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DIAGNOSTICS OF LOOSE CLAMPING JOINTS

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Abstract: *The point of this work is to examine dynamic properties of a bolted joint. The first task was to show the possibilities of modelling these bolted joints. We tried to compare simple models, the first one was prismatic beam, to beams connected in different ways, to match the measured values. Models were approximated based on data about natural frequencies and mode shapes. In the last step, we evaluated and compared the calculated values as well as the graphical solution of the mode shapes.*

Keywords: Fault detection, Modal analysis, Parameter identification, Correction of mathematical models, Lap joint models of overlapping components.

1. Introduction

In general, when modelling a screw joint, this connection is considered perfectly solid. Dynamic property simulations usually do not consider damping and stiffness properties of screw joints. In this work, we deal with the analysis of screw joints in beam systems. Screw joints are very often used to connect separate structures in the aerospace industry, such as the attachment of the aircraft engine. They are also the dominant connecting entity in structures that are subjected to intense dynamic loads. From this point of view, it is important to correctly understand the effect of screw joint parameters on the dynamic behaviour of connected structures. Significant damping in structures is directly related to the geometry and position of the screws. All components thus connected include sources of inaccuracy and nonlinearity, which are mainly caused by contact and friction between the different parts. Oscillation of parts such as aircraft engine can lead to a malfunction due to fatigue during the cycle. These structures are commonly subjected to high levels of vibration amplitudes, which are triggered by inertia forces. The complex behaviour of fasteners plays an important role in the overall dynamics of the structure, such as the damping ratio, natural frequencies, mode shapes, or nonlinear response to external excitation. It is therefore very important to observe the behaviour of such joints and to take them into account in modelled structures Titurus et al. (2016). In this work, we have mapped the different models of screw joints used in computing programs and try to create a trustworthy model in the ANSYS environment taking into account and approximating the dynamic properties of the screw joint.

1.1. Impact of changes in the physical properties of the joint on dynamic system parameters

The issue of the influence of changes in the physical properties of the screw joint on modal and spectral parameters is the subject of the work of Titurus et al. (2016). The screw joint is realized using two connected beams. The change in physical properties is represented by a change in the preload in the screw joint. For individual preload states, the author describes the experimental modal analysis for the integrated test system shown in Figure 1.

The results of the modal analysis describe changes in the natural frequencies of individual mode shapes and are further processed and compared. These results can be used to describe the nonlinear behaviour of given joint or to create or modify the created mathematical model.

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Fig. 1: Test system

Understanding the principle of linking changes in physical properties and changes in modal-spectral properties induced by them is the first step towards creating an algorithm for detecting damage to a given joint based on any of known detection methods.

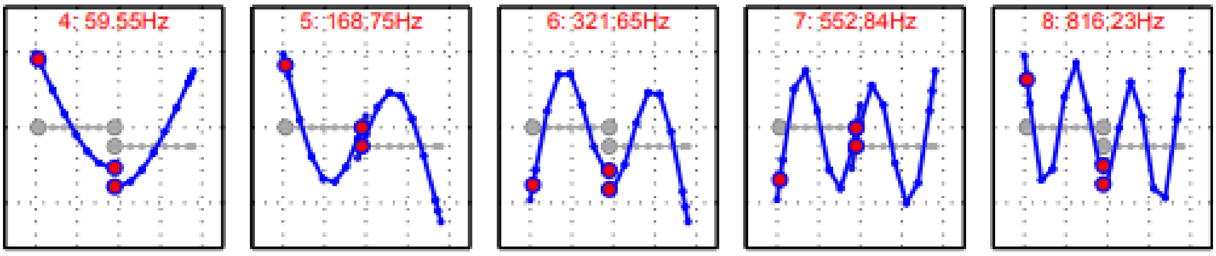

Fig. 2: The first five Eigen Frequencies and modal shapes of the test structure (Titurus, 2016)

1.2. Joints modelled using flexible-viscous elements

An approach based on the final thickness or zero interface thickness can be used to create an MKP model of contacting joint surfaces. In their work, Mayer and Gaul (2007) used a "segment-to-segment" element of contact that represents the approach mentioned above. This contact element can be described both linearly and nonlinear contact behaviour in both normal and tangential directions. The use of flexible-viscous members to model lap joints is engaged in the work of authors Gaul and Lenz (1997), who introduced the behaviour of the joint of overlapping components. A similar method of joint modelling was used by Ahmadian and Jalali (2007), who used a model with concentrated parameters consisting of a combination of linear and nonlinear springs and viscous damping members for the connection with the screw in the center of the overlapping elements, as can be seen in Figure 3.

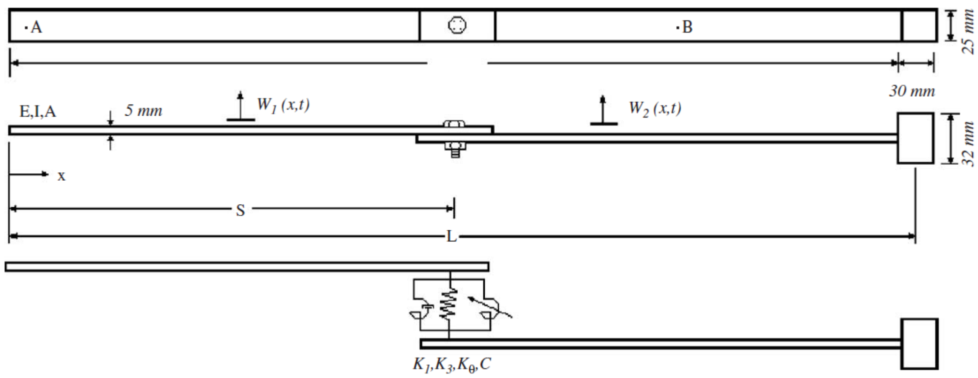

Fig. 3: The model is combined with flexible and viscous members

This model is created by two free Euler-Bernouli beams connected by their free ends using a screw joint. This connection was replaced by flexible and viscous members in order to describe nonlinearities. In particular, it is a translational flexible member expressed by the parameter K_1, as well as torsional linear and nonlinear springs expressed by parameters K_0 and K_3 and torsional viscous member represented by parameter C.

2. FEM screw joint

As we mentioned in Chapter 1, we also wanted to model the structure tested at work (Titurus, 2016) in ANSYS. In the work (Titurus, 2016), the author stated the respective design parameters and values of the first five natural frequencies with corresponding mode shapes. We used the same physical parameters of the systems for all cases. In the same way, the thickness and overall length of the beam remained identical.

First, we will use a smooth beam, the length of which is L = 0.76m, thickness b = 0.025m, height h = 0.008m, beam consists of steel with a density of ρ = 7850m3/kg, Young's elastic modulus E = 2,1*1011Pa.

Secondly, we analyse the same beam only with a thickened middle part. This part will characterize the screw connection between the two beams. This thickening is in the middle part of the beam and its length is l1 = 0.04m. At this length, the height of the beam h is doubled.

In the following analysis, we model the beam with the joint created by the offset function and the coupling function. Offset function moves the elements in the direction we choose and connects the two separate beams at the junction point and does not allow the node points to change the relative position.

Another model is a model of a screw joint using the spring element COMBIN40. This type of element is spring and its stiffness is used in size 1,15.108 N/m2. It was necessary to choose the mass of the spring element, but we left it elementary small so as not to affect the results of the analysis. Two elements used in the calculation model also have such rigidity. In the models, we have used the property of a gap element, which allows for a better approximation of the behaviour of the beams at the point of the screw joint. Its property allows the element to release the spring in a certain initial range, and we can simulate imperfect insertion at the point of the screw joint.

3. Mode shapes

We will show the joint location in more detail to see if we are getting collidizations between two nodes, in this we prove that we will use the third mode shape of the model with gap and with extra mass at the ends of the beams.

The calculations determined by the natural frequencies were for the so-called free system, just as the structure was tested. Shifts and rotations of individual node points remain valid. So we created a model with six ELEMENTS COMBIN40 in the place of the screw joint, all of which had the same stiffness. We have deployed the elements so that the middle two are without the possibility of a gap and the other four have this option. Thus, the four types of model structures were gradually calibrated:

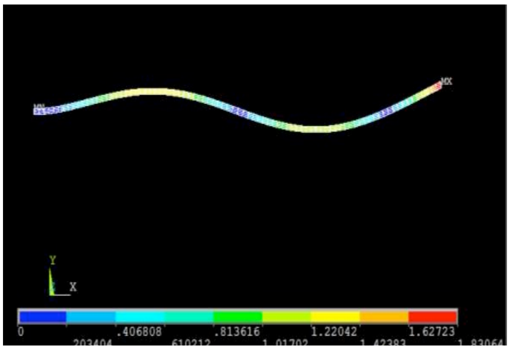

Fig. 4a: Mode shape of prismatic beam

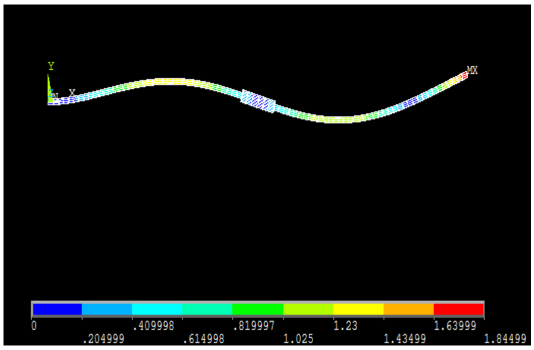

Fig. 4b: Mode shape of doubled beam

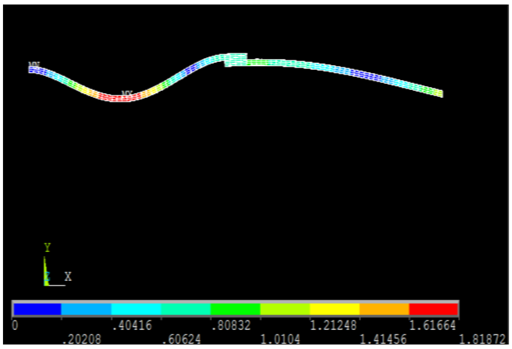

Fig. 4c: Mode shape with offset,

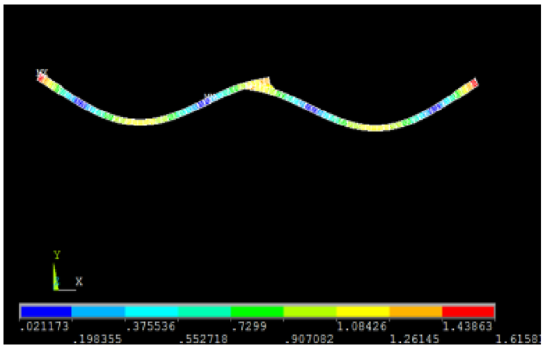

Fig. 4d: Mode shape wih flexible coupling and gap

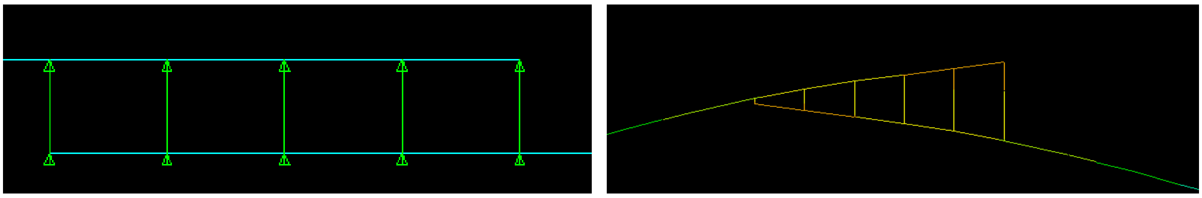

Fig. 5: Detail of flexible coupling and 3. mode shape

Tab. 1: Comparison of natural frequencies of the various model screw joints

Eig. Freq. [Hz]	Model with offset	Model with Comb.	Test structure
1	99,099	61,821	59,55
2	360,67	196,69	168,75
3	713,17	339,38	321,65
4	1073,1	640,69	552,84
5	1740,4	842,23	816,23

4. Conclusion

In this work, we summarized and showed different ways of modeling screw joints. It is important what form of calculation is used and we should take into consideration several aspects when creating a model. Ordinary beam structures have been compared to show that with very rough approximations, we can model the screw joint in this way as well. However, we must take care that there may be different deviations in the calculation. The structures were also compared by taking into account the screw joint in the form of an offset and the model with the connection of the beams using the coupling function. The model created using offset was stiffer than other models. In the last part, we modelled the screw joint as a connection of two or more spring elements. We used system parameters from previous research and compared the model thus compiled with a model that was calibrated using experimentally detected, measured values for the real system. It is very difficult without possible adjustment of parameters to find the model so that we achieve the desired result. We can conclude that we were able to model a trusted screw joint model using ANSYS software, and the model we created behaved similarly to the tested model, which was tuned to correlation with a real experiment.

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