REVISED ASSUMPTIONS FOR MONITORING AND CONTROL OF 3D LATTICE STRUCTURES

Witold Gutkowski, wgutkow@ippt.gov.pl
Institute of Mechanized Construction and Rock Mining,
Racjonalizacji 6, 02-673, Warsaw, Poland

Bartlomiej Blachowski, bblach@ippt.gov.pl
Institute of Fundamental Technological Reseach
Pawinskiego 5b, 02-106, Warsaw, Poland

Abstract. *A successful structural monitoring and control systems should be able to discern critical events, scan frequencies and dynamic ranges. This, in turn, requires that models, applied in these systems, are as close as possible to real structural behavior.*
Many structures, among them, electricity transmission towers, windmills, radio and TV masts, bridges and parabolic dishes, concentrating solar energy, are build as trusses. All of them are subjected dynamic loadings coming, mostly from wind gusts, water waves and thermal activity of sun.
The paper is revising assumptions, commonly made for trusses. The main assumption made is that systems of rods are pin joint. Such structures don't exist, in real engineering design. All, above, mentioned structures are made with rigid or flexible joints. The "pin joint" assumption was made for static analyses. It stated that if joint displacements caused by rod bending can be neglected, comparing with displacements caused by rod elongations, the structural system can be considered as pin joint. As it is commonly known, such cases occur when some necessary conditions joining number of joints and hinges are fulfilled.
The "pin joint", static assumptions has been, without any formal justification, taken for granted in dynamics. Simple examples presented in the paper show that "pin joint" assumption can lead to considerable errors.
The paper is illustrated with two numerical examples (simple 2 bar structure and 25 bar transmission tower). Presented examples allowing to compare results of different assumptions applied for structural elements connections.

Keywords: *lattice structures, monitoring, control, structural dynamics*

1. INTRODUCTION

Monitoring of structures and the ability to detect damage at the earliest possible stage is very important in many engineering structures. Health-monitoring techniques have been developed and employed as a means for an overall, continuous condition for assessment of complex structures. These complex systems are subject to faults, coming, among others, from assumed models, which should be, as close as possible to real structural behavior.

Many structures, among them, electricity transmission towers, windmills, radio and TV masts, bridges and parabolic dishes, concentrating solar energy, are built as trusses. All of them are subjected to dynamic loadings coming, mostly from winds, water waves and sun.

In last two decades, a lot of attention has been paid to the detection of damages in structures, among them in trusses. Smiths et al. (1988) present comparison and evaluation of several identification methods. Most were based on dynamic approach. Ayers et al. (1998) discussed a technique, using monitoring the structural mechanics impedance, which is changing in the presence of damages. Tong et al. (2000) investigated existence of solution of frequency optimization of trusses. Mickens et al. (2003) investigated a very important problem of damages of structural joint, which occur more often than damages in truss members. Park et al. (2002) proposed a nondestructive method of structural assessment, applying nondestructive damage detection, based on monitoring structural vibration. Gao et al. (2004) verified the method of the damage locating vector method by an experiment on a multi member truss. The experimental results didn't show any significant differences between eigenfrequencies of damaged and non damaged structures.

All above works, as well, as many others devoted to structural assessment are based on the assumption that trusses are structures with pin joints.

The paper is revising this assumption. In real engineering design, there are no structures composed of rods connected with hinges. All, above-mentioned structures are made with rigid or flexible joints. The "pin joint" assumption is valid only for static analyses. It stated that if joint displacements caused by rod bending can be neglected, comparing with displacements caused by rod elongations, the structural system can be considered as pin joint. As it is commonly known, such cases occur when some necessary conditions joining numbers of joints and hinges are fulfilled.

The "pin joint", static assumptions has been, without any formal justification, taken for granted in dynamics. Simple examples presented in the paper show that "pin joint" assumption can lead to considerable errors.

The paper is illustrated with numerical examples of two bar and 25 bar tower structures. Results of different assumptions, applied to the structural elements connections are discussed.

2. A SIMPLE PROBLEM PRESENTING THE DISCUSSED QUESTION

Consider two bar structure (Fig.1). Usually discussing trusses, we replace a real beam by an almost dimensionless straight line.

Two problems are solved. The first one, (a) is a frame with rigid connections. The second one (b) is a simplified model of the first one, with an assumption that the bars are connected with hinges. In static analyses, such an assumption is justified because the axial rigidity of a beam, by an order of hundred, or even more, is larger than the flexural one. If displacements caused by beam elongation and beam bending are of the same order, the internal forces caused by bending can be neglected. Then, the beam connections can be seen as hinges (pins).

This is not the case when dealing with dynamics. The eigenfrequency of the structure (a) should be calculated like for a frame. In the case discussed, both beams are divided into several finite elements, so the overall structure has many degrees of freedom. For structure (b), the number of degrees of freedom is two – say vertical and horizontal displacements of the connecting hinge.

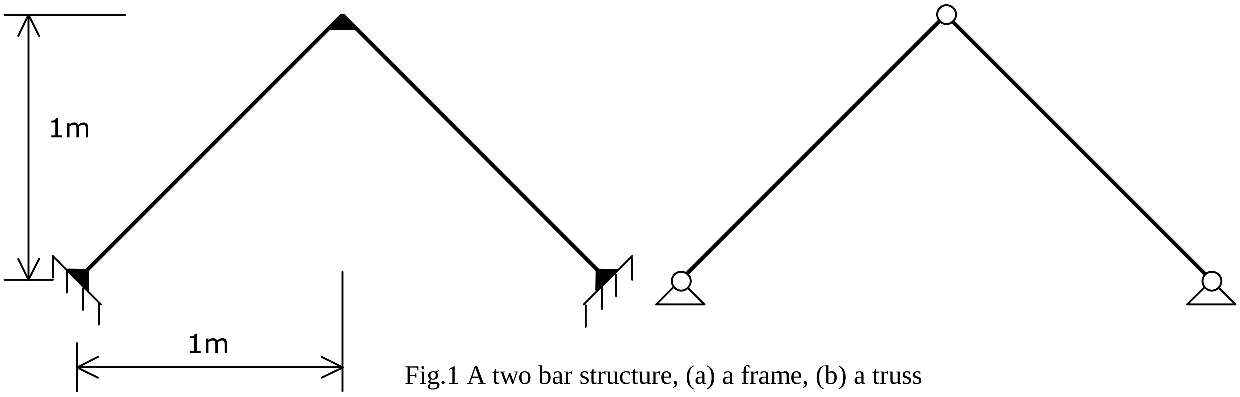

Fig.1 A two bar structure, (a) a frame, (b) a truss

In Fig.2, first eigenfrequencies, for both structures (a) and (b), related to varying beam cross section areas, and constant lengths, are presented. The very large differences between obtained results, for both cases, show, that pin joint assumption may lead to considerable errors if applied to frame dynamics.

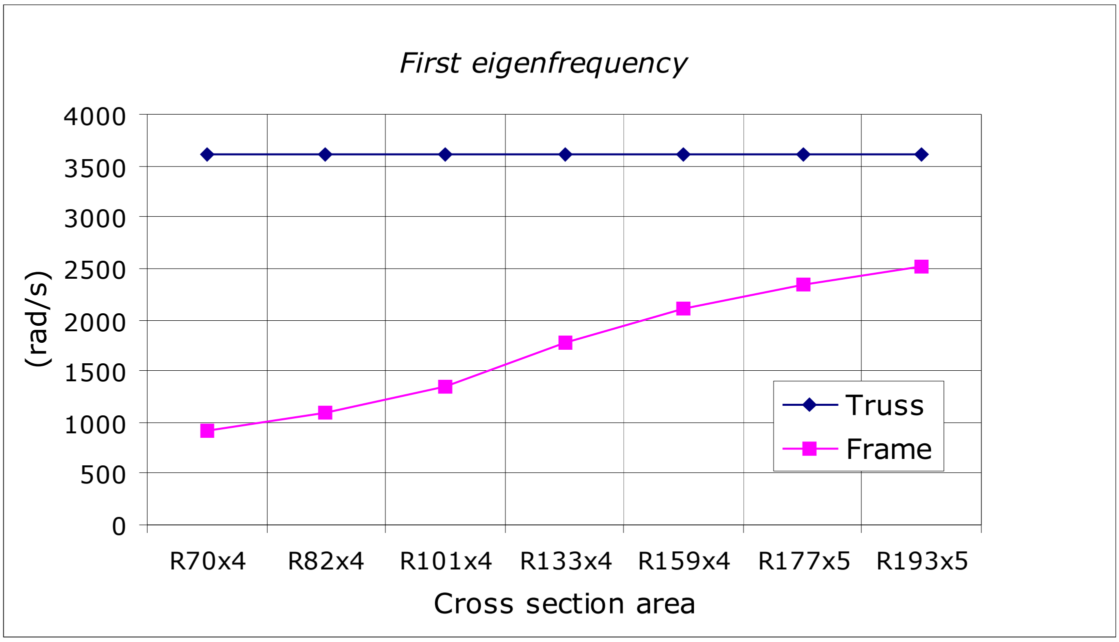

Fig.2 Comparison of the first eigenfrequencies for two bar structure.

3. VIBRATION OF A 25-BAR, 3D TRANSMISSION TOWER

The 25 bar truss, shown in Figure 3, is build with pipes of 159 mm diameter and 8 mm wall thickness. The material is steel, with Young modulus 205 GPa.

Two structures of the same geometry are discussed. The first one (a) is considered to be a truss. The second one (b) is seen as a frame. Both structures are solved for eigenfrequencis and eigenmodes.

In Fig.4a and 4c, two eigenmodes, together with their eigenfrequecies are presented, for the truss. In Fig.4b and 4d, also first two eigenmodes and egenfrequencies are shown for the same structure, however treated as a frame.

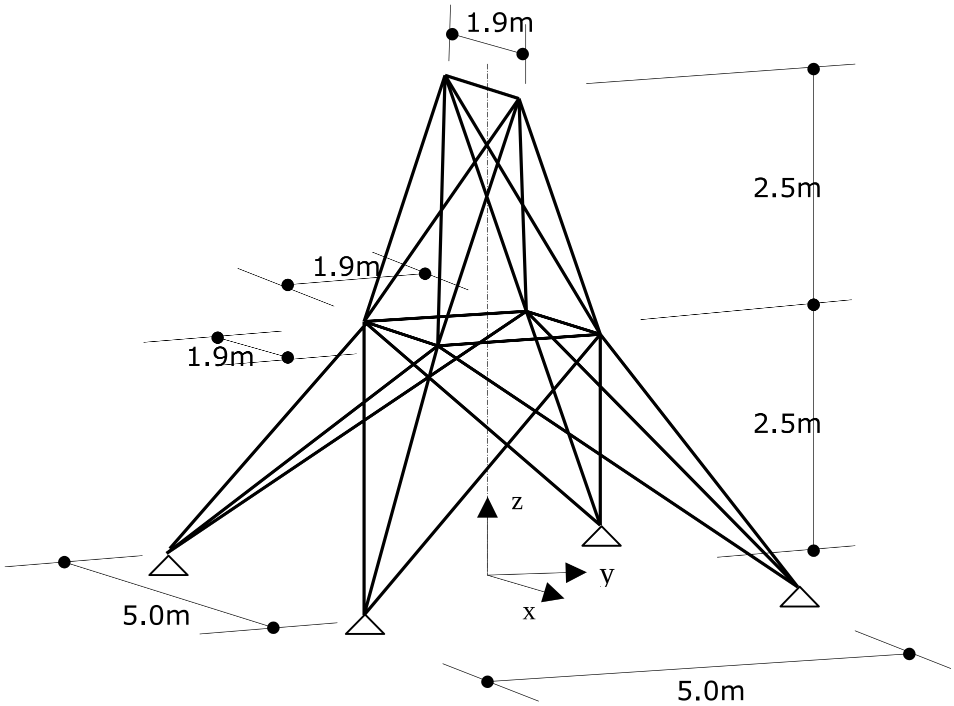

Fig.3. 25 bar transmission tower

It is interesting to note, that not only values of eigenfrequencies in both cases differ significantly, but also eigenmodes are completely different. In case of the truss, the first eigenmode is showing larger displacement of the upper part of the structure. This in the contrary to the fist eigenmode for frame, which is demonstrated by a kind of “local vibration” of lower structural members. The similar observation can be made concerning second modes.

4. CONCLUSIONS

A critical discussion of traditional assumptions made in the dynamic of trusses is undertaken. Result obtained for two structures show, that assumption on hinge connections of truss members may lead to significant errors in structural health monitoring. Particularly, results obtained for 25 bar structure justify such a statement.

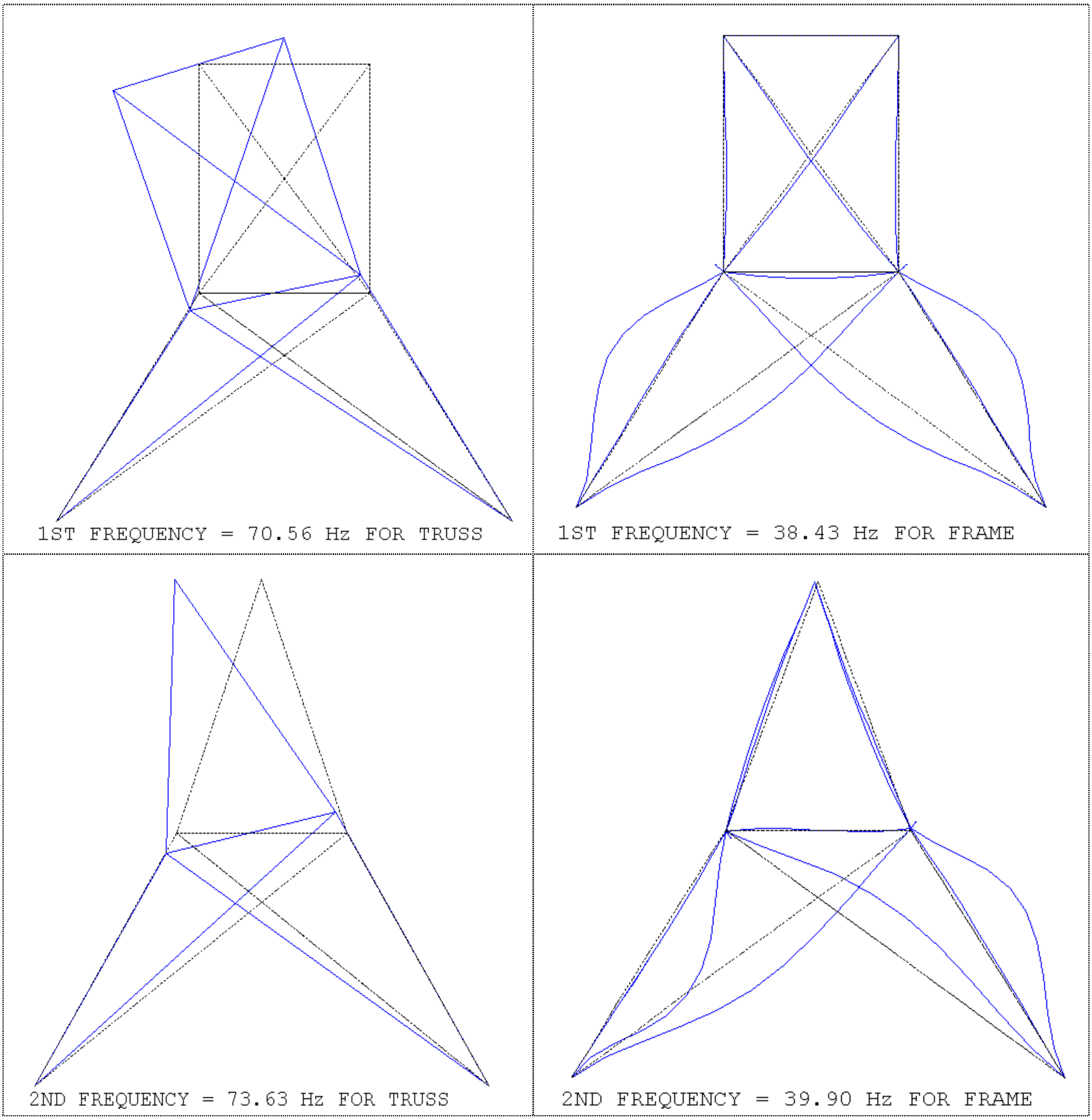

Fig.4 Two first eigenfrequencies and eigenmodes;(a) first eigenmode for the truss (view along y direction); (b) first eigenmode for the frame (view from y direction); (c) second eigenmode for the truss (view from x direction); (d) second eigenmode for the frame (view from x direction)

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