A MOTORCYCLE VIRTUAL MODEL

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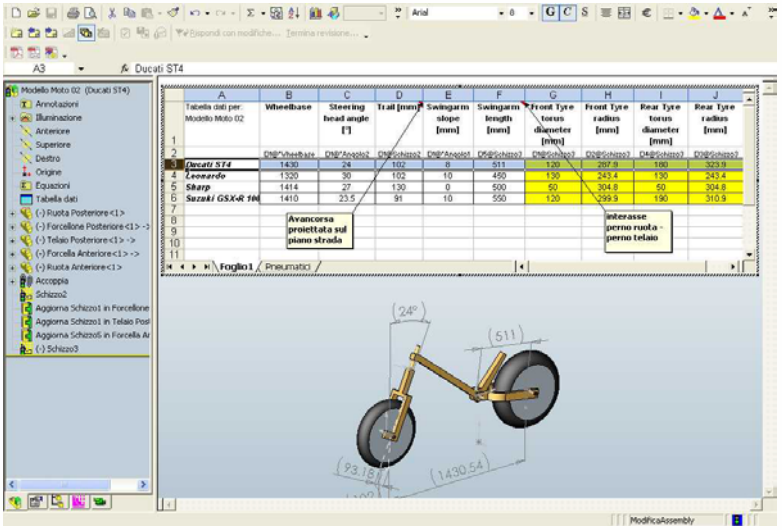
Objectives

- General

  Set up a friendly procedure, based on CAD – MBS – DA sw integration, to define geometric, kinematic and dynamic parameters of a MOTORCYCLE

- Strategic
  - Tire profile submodeling and influence on the dynamic behavior
  - Some examples of kinematic and dynamic analysis

Parameters



The first phase of the model development consists of the choice of the motorcycle parameters. They must be enough to describe it, for any aspects of interest of the simulation.

The selected parameters are: the wheelbase, the trail, the rake of the steering axis (caster angle), the distance between the axis of the rear wheel and the axis of the swing arm hinge, the distance between the swing arm hinge axis and the steering axis and, finally, the dimensions of the wheels directly calculated from the acronym of the used tire (es. 180/55 R17).

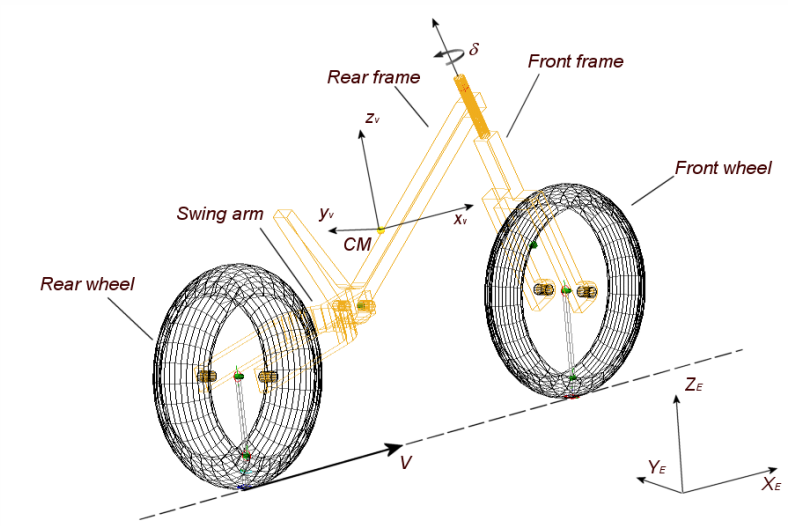
In the slide the typical values for the above mentioned parameters, for different kind of motorcycles, are reported. The motorcycle geometric model, generated by the cad code, is also reported.

To develop the motorcycle geometric model a parametric three-dimensional cad (*SolidWorks*) was chosen. Such tool gives the advantage to have quickly various motorcycle typological configurations of the model. For every configuration the geometrical parameters can be inserted in electronic datasheet, like *Microsoft Excel*. The procedure allows to quickly vary these parameters to construct various motorcycles models.

CAD Model Examples

These are four different motorcycle geometric models generated by the cad software for the motorcycle parameters reported in a previous slide.

Motorcycle multibody model

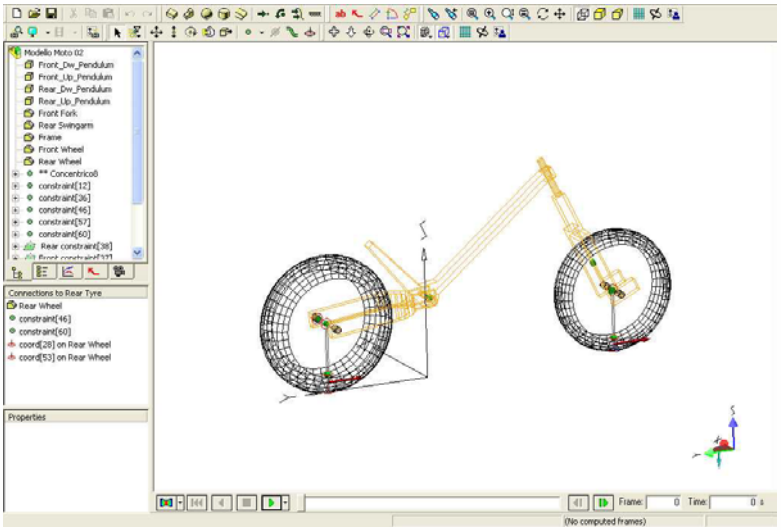


The SolidWorks cad model can be immediately imported in the multibody MSC-Visual Nastran code, to perform kinematic and dynamic simulations.

The multibody model is constituted of five bodies: the two wheels, the rear frame, the swing arm, and the front frame. Such bodies have been constrained each other so that the simulation code can properly interpret them during the import phase.

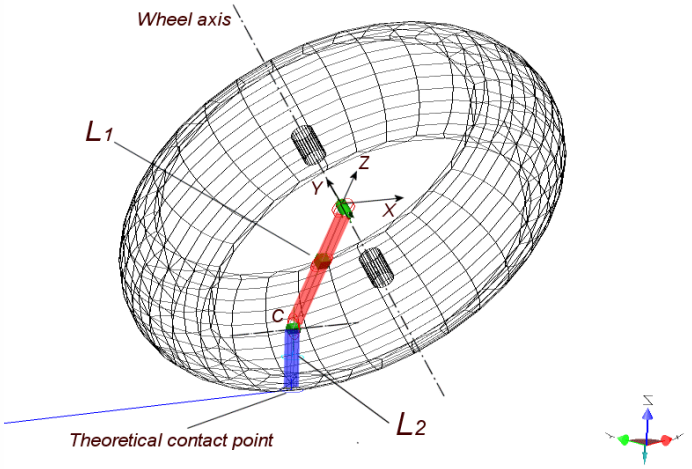
The rear suspension can be schematized through a rotational spring, located in the swing arm hinge, whose stiffness and damping are equivalent to the rear suspension ones. In the same way the front suspension can be schematized with a linear spring located between the front frame and the rear frame.

MSC VisualNastran Model



This slide shows the motorcycle model imported in MSC-Visual Nastran

Massless double-link wheel submodel

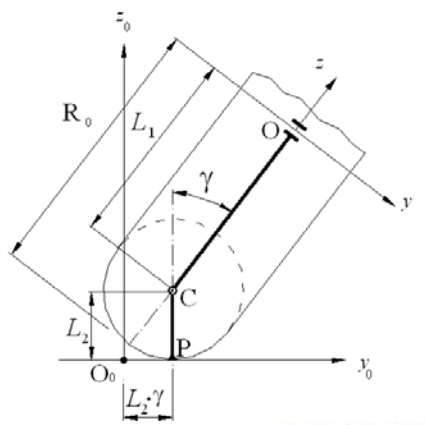


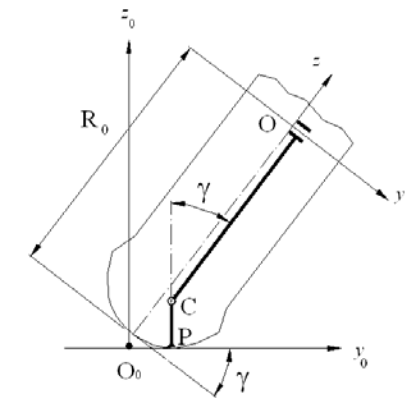
For the tire-road interaction, the Pacejka “magic formula” was chosen as starting point. This model allows to define the interaction as a single force vector applied in the theoretical contact point between tire and road and a single moment vector. So the location of the application point of the force, continuously vary along tire tread, with the wheel spin and attitude.

As a multibody code does not allow to define a force whose application point varies along the body, a massless double-link () submodel is adopteded, for each wheel, whose one free end is located in the theoretical contact point.

Massless double-link for different tire profile geometry

Circular tire cross section





Generic tire cross section

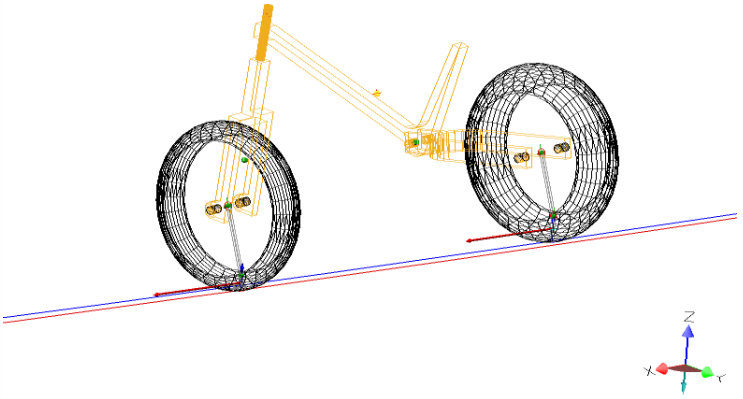
For a circular tire cross section, the upper link () is constrained to rotate with respect to the motorcycle frame around the wheel axis. The lower link () can rotate with respect to the upper one around an axis parallel to the axis through the point C. This latter is the geometrical centre of the tire profile. The lower link is further constrained to remain orthogonal to the road plane.

The tire rolling motion is so described by a rotation around the point C and by a lateral translation along the axis of the contact point P, that in kinematical condition is equal to .

From a dynamical point of view the wheels are however present in the model as rigid bodies in order to take in account their inertia actions due to the rotation. The wheels rotation speed is related to the forward speed *V* through the longitudinal slip: .

To describe a non circular tire profile with the same approach, the links lengths and the C point position must vary with the camber angle with a procedure describe in [].

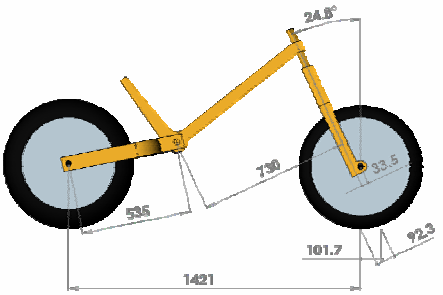
The wheels



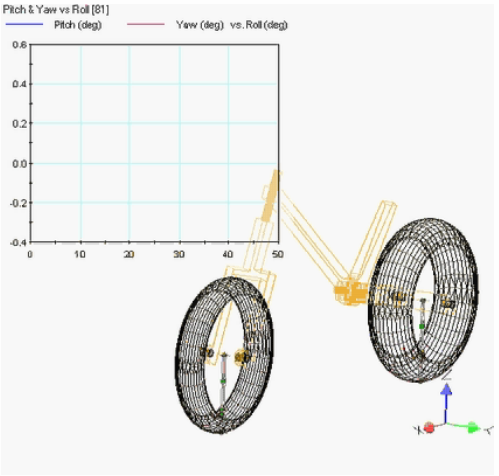
From a dynamical point of view the wheels are however present in the model as rigid bodies in order to take in account their inertia actions due to the rotation. The rotation speed of each wheels is related to the forward speed through the longitudinal slip.

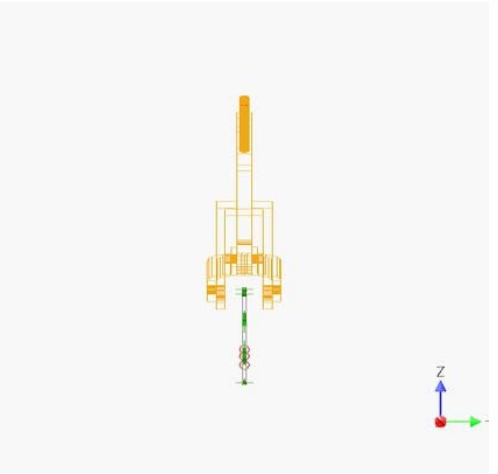
Motorcycle model characteristic

- **Wheelbase** **1421 mm**
- **Caster angle** **24,8 deg**
- **Trail** **101,7mm**
- **Front tire 120/60 R17**
- **Rear tire 180/55 R17**
- **Front tire wheel plane radius** **300 mm**
- **Rear tire wheel plane radius** **315 mm**
- **Rear wheel equivalent circular profile: L1R = 91mm, L2R = 224mm**
- **Front wheel equivalent circular profile: L1F = 54mm, L2F = 246mm**



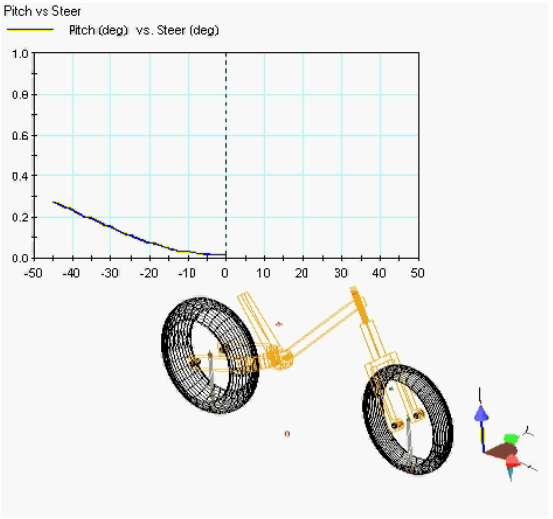
Pitch and Yaw versus Roll





The multibody model allows to define the kinematic characteristic of the motorcycle: as an example in the slide pitch and yaw angles versus the roll angle is reported.

Pitch versus Steer



This is the pitch diagram in function of the steer angle.

Is this a “wobble” oscillation ?

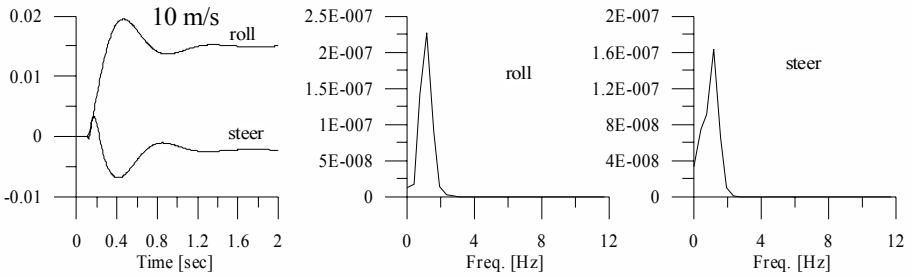
The multibody model can be adopted to define the motorcycles dynamic characteristics.

The eigenvalue analysis of a motorcycle linearized model adopting forward speed as free parameter is reported in a famous paper of R.S. Sharp, published in 1971.

In the case of free control steer the Sharp model highlights three main oscillation modes named respectively *capsize*, *weave* and *wobble.* These oscillation modes can become unstable within some forward speed intervals.

In the movie an unstable oscillation is shown.

Motorcycle response to a lateral impulsive force : V=10 ms-1



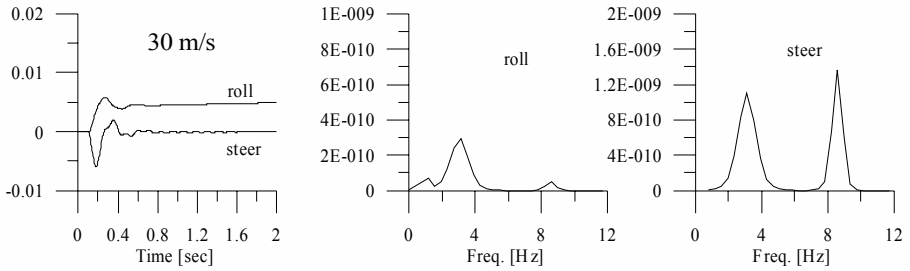
The time history realized by dynamical simulation allows some considerations on the system The oscillation modes have frequencies and damping depending on both geometrical / inertial parameters and on the forward speed.

In the slide, for the above defined motorcycles equipped with a 20kg rear bag , the roll and the steer rotations and the relative FFT are reported for different values of the forward speed.

It can be pointed out :

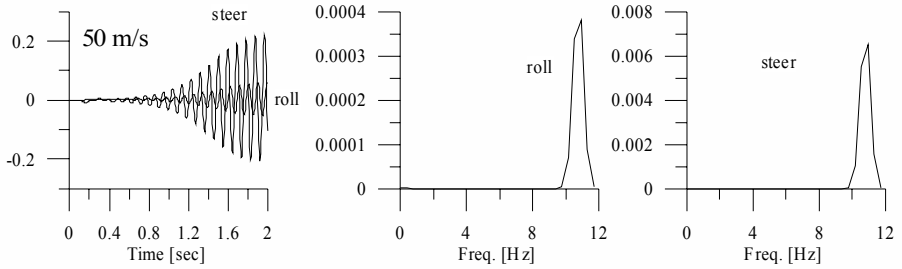
- an overdamped oscillation at V=10ms-1;

Motorcycle response to a lateral impulsive force : V=30 ms^{-1}



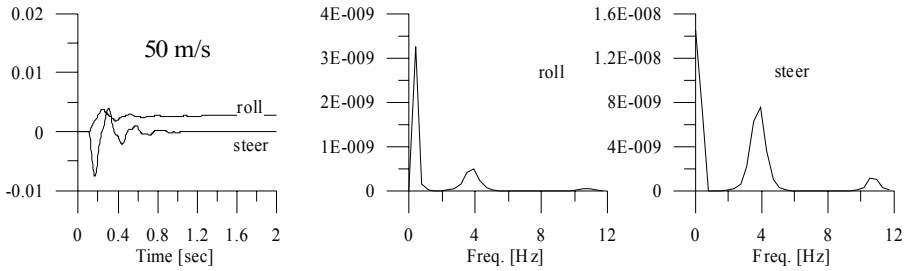
- a damped oscillations at V=30ms-1 are present at 3Hz and a 8.5Hz (weave and wobble frequencies);

Motorcycle response to a lateral impulsive force : V=50 ms^{-1}



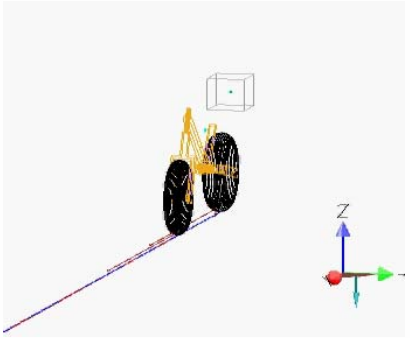
- an expansive (unstable) oscillation at V=50ms-1 characterized by a large harmonic component at 11Hz;

Motorcycle response to a lateral impulsive force : V=50 ms^{-1}: steer damping



- At V=50ms-1 the 11Hz oscillation can be reduced adopting a suitable steering damper eventhough the 3.5Hz oscillation is less damped.

Dynamical simulations for V=60ms^{-1} without steering damper



Conclusions

- A tool for kinematic and dynamic analysis, starting from geometric parameters of a MOTORCYCLE, has been presented.
- Simulation results are according to reliable models.
- The tool is friendly for user, even though a CAD – MBS – Data Analysis software have to be available and integrated.
- It will be necessary to augment the tool implementing the suitable control strategies for realistic driving conditions.

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