WORKING VEHICLES ELECTRIFICATION: DESIGN, MODELING, PROTOTYPING

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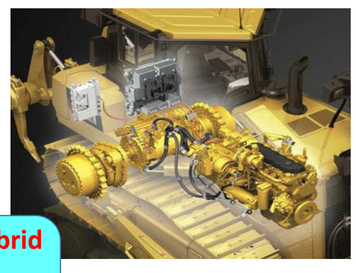


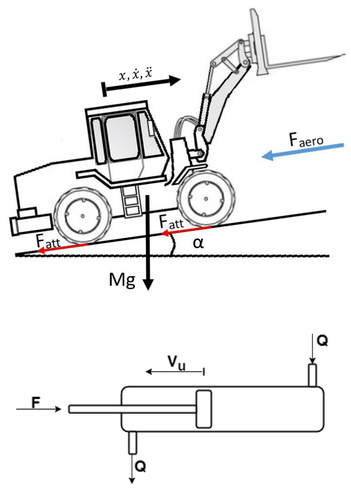
Innovative hybrid electric architectures for working vehicles

Introduction

In the last decade the automotive field has seen a growing diffusion of electric and hybrid electric vehicles due to the need to reduce pollutant emissions. Nowadays this trend is also involving the working vehicles field where low efficiency is a well known problem. Unlike automotive vehicles, a great amount of power is involved both for traction and hydraulic tools leading to a completely new class of problems in terms of energy management during the working session. The hybridization of conventional diesel architectures with innovative electric systems is one the most discussed topic towards efficiency improvement of these machines. The design process of a hybrid electric working vehicle involves several disciplines such as mechanics, power electronics, informatics and much more. Thus the integration between each physical subsystem of the machine is a crucial point and needs to be exploited. This is the main topic that led this PhD activity in the first two year.

DESIGN MODELING PROTOTYPING MONITORING

System Modeling

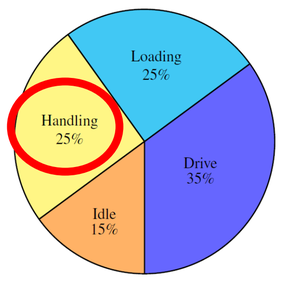


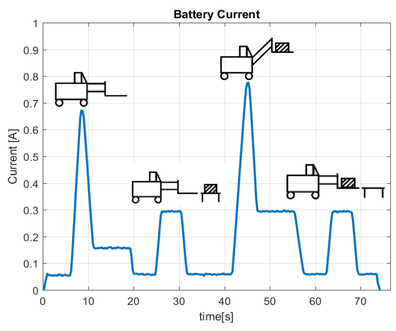
Multi physics system model

Hybrid and electric working vehicles are complex systems where **mechanical**, **electrical**, **hydraulic** and **electronic** components have to work together to obtain the desired output.

There are several ways to model such a complex system, depending on what aspect has to be exploit. In the specific case, the energetic approach was considered as the best trade off between accuracy and computational efforts. The numerical model is used in the HIL bench (see below) to simulate the motor shaft load.

Working cycle analysis





Performance of a working vehicle are usually evaluated in terms of:

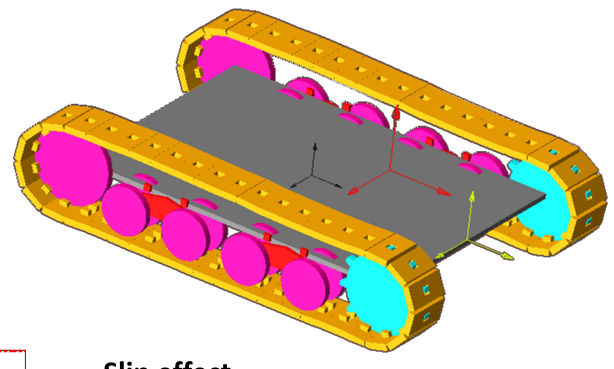
- **productivity**
- **pollutant emissions**
- **efficiency**

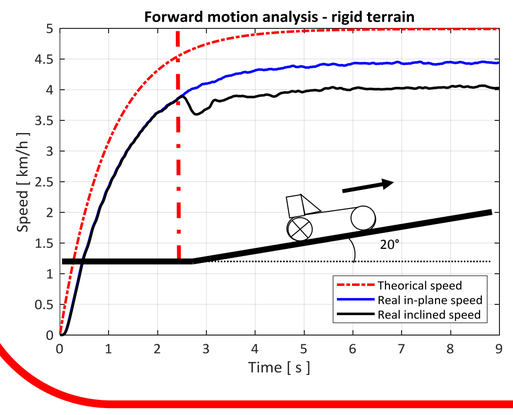
It may seem contradictory to consider efficiency and pollutant emissions as two different points, but it is what actually happens when manufacturers prefers to control emissions using post combustion additives instead of improving the overall efficiency of the machine.

Hybrid/electric machines allows to both match the two requirements. Moreover, performance can strongly be improved with a deep understanding of the machine final destination. The machine **working cycle** should also lead the design stage. Improvements in those phases with the highest amount of working hours during the lifespan of the machine translate in higher efficiency benefits.

MTB model

- **Track Model**
- **Chassis body design**
- **Tensioning system**
- **Inertia properties**





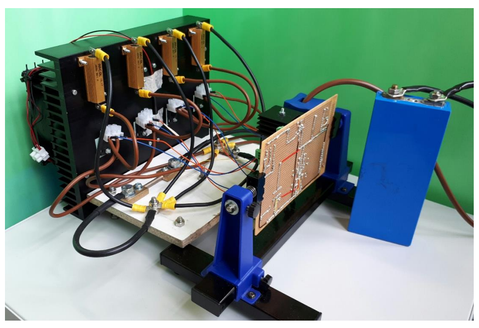
Slip effect

The difference between the real speed of the vehicle and the ideal one is shown, for forward motion on horizontal plane and on a ramp. In this test, intended to the model validation, the contact model was simplified with a Coulomb friction model.

Experimental activities

HIL mechanical test bench

The activity started in the first year when the main mechanical components were designed and built. This year, the attention was mainly focus on the control algorithm that allows to simulate the behaviour of the vehicle and apply an equivalent load on the motor shaft. This bench is used to test real components of an electric architecture under real operating conditions of a working vehicle.



HIL cell test bench (feat. Elena Vergori)

A scaled mechanical bench allows for system analysis on components behaviour. To analyze the cell behaviour it is necessary to apply the full load and see how the cell adapts to real working conditions. This is the reason why a prototype of a charging/discharging testing equipment was built. It allows continuous cell discharge up to 120 A thanks to a properly designed cooling system. With a dedicated software written in Matlab/Simulink, it is possible to obtain complex predefined current load profiles for deep cell testing.

Other activities

Supertino Electra 21

On February 2017, the first electric prototype of an electric vertical feed mixer was presented in Paris. The activity started on 2016, when a set of field test allowed to obtain the **working cycle** of the traditional machine and thus the requirements for the new electric system. Now the machine is under an extensive testing program to fully exploit its reliability. Thanks to the monitoring system developed and installed on the machine, it is possible to continuously look at the machine performance.

Publications

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