TILTING TRAIN SIMULATION IN ADAMS

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Abstract

The ADAMS code and its RAIL interface have been used for the modelling of a train tilting system and for the definition of working laws for actuation and control.
Special USERSUBs have been developed to integrate in ADAMS the software defining control laws and actuation system functionality of an **existing tilting train application**.
The model has been built up using rigid bodies, elastic linear/non linear connections and forces elements from ADAMS library. Track and wheel–rail interaction forces were the RAIL standard ones.
The performed simulation analysis proved good results in comparison with the true train behaviour and appears to be a **valid tool for control law optimisation and safety system failure modes**.

1. INTRODUCTION

The **increase of speed** on railway networks is substantially due to the construction of new, mostly **dedicated, railway lines** that require considerable investments and extremely long implementation periods, in particular with uneven territorial orography.
The outcome of this approach, initially undertaken by Japan and subsequently by other countries such as France, Germany and Spain, is that a number of high speed lines have been built, representing however only a small percentage of the overall railway networks of these Countries.
Consequently, in order to increase rolling stock speed on **existing lines**, a solution must be sought to avoid the great investments required for modifying existing structures and allowing a timely answer to passengers' demand on cutting journey duration.
The main problem faced moving towards this goal is to **increase rolling stock speed in curves**, without exceeding the acceptable value of centrifugal acceleration uncompensated by the cant and compromizeing passangers´comfort.
Therefore, it is necessary to introduce an offset factor that compensates for deficiencies of the cant. On **PENDOLINO**, this basic compensation is obtained by an **active rotation of the body** with respect to the longitudinal centreline of the vehicle. This approach keeps and besides increases passangers´comfort, to a very high level

without compromise running safety.
An 8 degrees tilting angle let the train to approach curves up to the 25÷35 % faster than a traditional train (without tilting system).

Obviously this speed increase have to be obtained while drastically **reduceing stress** on the track and **guaranteeing maximum safety against derailment**.

2. DESCRIPTION OF THE MODEL

The ADAMS model of the train is the modified version of an existing and tested model that we use for stability and confort study. A tilting bolster with links were insert between the wagon and the bogie frame. Two actuators impose the relative rotations in X axes between the two bolsters (fig. 1), the block diagram of the ADAMS model is in fig. 2.
The control law of the rotation is made by the software used on the tilting train compiled in ADAMS with an user written subroutine (fig. 3)

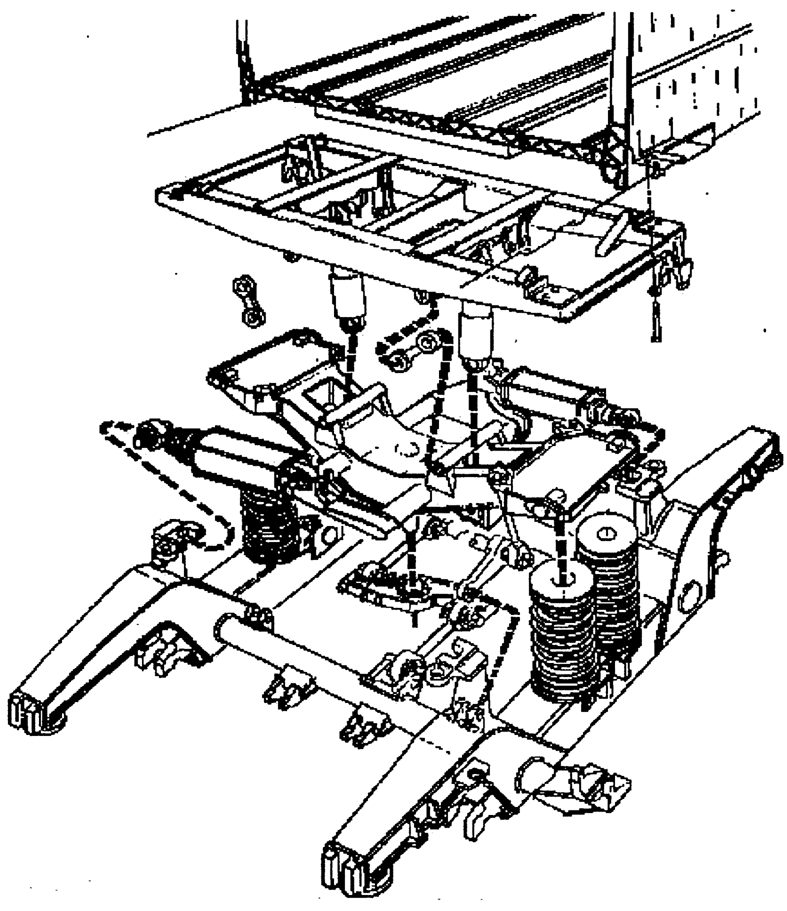

fig. 1 Scheme of tilting bogie

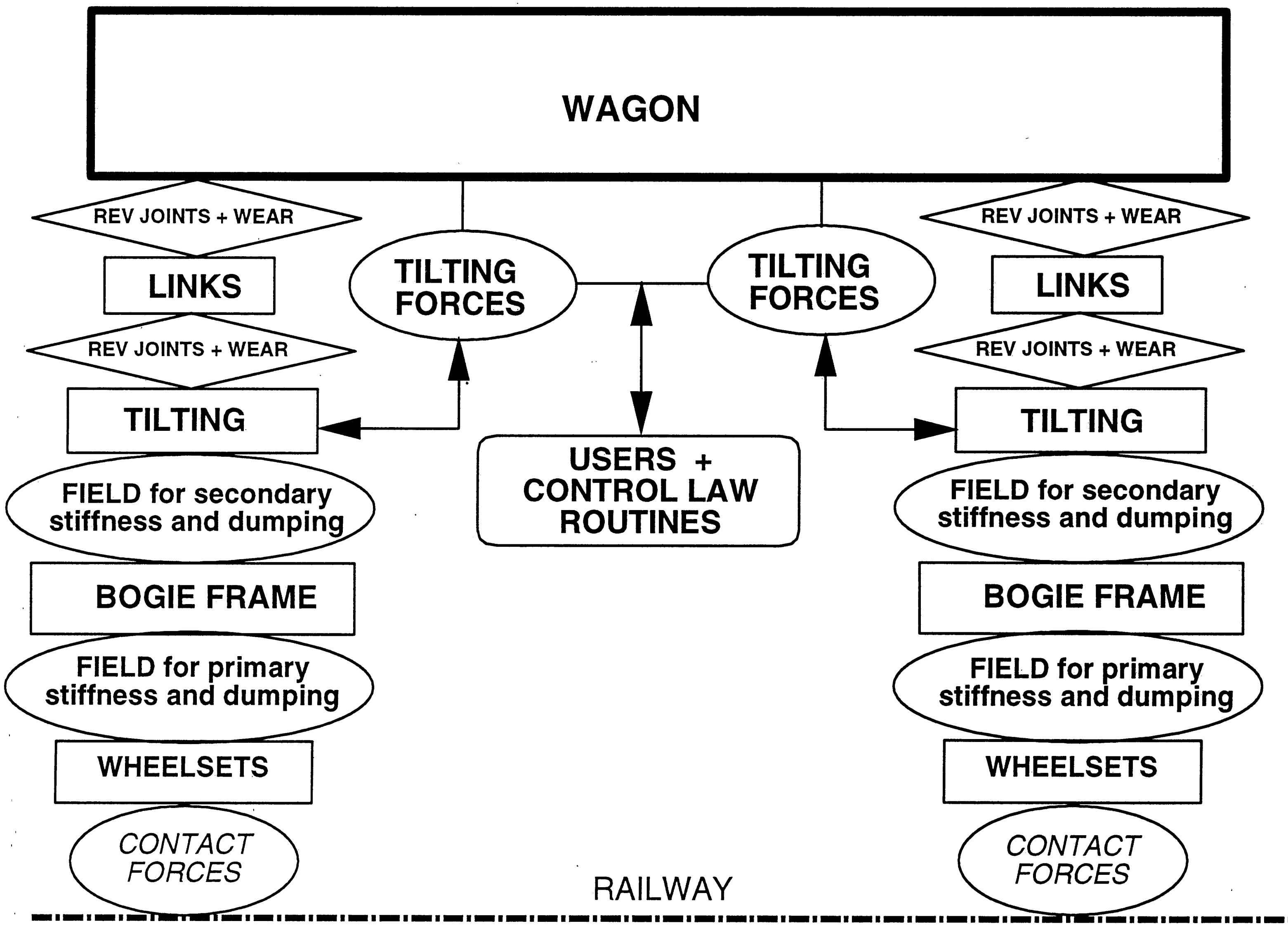

fig. 2 Block diagram of adams tilting train model

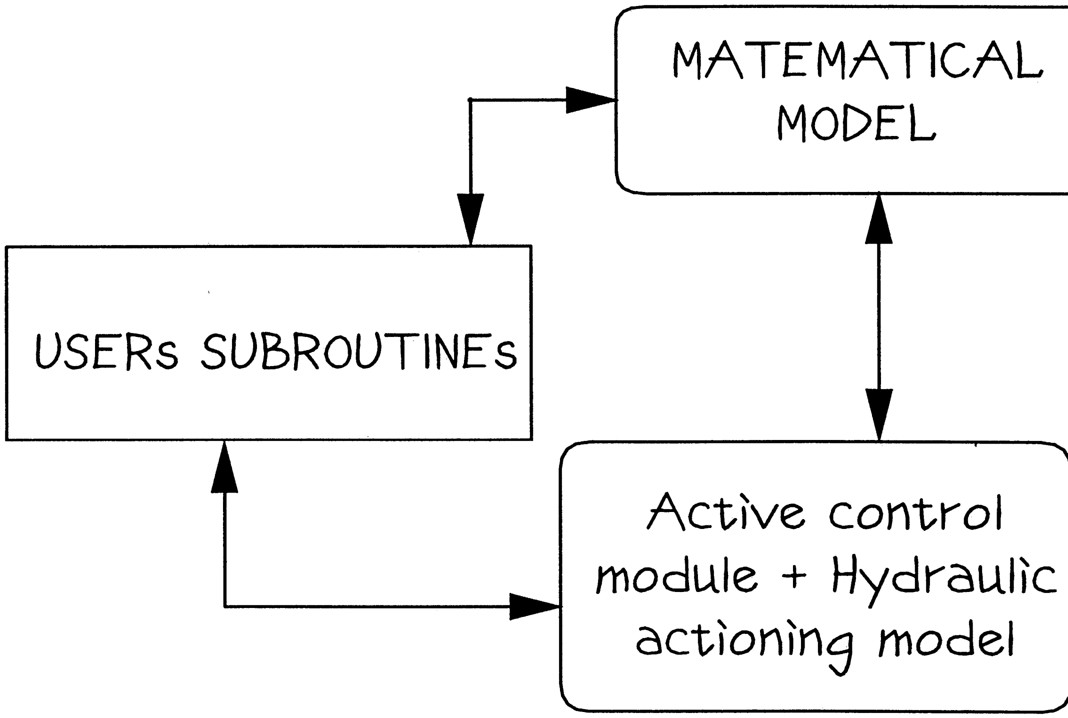

fig. 3 Block diagrams of the model

3. SIGNAL AND PASSENGER'S ACCELERATION

Used signals for the generation of the tilting forces (fig. 4):
- uncompensed acceleration on the bogie frame;
- angular velocity around X axis of the bogie;
- angles between the tilting bolster and the bogie frame;
- longitudinal velocity of the train.

The signal of the angular velocity of the bogie (in fig. 4 named: gyro) individuates the sign of the cant of the curve; the uncompensed lateral acceleration (in fig. 4 named **anc**) has to be filtered in order to obtain a more clear curve that represents the need of the wagon rotation. The filtered signal presents a delay (δ) introduced by the filter: this is a problem for the first wagon because this delay produces a low confort for the passengers. So we use a trapezoidal signal (in fig. 4 named: trapezio) that introduces a first signal that is added to the filtered one. The other wagons do not present this situation, it is possible to use this signal translated in time.

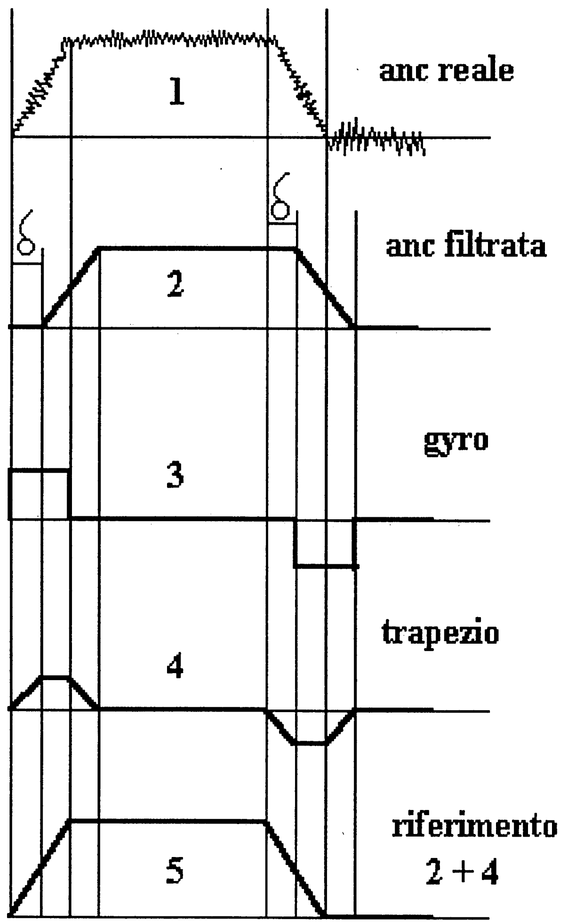

fig. 4 Generated and needed signals

The angles between the tilting frame and the bogie (named: kinax) indicate the rotational position of the wagon step by step and they are used for the comparison with the need of the wagon rotation in order to create a "control loop" of the necessary angular position.

The **control law** subroutine is the **same used on the train** in order to obtain a good and significative simulation of its dynamic behaviours. The actuator forces are genarated with a routine that describes the actual hydraulic scheme taking in account the whole system.

In figure 5 we report an example of studied curve with cant angles and horizonatal curvatures. We started with the simulation of a regular track and we will continue with irregular and measured data.

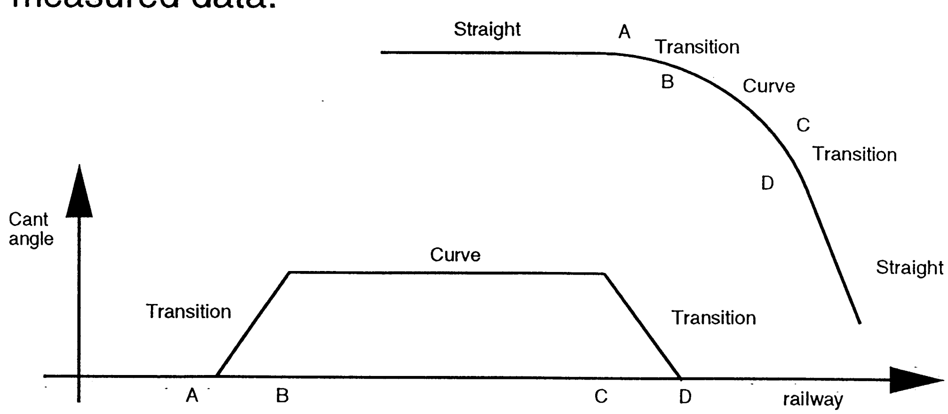

Fig. 5 Example of a railway curve

In order to reduce the variation of the acceleration on passengers the system can tilt the wagon gradually with a percentage of compensation like in figure 6. We can observe that the acceleration on passenger is less heavy if the compensation is 80% than 100% also if the maximum value is the same (0.8 m/s^2).

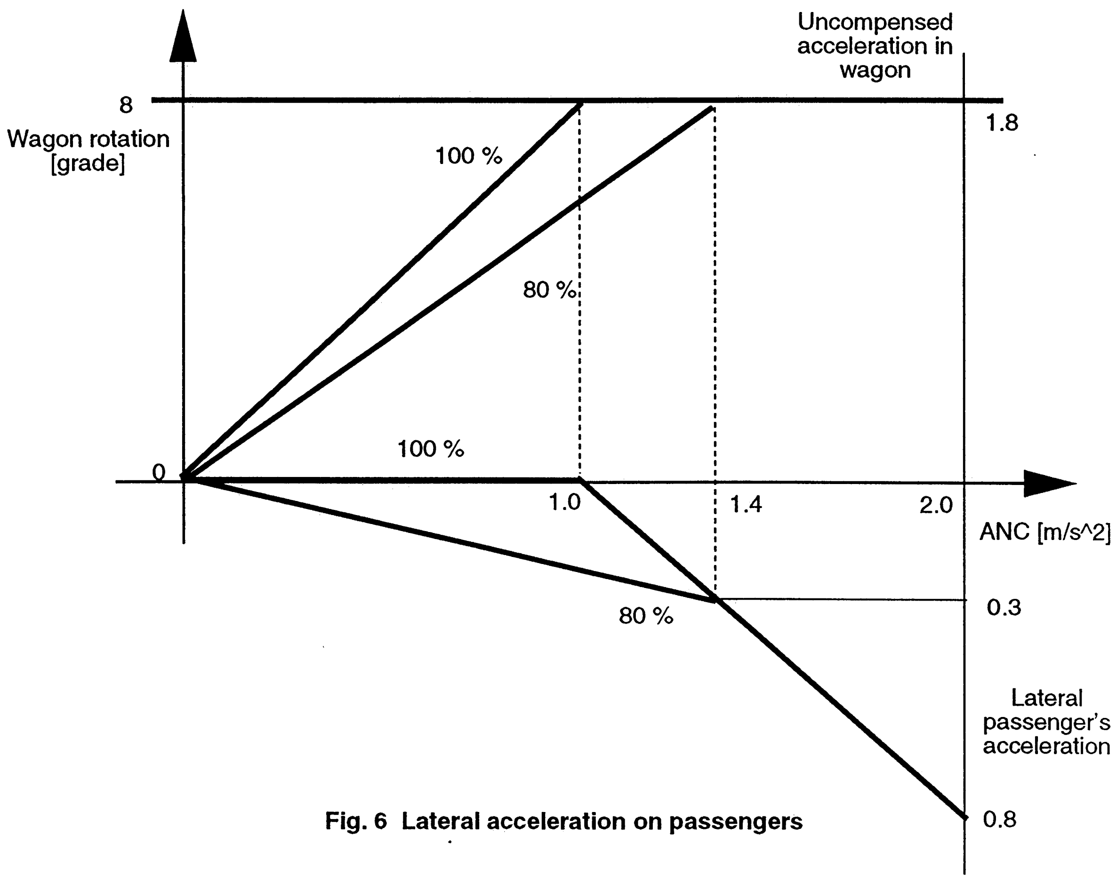

Fig. 6 Lateral acceleration on passengers

3. RESULTS

In figure 7 we can see the needed signal in respect to the angle of rotation of the wagon during a simualtion. The uncompensed acceleration reaches 2 m/s^2 while the maximum value on the passenger is under 0.8 m/s^2. This is an hypotetical case in which the velocity of the rotation is very high in order to reach quickly the target signal.

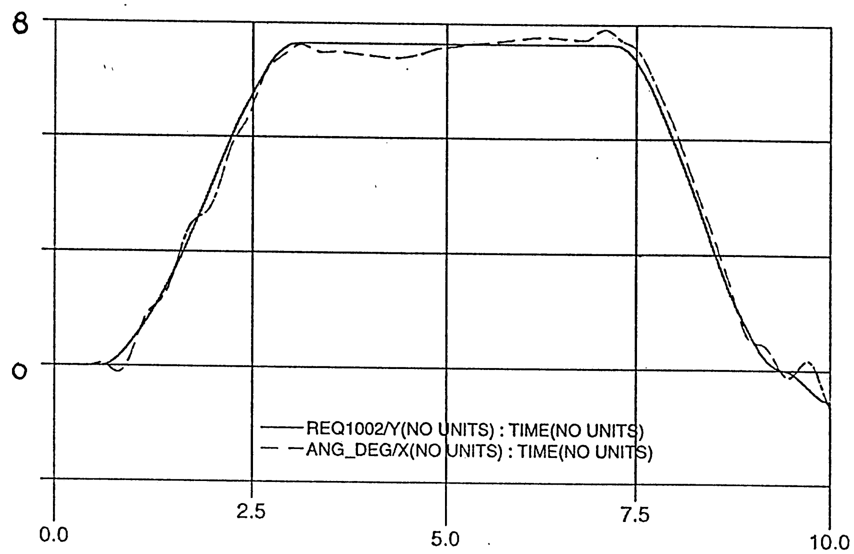

Fig. 7

Figure 8 shows a complete simulation of a curve.

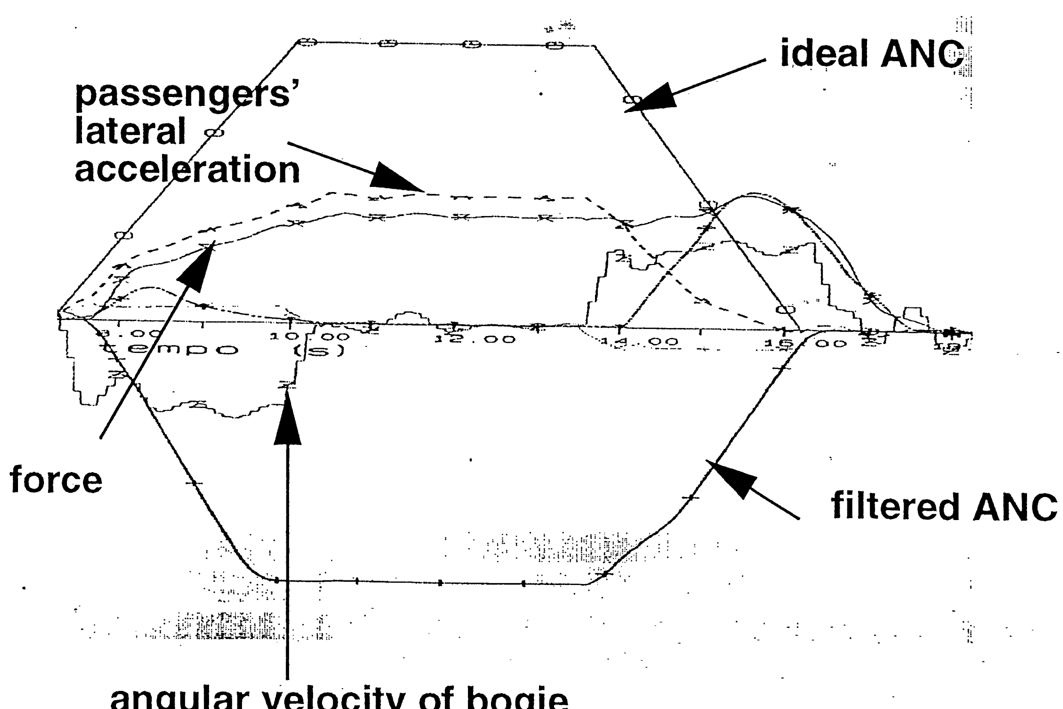

Fig. 8 Complete simulation

4. CONCLUSIONS

The multibody code ADAMS with users subroutines permites us to integrate the actual tilting control law and to simulate the tests. It is possible to made an optimisation of new control laws with more facility and less costs and we are working for reach this goals.

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