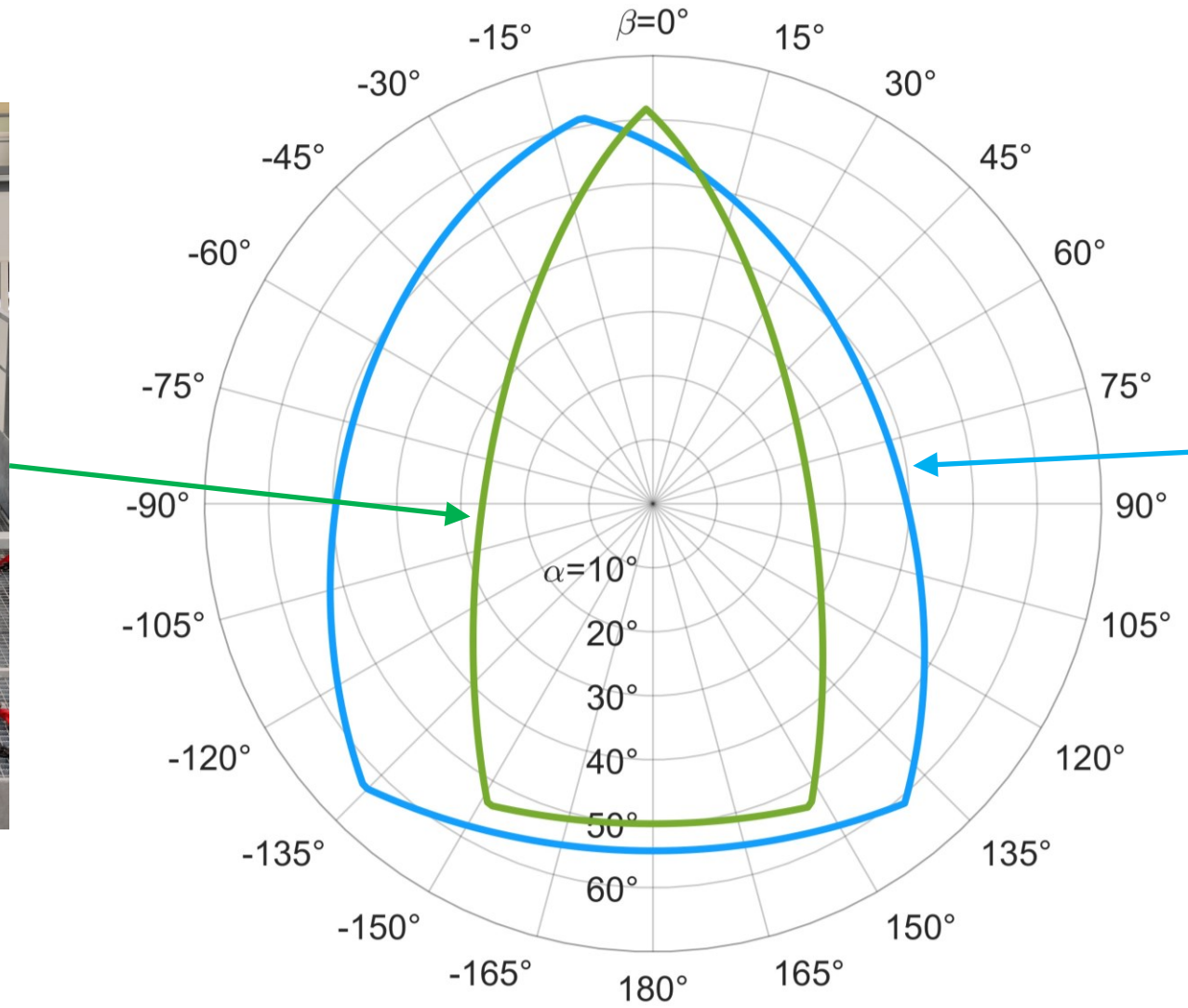
Static roll-over stability evaluation

- Different orientations and tractor configurations.
- The result is a rollover stability map.



Stability test-rig test

Static roll-over stability evaluation

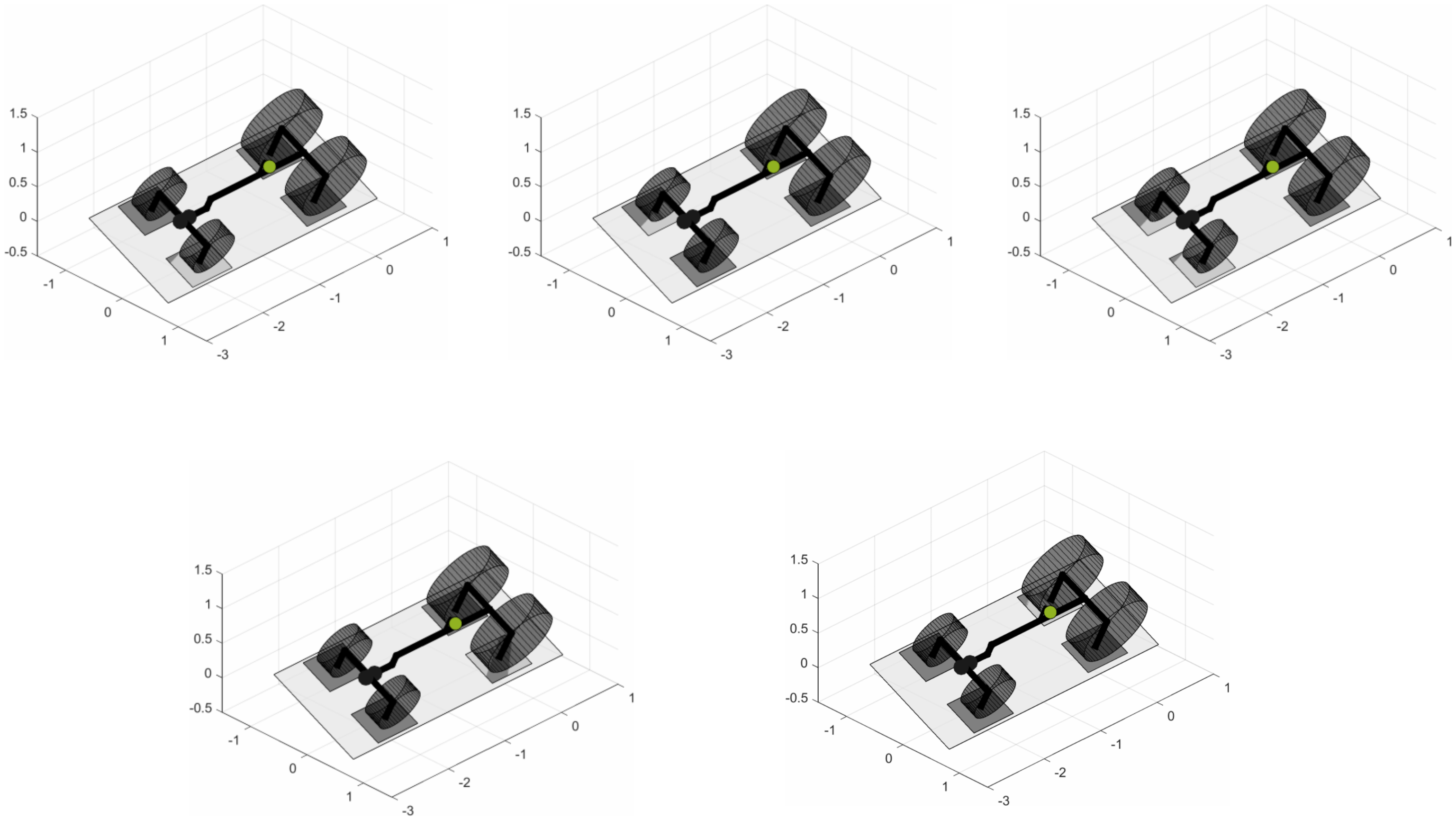


Orchard tractor

Specialized mountain tractor

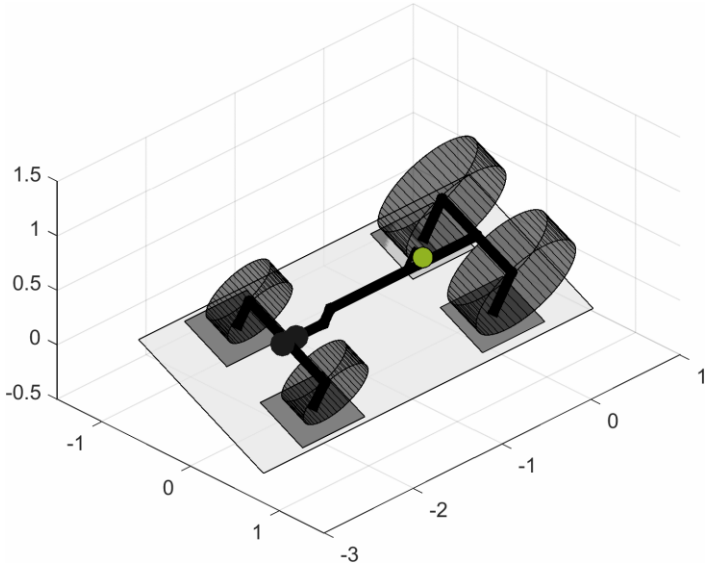
Stability test-rig test

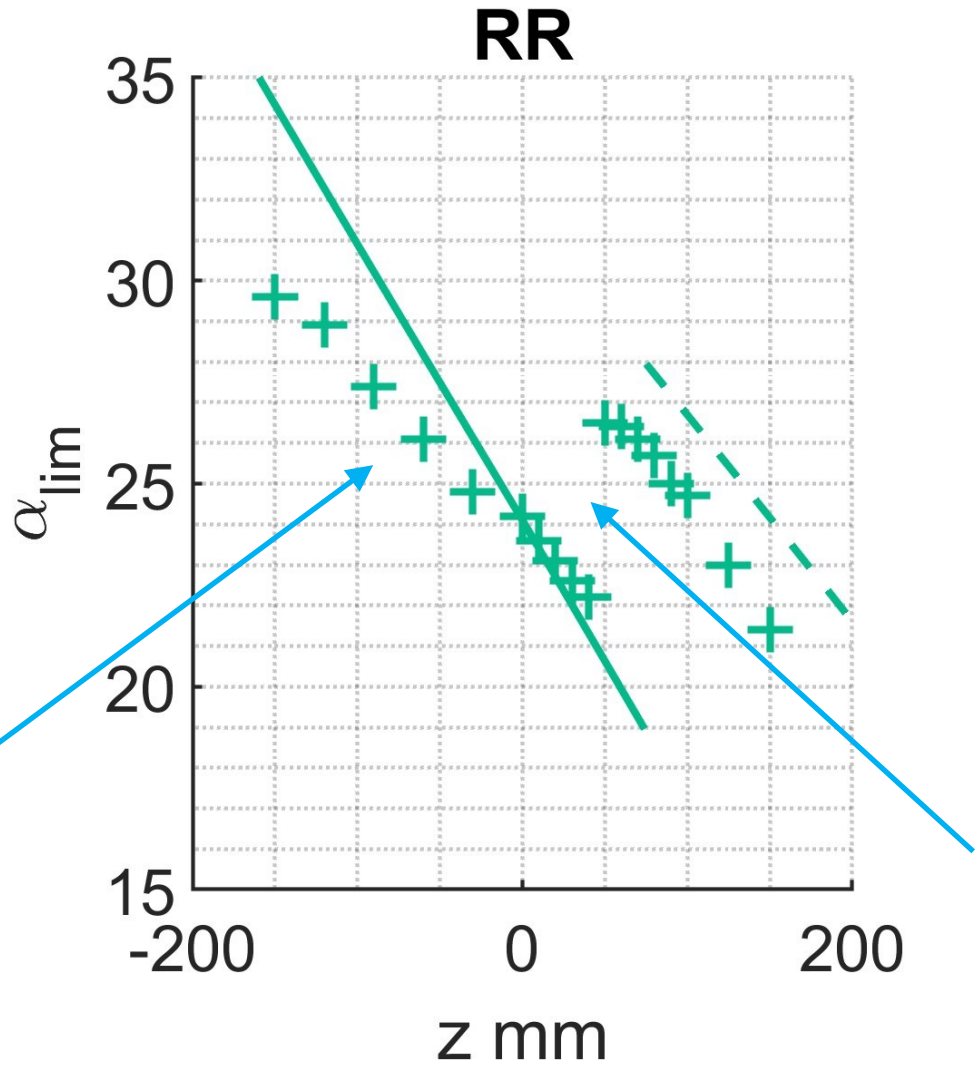
Stability analysis in presence of different ground conformations.



Stability test-rig test

Stability analysis in presence of different ground conformations





Stability decreases as the rear right wheel obstacle height increases.

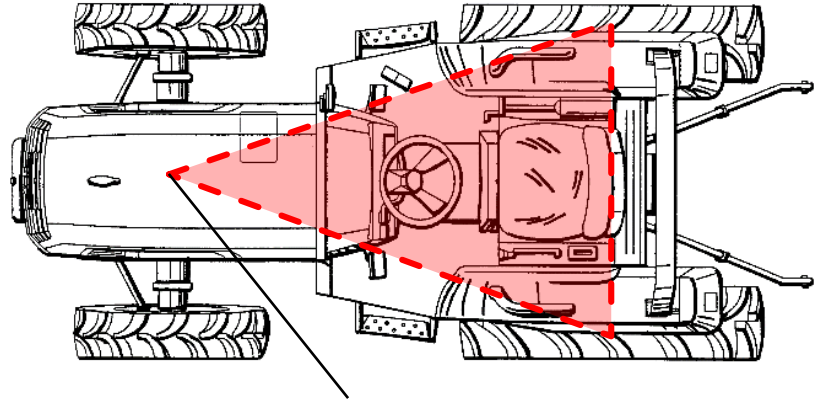
Transition phase: when the front axle joint reaches it limit range and goes in contact with the mechanical end-stop, the stability increases.

Stability test-rig test

Stability analysis in presence of different ground conformations

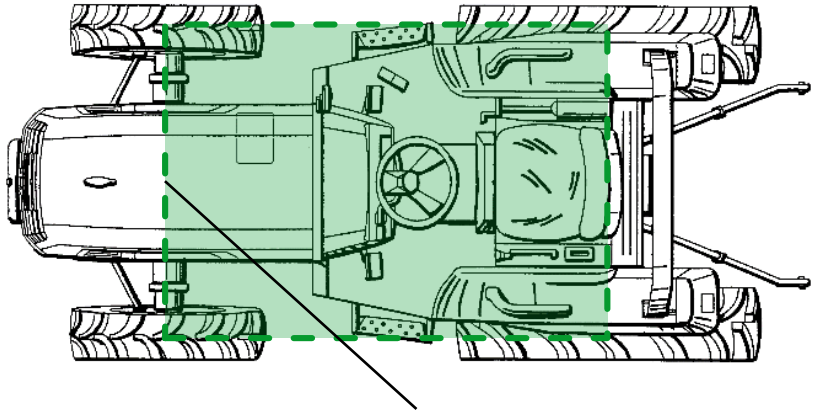
- After a certain level of misalignment, the front axle rotations is blocked by the mechanical stop and the tractor behaves as a single rigid body.

Phase I instability



Pivoting axle joint

Phase II instability



Pivoting axle joint blocked

Stability test-rig test

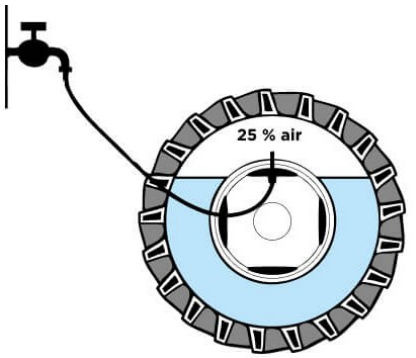
Stability analysis on tractor following particular path

- e.g., helical path to move to the next row in a terraced orchard/vineyard.

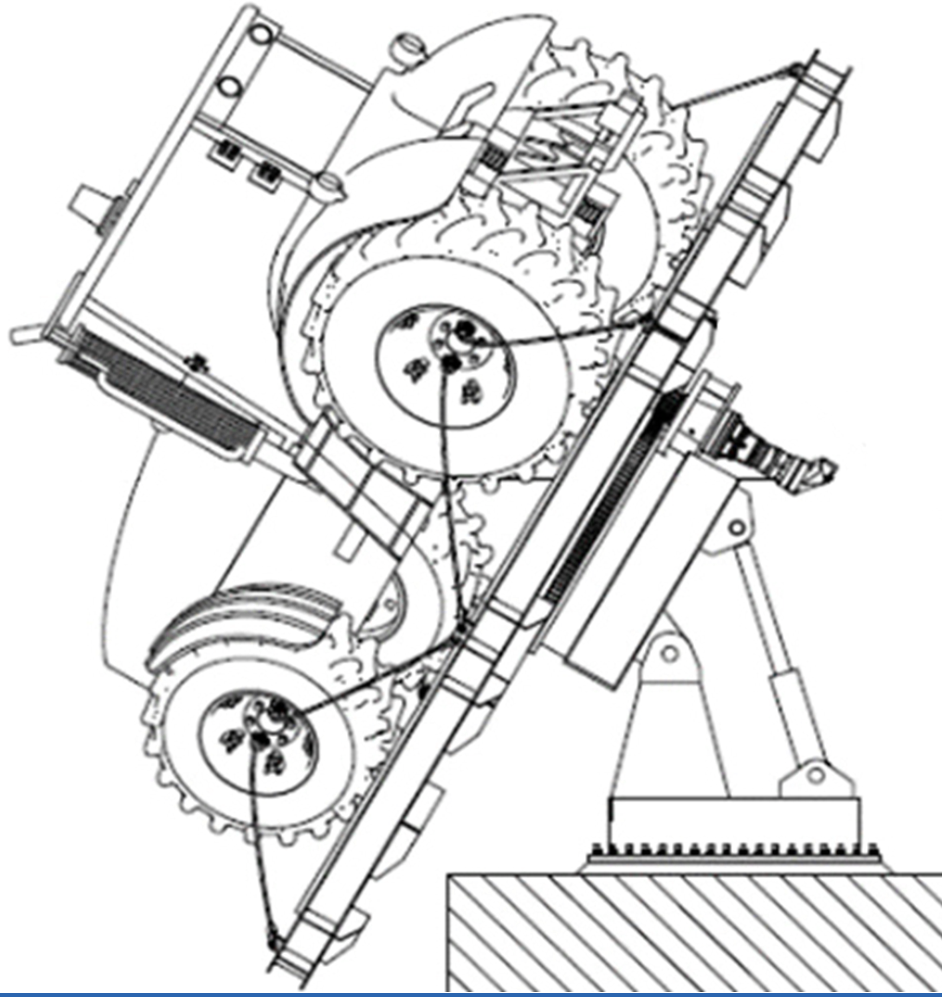
Conclusions and Future Works

Future works

- Experiments with different machine configurations:
  - Different inflation pressures
  - Double wheel systems
  - Water ballasting
- Experiments with different equipment.
- Improvement of the stability model (wheel as a non-rigid body).
- Development of rollover warning systems.



Vielen Dank für Ihre Aufmerksamkeit!



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