FLEXIBLE MULTIBODY MODELISATION OF A DISC BRAKE

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ABSTRACT :

This work deals with a global simulation of the dynamic behaviour of the TGV railway disc brake system. A model based on a rigid multibody approach was developed, describing the architecture of the braking system. The flexibility of the most sensitive elements is introduced by various techniques according to the geometry and the sollicitations (bases modal, beam, etc). The described application studies the response of the braking system in the presence of "hot spots" on the surface of the discs.

I. INTRODUCTION

In the study of the performances of the braking systems, the thermomechanical and tribological phenomenon correspond to the major fields of investigation. Nevertheless, the influence of the dynamic behaviour of the braking system can not be ignored both locally on the contact surface, and more overall on the whole braking system. A numerical approach by a multibody model of the architecture of the braking system, using the dynamic computation software ADAMS®, is proposed. The introduction of flexible models of bodies known as "sensitive" according to their geometry and the sollicitations was initiated. The dynamic sollicitations applied on the braking system can be of two types:

- the sollicitations which can be described as "external ", resulting from the irregularities of the way, the effects of inertia of the vehicles, the atmospheric conditions, etc. They are transmitted to the disc by the axle or to the braking system via the connector and the rods (Fig.1).
- the " internal " sollicitations, due to the behaviour between the disc and the pad, induced by friction or by the thermomechanical surface distortions [Dufrénoy 1995] (Fig.2).

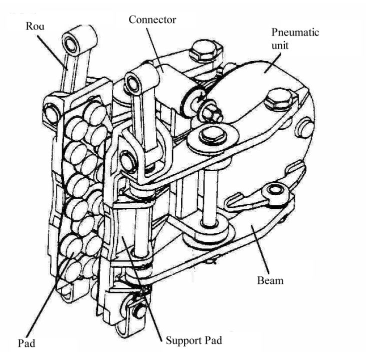

Fig.1 : Scheme of the TGV braking system

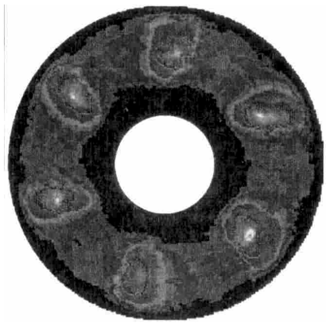

Fig.2 : Hot spots on the disc

In this paper, internal sollicitations, due to the occurrence of hot spots on the disc, is taken into account. The corresponding thermomecanical distortions, generate a dynamic internal excitation on the sliding contact. The incidence on the variation of contact normal reaction on the pad is studied.

II. DYNAMIC MODEL OF THE BRAKING SYSTEM :

1. Description of the braking system :

The disc brake is constituted of one disc fixed on the wheels axle, sliding bodies called pads and the brake gear (Fig.1). The pressure is developed by a pneumatic unit and is transmitted to the pads via two pairs of articulated beams on the body of the brake gear called connector. The braking system has three points of fixation on the frame of the bogie: an elastic connection (silentbloc) on the connector and two rods of guidance of the pads.

2. *Multibody numerical model :*

The model is based on an multibody architecture obtained by ADAMS® software. The basic rigid model gives the movement of the mechanism by describing the mechanical connections, the input pressure, environmental conditions and the bodies (by their inertial parameters: mass, center of masse, tensor of inertia). The movement of the mechanism is governed by three systems of equations; a system of differential equations of the movement and two systems of equations defining the boundary conditions. The result is based on the resolution of the equations of Lagrange. Because of the hyperstatism resulting at the beams, the kinematic architecture of the braking system can be simplify by taking into account two of the four beams (Fig.3). The multibody dynamic virtual model can be provided with only representative volumes (Fig.4).

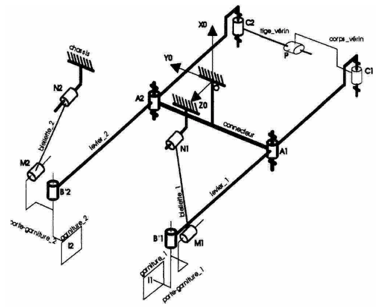

Fig. 3 : Equivalent kinematic model

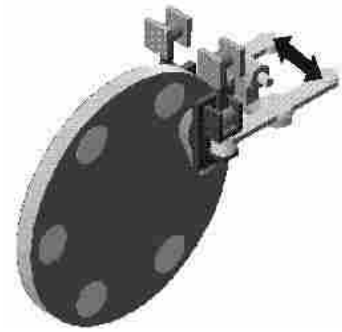

Fig. 4 : Virtual model of the braking system

III. DYNAMIC RESPONSE IN THE PRESENCE OF HOT SPOTS :

1. *Description of the studied configurations :*

Two applications are treated: a conventional braking (FS) and an emergency braking (FU). In there two cases, for the TGV, there are two levels of applications of the normal force, up and below 215 km/h (Fig.5). For the FS, deceleration is assumed to be constant, but not for an FU because of removing of the electric brakes (Fig.6).

The friction coefficient measured on the testing bench is given on figure 7 as function of the velocity.

The excitation of the dynamic model results from thermomechanical calculation of the disc when hot spots occur. It results in an excitation into displacement given by the evolution of the maximum amplitudes of the ridges and troughs. Figure 8 presents the envelope of the excitation as the evolution of the maximum amplitudes of the ridges and troughs, knowing that the frequency of " passage " of the ridges decreases with the velocity.

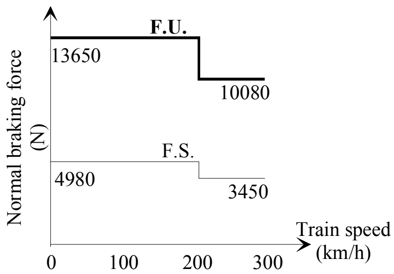

Fig.5 : Normal braking force

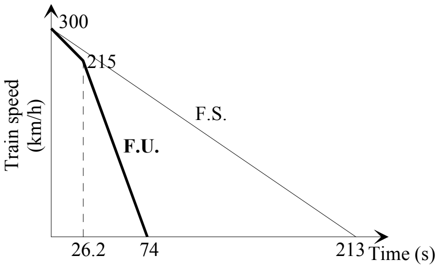

Fig.6 : Graph of the train speed

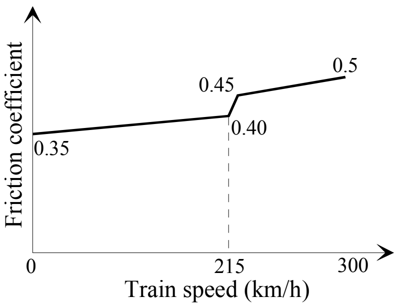

Fig.7 : Friction coefficient

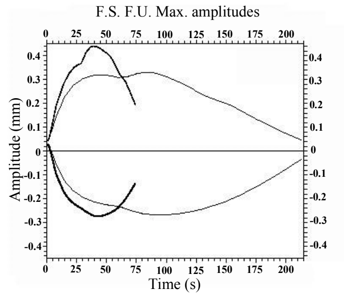

Fig.8 : Max. amplitude of ridges and throughs

2. *Results:*

The results describe the contact normal reaction at the contact between the disc and the pad during braking (Fig.9 and 10), only the maximal and minimal amplitudes are plotted. Strong variations are obtained even if they oscillate logically around the inlet force of pneumatic unit. Step of pressure at 215 km/h remains visible. One notes a loss of contact for the FS given by negative reaction, bidirectional contact model, but comparable to a separation of the pad and the disc. Even if for the FS the amplitude of excitation is less than for the FU, the less level of the inlet pressure induces a dynamic response of the pad [Musial 1996, 1998].

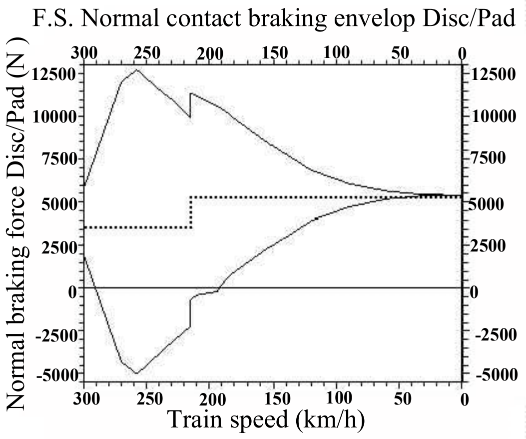

Fig.9 : Normal contact force (FS)

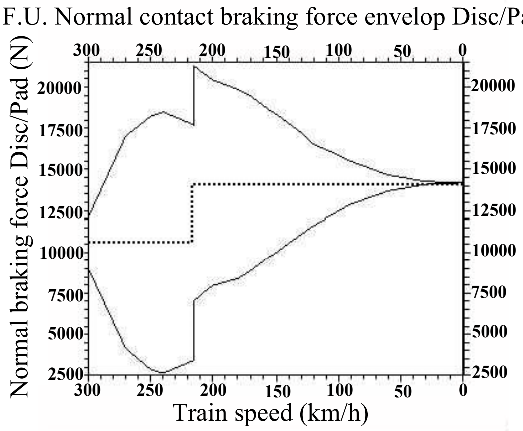

Fig.10 : Normal contact force (FU)

3. *Taking into account of the flexibility of braking system elements :*

Three types of models are used for the introduction of the flexibility of the "sensitive" elements :

- Introduction of rheological models is the simplest technique. It has been used as the model of the connection connector-frame (silent-block type) by an element shock absorber whose values of rigidity and damping are defined in the axial, radial and conical directions according to the frequency
- The second technique consists in modeling the deformable bodies by a beam model which describes the following elastic behaviour for example by the theory of Timoshenko. Levers and rods correspond to this type of modeling.
- The last technique consists in introducing into the code of multibody dynamics, the data of a flexible structure characterized by a model with the finite elements (E.F.). Two methods may be used : the discrete method which consist of a transfer of the reduced matrices of masses, rigidity and damping and the modal method which consists in transferring the modal base from the flexible structure [Majcherczak 1998]. Pads and levers correspond to this type of modeling.

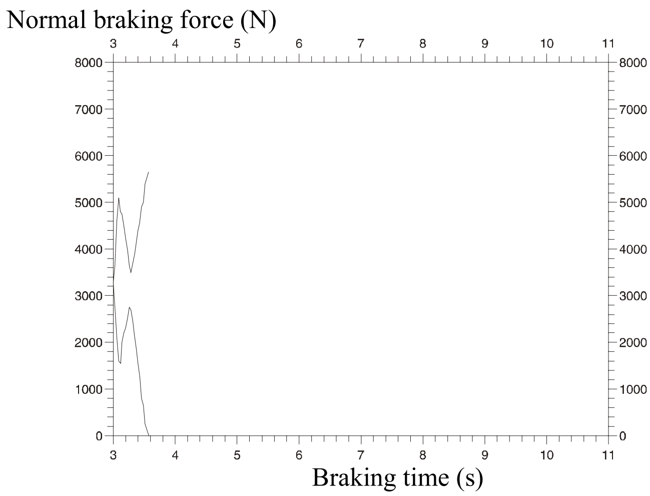

Fig.10 : Rigid model

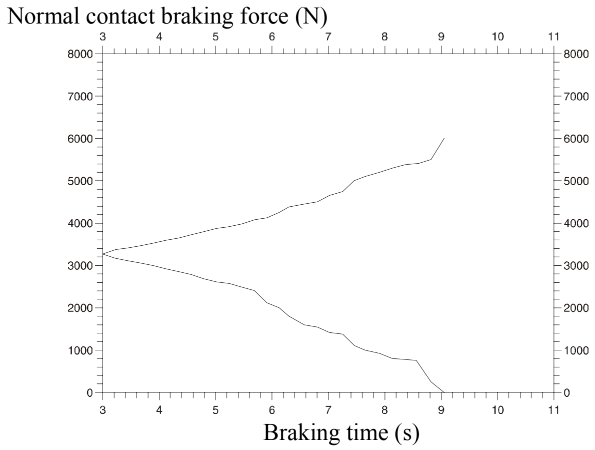

Fig. 10 : Result : Flexible pad model

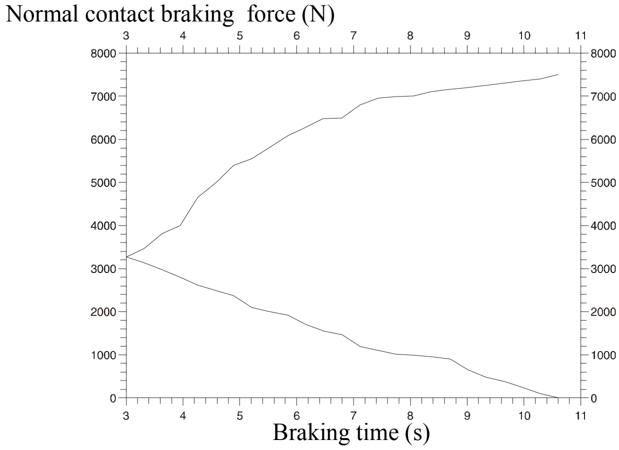

Fig. 11 : Result : Flexible pad and levers model

The first results show a great disparity with regard to the moment of contact separation for the FS. In the case of the rigid model, presented previously, it takes place almost immediately (at the end of an half second of braking) (fig. 11).

Since the flexibility of one or more elements is considered, the moment of separation is delayed (6s after the pressurization of the pneumatic unit if only the pad are flexible (Fig.12) and 7.5s when the pads and the levers are flexible (Fig.13) [Majcherczak 1999].

IV. CONCLUSION :

The complexity of the dynamic study of the braking system implies a gradual but necessarily complete methodology. The model presented here is only one first approach of the dynamic behaviour, whose basic architecture is described, with the capabilities of integration of the thermomechanical and tribological couplings.

The first results show the influence of a surface internal excitation of the disc or of the architecture of the braking system (role of the rods) on the normal force of sliding contact. Taking into account the flexibility of certain elements of the braking system (in particular pads and levers) has been initiated. Its interest was shown with regard to the moment of separation between the disc and the pads.

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