MODELING OF THE DAMPED OSCILLATIONS OF THE VISCOUS BEAMS STRUCTURES WITH SWIVEL JOINTS FOR HARMONIC MODE

M. Dawoua Kaoutoing[1], G.E Ntamack[2], K. Mansouri[3], T.Beda[4], S. Charif D'Ouazzane[5]

[1, 2, 4] *Groupe de Mécanique et des Matériaux, GMM, Département de Physique, Faculté des Sciences, Université de Ngaounderé, Cameroun,* ***dawouakaoutoingmaxime@yahoo.fr, guyedgar@yahoo.fr, tbeda@yahoo.fr***

[3] *Laboratoire des Signaux, Systèmes Distribués et Intelligence Artificielle (LSSDIA) ENSET de Mohammedia, Université Hassan II Mohammédia Casablanca, Maroc,* ***khmansouri@hotmail.fr***

[5] *Laboratoire de Mécanique, Thermique et Matériaux, LMTM, Ecole Nationale de l'Industrie Minérale, ENIM, B.P. 753 Rabat, Maroc,* ***charif.enim@hotmail.com***

Abstract

Mechanic studies realized on the two dimensional beams structures with swivel joints show that in statics, the vertical displacement is continuous, but the rotation is discontinuous at the node where there is a swivel joint. Moreover, in dynamics, many authors do not usually take into account the friction effect, modeling of these structures. We propose in this paper, a modeling of the beams structures with swivel joints which integrates viscosity effects in dynamics. Hence this work we will present the formulation of motion equations of such structures and the modal analysis method which is used to solve these equations.

Keywords: *Beams, Swivel joint, Viscosity, Vibration, Modal Method.*

---***---

1. INTRODUCTION

Swivel joint is a spherical mechanical piece used as articulation in the framework, which allows turning over in all directions [1]. The swivel joint does not transmit moment. Its action is reduced to a force passing through its center [2, 3]. The work carried out on the framework in beams with swivel joints indicates that, in statics there is continuity of the arrow, but a discontinuity of rotation to the swivel node [4, 5.6]. In dynamics, frictions are often neglected during the evaluation of the degrees of freedom of the structures containing swivel joints. In this work, we propose a technique of calculation which helps to evaluate the vertical displacement and rotation, taking into account the frictions in the calculation of the degrees of freedom of the structures in beams with swivel joint in dynamics. The evaluation of these degrees of freedom is based on the setting in equation of these structures in dynamics and given their solutions by the modal method.

This paper is organized in the following ways: in the first part, we present the model which enables us to establish the motion equations of such structures. This step is followed by the presentation of the solution of these equations by the modal method of analysis. The last part of this work is related to the analysis and the discussion of results.

2. THEORETICAL MODEL

When a swivel joint is inserted between two beams, the node that makes connection between the two points, we can consider that one of the nodes is embedded in the beam and the other is a steering joint [1]. As an example let us consider the structure of the following figure with a swivel joint at node 2.

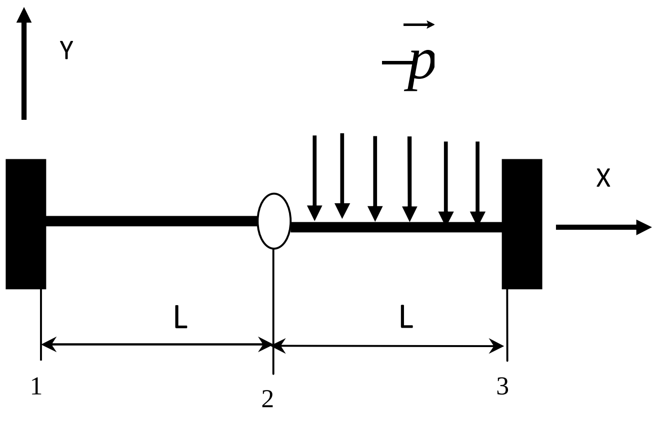

Figure 1: Structure in beams with a swivel joint

The node with swivel joint is modeled by two nodes, a node kneecap and an embedded node as shown in figure 2:

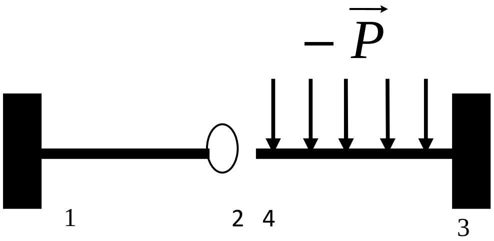

Figure 2: Modeling the swivel joints, node 2 with swivel joint, node 4 with embedded node

Study of the swivel joint's problem consists of determining the value of displacements and rotations of node 2 and 4. In statics several works are related to the evaluation of these degrees of freedom [5, 6]. In these references vertical displacements of nodes 2 and 4 are identical. The rotation of node with swivel joint, node 2 is locally evaluated by solving the elementary system of statics equations. But to determine the rotation of the embedded node 4, it is initially necessary to make the assembly of the global stiffness matrix of all the frameworks, by taking into account the disturbance of the elements with swivel joint nodes. In this work, we will propose a technique to evaluate the same degrees of freedom, in dynamics and introducing viscosity for the swivel joint nodes .The motion equations of a framework in dynamics with external forces can be formulated as following:

$$M\ddot{u} + C\dot{u} + Ku = f(t) \qquad (1)$$

In equation (1),
M, is the mass matrix;
C, is the damping matrix;
K, the stiffness matrix;
F(t), is the external disturbance.

In general to solve the system of equations (1), inverse methods are used, which consists of going from physical space to space modes, to find the solution in modal space and to come back to physical space [3, 6, 7]. In the case of framework with viscosity, by considering structure of figure 1 example f, by using modal method analysis, we obtain a system in the following form:

$$\begin{bmatrix} m_1 & 0 & 0 & 0 \\ 0 & m_2 & 0 & 0 \\ 0 & 0 & m_3 & 0 \\ 0 & 0 & 0 & m_4 \end{bmatrix}\begin{Bmatrix} \ddot{\eta}_1 \\ \ddot{\eta}_2 \\ \ddot{\eta}_3 \\ \ddot{\eta}_4 \end{Bmatrix} + \begin{bmatrix} 2m_1\omega_1\xi_1 & 0 & 0 & 0 \\ 0 & 2m_2\omega_2\xi_2 & 0 & 0 \\ 0 & 0 & 2m_3\omega_3\xi_3 & 0 \\ 0 & 0 & 0 & 2m_4\omega_4\xi_4 \end{bmatrix}\begin{Bmatrix} \dot{\eta}_1 \\ \dot{\eta}_2 \\ \dot{\eta}_3 \\ \dot{\eta}_4 \end{Bmatrix} + \begin{bmatrix} k_1 & 0 & 0 & 0 \\ 0 & k_2 & 0 & 0 \\ 0 & 0 & k_3 & 0 \\ 0 & 0 & 0 & k_4 \end{bmatrix}\begin{Bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{Bmatrix} = \begin{Bmatrix} f_1(t) \\ f_2(t) \\ f_3(t) \\ f_4(t) \end{Bmatrix}$$

(2)

It is a system of uncoupled equations where each i mode is put in the following form [4]:

$$\ddot{\eta}_i + 2\omega_i\xi_i\dot{\eta}_i + \omega_i^2\eta_i = \frac{f_i(t)}{m_i} \qquad (3)$$

Equation (3) has as the following solution:

$$q(t) = \begin{Bmatrix} q_1 = \dfrac{H_1(\omega)}{m_1\omega_1^2} x^{(1)} x^{(1)T} F_0 e^{j\omega t} \\ q_2 = \dfrac{H_2(\omega)}{m_2\omega_2^2} x^{(2)} x^{(2)T} F_0 e^{j\omega t} \\ q_3 = \dfrac{H_3(\omega)}{m_3\omega_3^2} x^{(3)} x^{(3)T} F_0 e^{j\omega t} \\ q_4 = \dfrac{H_4(\omega)}{m_4\omega_4^2} x^{(4)} x^{(4)T} F_0 e^{j\omega t} \end{Bmatrix} \qquad (4)$$

Where:
$x^{(i)}$ are the eigenvectors;
ω_i^i are the self throb;
H_i amplification dynamic factor of.

To calculate the rotation of node 2, we have to solve the elementary system (1), by writing in the member of the elementary force $f_2(t) = 0$. But to calculate the rotation of node 4, it is initially necessary to assemble all global matrices of the structure. In the continuation of this work, we present the solutions obtained in the evaluation of the rotation of the node kneecap 2 on the case of figure 1 structure.

3. SIMULATIONS AND ANALYSIS OF RESULTS

For simulations, we will consider identical beams of constant cross-section S, quadratic moment I_Z, density ρ and Young's modulus E. The selected beams have the length L, of type IPN of iron with the following mechanical characteristics:

E=210000 MPa, I_z=77,67 cm^4 S=7,57 cm^2, $\rho = 7850 Kg/m^3$ [8].

The useful part, after taking into account the boundary conditions, the motions equation of the structure in figure 1, subjected to harmonic excitations is in the form:

$$\frac{\rho SL}{16800}\begin{bmatrix}2800 & 0\\ 0 & 8L^2\end{bmatrix}\begin{Bmatrix}\ddot{v}_2\\ \ddot{\theta}_2\end{Bmatrix}+\begin{bmatrix}C_1 & 0\\ 0 & C_2\end{bmatrix}\begin{Bmatrix}\dot{v}_2\\ \dot{\theta}_2\end{Bmatrix}+\frac{EI_z}{L^3}\begin{bmatrix}6 & 0\\ 0 & 8L^2\end{bmatrix}\begin{Bmatrix}v_2\\ \theta_2\end{Bmatrix}=\begin{Bmatrix}P_0\sin\omega t\\ 0\end{Bmatrix}$$

(5)

The solution of this system is:

$$v(t)=v_h(t)+v_p(t)=v(t)=e^{-\xi\omega t}(A\cos\omega_d t+B\sin\omega_d t)+\frac{P_0}{K}\left[\frac{1}{(1-\beta^2)+(2\beta\xi)^2}\right]^{1/2}\sin(\omega_f t-\phi)$$

(6)

With:

$$\beta=\frac{\omega_f}{\omega}$$

and:

$$\theta(t)=Ae^{-\xi\omega t}(\omega t+\phi)$$

Where:

$$\omega=\omega_f\sqrt{1-\xi^2}$$

The amplitude and the phase are:

$$\begin{cases}A=\sqrt{\theta_0^2+\left(\dfrac{\dot{\theta}_0+\xi\omega\theta_0}{\omega}\right)^2}\\ \phi=\arctan\left(\dfrac{(\dot{\theta}_0+\xi\omega\theta_0)}{\omega\theta_0}\right)\end{cases}$$

The self throbs of the structure are:

$$\omega_1=6\sqrt{\frac{EI_z}{\rho SL^4}}\quad \text{et}\quad \omega_2=40{,}98\sqrt{\frac{EI_z}{\rho SL^4}}$$

When taking $v_0=0.5m$, $\dot{v}_0=1ms^{-1}$, $\theta_0=0.5rad$, and $\dot{\theta}_0=1$ rad s^{-1} we obtain in the case as of free vibrations the solution represented on figure 3:

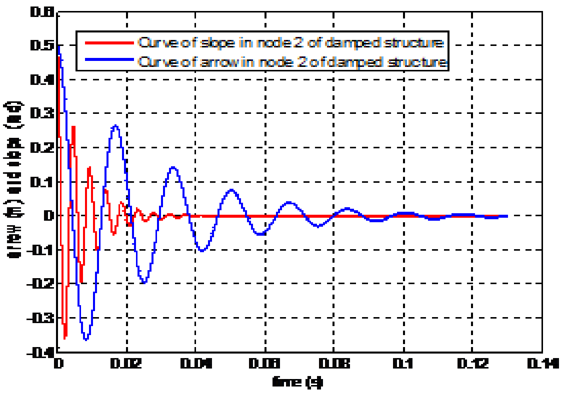

Figure 3: Graphs rotation and vertical displacement of node 2 of damping structure against time

When taking, $v_0=0.5m$, $\dot{v}_0=1ms^{-1}$, $\theta_0=0.5rad$ and $\dot{\theta}_0=1$ rad s^{-1} under harmonic forces of vibration amplitude P_0=10N and in the case of weak oscillations ($\xi=0.5$), we obtain the solution represented in figure 4:

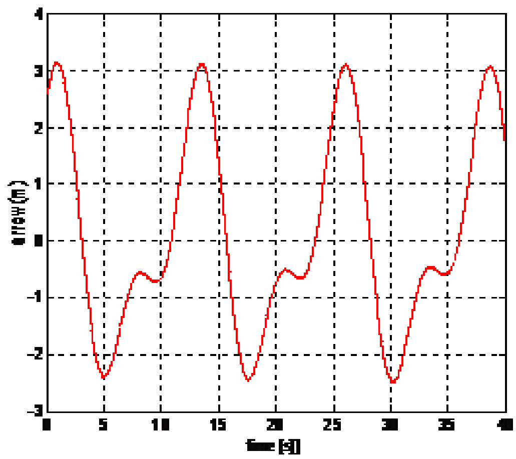

Figure 4: Graph of rotation of the node 2 of viscous swivel joint under harmonic force against time

When we plotted the rotation curves as a function of time, in figure 3, for t varying from 0 to 40 s per step of 0.01 s, we observed the attenuation of rotation, which characterizes the presence of damping. Beyond 0.12 s, rotation stops probably because of viscosity. To look further into this phenomenon, it is necessary to make several tests while varying the damping ratio.

On figure 4, t varies from 0 to 40 s and we did not observe the disappearance of signal. This is due to the presence of the external forces which are supposed to be harmonic. With this assumption rotation is maintained during the vibration of the framework. But that in the case of figure 3 (damped free oscillations) or the case of figure 4 (quenched forced oscillations) a major analysis of these swivel joints requires the comparison between the rotation of the swivel node and the node embedded in order to better understand the influence of these connections in the structures. This is the direction in which we will pursue our research in this field.

CONCLUSIONS

The work aims at proposing a method of modeling beams structures with swivel joints by taking into account the frictions in dynamics. The Lagrange's method allowed us to establish the motion equations of frameworks. The technical modal analysis permitted to solve the system of motion equations obtained and the cancellation of the transmission of moments in swivel nodes to the embedded node enabled. Graphs of the results give the opportunity to see the behavior of the deadened and free forced structures. But the completion of these swivel joints study requires investigation of several comparison and damping ratios between the behavior of the swivel nodes and the embedded nodes at the node where there is a swivel joint.

REFERENCES

[1] J.L. Batoz et G.Dhatt, «Modélisation des structures par éléments finis. Hermes Volume 2: poutres et plaques» (1990).
[2] L. R. Rakotomanana, «Eléments de dynamique des solides et structures déformables», Université de Rennes 1, (2006).
[3] M. J.Turner, R. W. Clough, H. C. Marlin, and L. J. Topp, «Stiffness and deflection analysis of complex structures». J. Aero. Sci., vol.23, (1956), PP 805-823.
[4] J.F. Imbert, «Analyse des structures par éléments finis. Ecole nationale supérieure de l'aéronautique et de l'espace». 3ème édition, Cepaduès édition 111, rue Nicolas – Vauquelin 31100 Toulouse.
[5] H. Bouabid, S. Charif d'Ouazzane, O. Fassi-Fehri et K. Zine-dine A, «Representation of swivel joints in computing tridimensional structures» 3ème Congrès de Mécanique, Tétouan, (1997).
[6] G.E. Ntamack, M. Dawoua Kaoutoing, T. Beda, S. Charif D'Ouazzane. «Modeling of swivel joint in two dimensional beams frameworks». Int. J. Sc. and Tech. 3, 1, (2013), 21-25.
[7] R. J. Guyan, « Reduction of stiffness and Mass Matrices », AIAA, 3; 80, (1965).
[8] Kerguignas, «La méthode des déplacements: application à la résolution des structures planes à nœuds rigides», EMI-RABAT, (1982).
[9] A. Bennani, V. Blanchot, G. Lhermet, M. Massenzio, S. Ronel, «Dimensionnement des structures», (2007).