Analysis and modelling of rotational systems with the Modyfit application

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Analysis and modelling

ABSTRACT

Purpose: of this article is to present an application to analysis and modelling of rotational systems. Independent modules of application enables controlling and regulation of characteristics of systems in transportation. The base problem of analyzing systems in transportation is expressing the interaction between the main motion and local vibrations of subsystems.

Design/methodology/approach: Mathematical models derived in previous articles were used to implement the mathematical models in numerical calculations. The objectives of creating the Modyfit application were connected with analyzing and modelling rotating systems with taking into account relations between major and local motions. Considerations were done by the Galerkin's method.

Findings: There are many effects of analyzing systems with rotation consideration. Main of them are connected with analyzing systems in function of increasing the value of angular velocity. In such way of analyzing we can observe creating additional poles in the dynamical characteristics and we can also observe that instead of modes there are created zeros.

Research limitations/implications: Analyzed systems are simple linear homogeneous beams and rods. Working motion is limited to plane motion. Future research would consider complex systems, damping and nonlinearity.

Practical implications: of the application are numerical analysis of beams and rods in rotational transportation and designing such systems. Thank to the Modyfit we can derived the stability zones of analyzed beams and rods and we can observe eigenfrequencies and zeros in function of angular velocity.

Originality/value: The Modyfit is a forerunner implementation of derived models in a numerical environment of dynamical flexibility. Analyzing models are rotating flexible systems with consideration the rotational transportation effect.

Keywords: Numerical techniques; Computational mechanics; Applied mechanics; Transportation effect

1. Introduction

The problem of numerical computations of rotating machines and mechanisms very often is not enough appreciated. Aim of this thesis is present the numerical application for dynamical analysis of systems in rotating motion. This analysis enables modelling beam and rod systems in aspect of frequency response on dynamical flexibility characteristics.

Many technical books and articles e.g. [2-6, 12-13] concern the subject area of vibrating systems in transportation and as distinguished from ones concerning stationary systems [1, 7-11, 14-19] is the widening of the dynamical analysis at all. The program Modyfit enables the analysis of models of beams and rods rotating onto the one of planes of global reference frame. The systems are modeled as beams in case that the load was assumed as the unitary harmonic transverse force that generates flexural transverse vibrations and as rods in case that the load was assumed as the unitary harmonic axial force that generates longitudinal vibrations. Solutions of dynamical analysis of systems in motion can be objectives of practical applications on a wide scale. For example applications we can specify wind power plants, different kind of turbines, helicopters, and any other rotor systems, etc.

Because of the mathematical character of performing solutions, an approximate method, the Galerkin's method was decided to use. Dynamical flexibilities of analyzed systems derived using the Galerkin's method were compared with dynamical flexibility of stationary systems derived with help of "accurate" method. The results confirm the high effectiveness of given method in case of rotational system with the zero-value angular velocity. Based on this there was accepted the Galerkin's method as a sufficient method for objectives of analysis of systems in motion.

2. General information about the "Modyfit" application

The Modyfit is Modelling of Dynamical Flexible Systems In Transportation and it is an application made in Microsoft Visual Basic Programming Environment. In Figure 1 the print screen of the main window of Modyfit was presented.

The code of the application is based on mathematical models derived in previous research. The Modyfit is distributed as executive file and can be run under MS Windows XP operating system. A directory for Modyfit should be created on the hard disk or the application can be run form any other medium. To run the program, the MS Framework .NET ought to be installed first at least in 1.1 version. The Modyfit is a tool for dynamical analysis of both flexible rotating beams or rods and stationary ones. The program has very simple user's interface and is easy-to-operate. Therefore the easiest way of dynamical analyzing systems using the Modyfit is to adopt the analyzing systems to simple beam and rod systems, but of course there is a possibility to implement particular mathematical models into the Modyfit after separate agreement with authors.
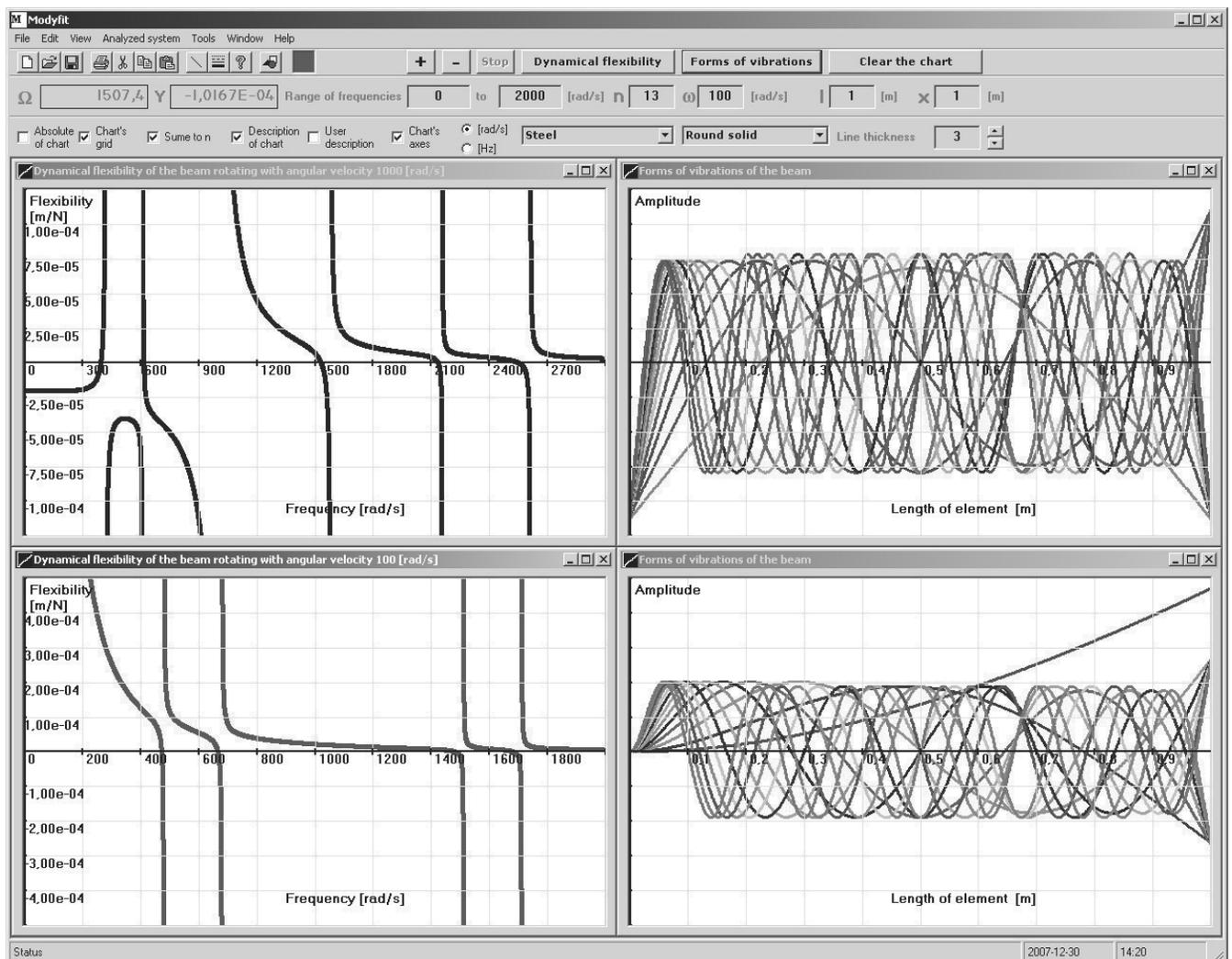
Fig. 1. Graphical interface of the Modyfit application

2.1. Option bar

The Modyfit application has some useful toolbars. In the Figure 2 there was presented the option bar of Modyfit application.

Fig. 2. The option bar of Modyfit application

That bar contains checkboxes of the main functions of the application such as:
- absolute of chart,
- chart's grid,
- sume to n,
- description of chart
- user description,
- chart's axes.

There are also option boxes for appropriate units, for example:
- radians per second,
- Hertz.

Users can also choose the material of analysed systems and choose the type of cross-section. Additional option is the line thickness drawing on the charts.

2.2. Navigation bar

In Figure 3 there are presented textboxes displaying actual value of frequency and applicable value of dynamical flexibility. Users can very easily read from the active chart interesting values of these numerical quantities.

Fig. 3. The information boxes

The Figure 4 presents the part of navigation bar that enables setting start and end of range of frequencies both in Hertz and in radians per second. There are also boxes to set the number of modes of vibrations and value of angular velocity treated in this environment as transportation velocity (in radians per second).

Fig. 4. The parameters sets boxes

Last part of the navigation bar is presented in the Figure 5. This part apply to the length of analyzing system and the dimension from where the dynamical flexibility was calculated.

Fig. 5. The boxes of geometrical dimensions of length and localisation of analyzed cross-section

2.3. Main menu

In main menu of the program there are following functions:
- file (opening, saving, printing, closing),
- edit (copying, pasting, cutting),
- view (toolbars, navigation bar, option bar, status bar, options),
- analyzed systems (project schemes, free-free rod, fixed rod, free-free beam, fixed beam, complex systems),
- tools (precision of the chart from highest performance to highest precision, analyzed system information, auxiliary lines, options),
- window (cascade, horizontal, vertical, arrange),
- help.

2.4. Toolbars

Apart form that users can take advantage of the small button menu with functionality of zooming charts, clearing charts and changing colours.

2.5. Chart's generating

The program makes possible generating of charts with default data or with data defined by users. Generating of charts is a very easy process with duration depending on chosen parameters of precision and type of the analyzed system.

3. Numerical examples

3.1. Dynamical flexibilities

The Modyfit application makes possible generating dynamical characteristics of beams and rods both stationary systems and moving ones. The example characteristics of systems in transportation were presented in this subsection. The characteristics concerns the beam system in transportation presented in Figure 6 and the rod system in transportation presented in Figure 7. In the Figure 6 the dynamical flexibility of the fixed beam rotating with angular velocity equal 100 rad/s was presented.

The dynamical flexibility of fixed rod rotating with angular velocity equal 500 rad/s was presented in the Figure 7. Users can place onto chart one or more functions comparatively.

There was presented the dynamical flexibility of free-free beam rotating with angular velocity equal 500 rad/s in the Figure 8.

In the Figure 9 there was presented the dynamical flexibility of rotating free-free rod system. That system is rotated with angular velocity equal 1500 rad/s.

Figure 10 presents the dynamical flexibility of fixed stationary beam system (assumed as rotational system with zero's velocity) for first, second and third modes of vibrations.

There is also an option to limit the range of chart, this option function close to zooming but that is not the same. Additional fault of this option is a possibility to emerge the computation errors such as presented in Figure 11, where errors occurs in first mode of vibrations. Figure 11 presents the same dynamical flexibility as presented in Figure 10, but the limit of amplitude is set. These unexpected errors are connected with the algorithm of computations and the way of generating the chart oneself. On present stage there are not practicability of analysis of nonlinear systems in the Modyfit but next version of the program should be developed in this direction both in geometrical and physical meaning. Nowadays systems were assumed as linear and isotropic.
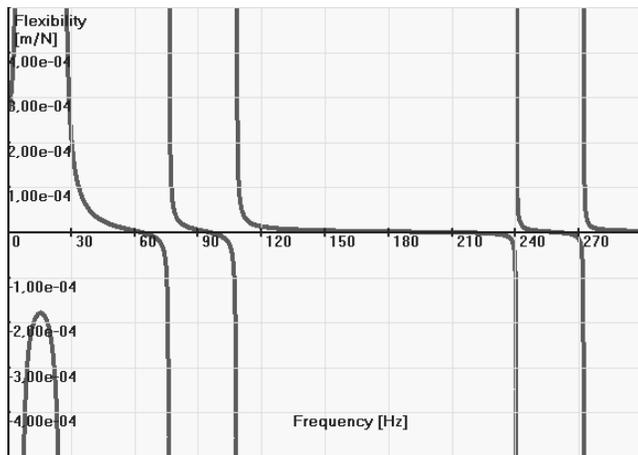
Fig. 6. Dynamical flexibility of the fixed beam system rotating with angular velocity equal 100 rad/s
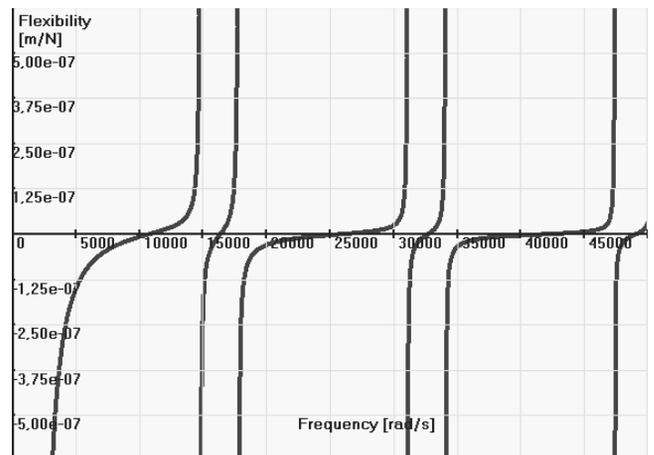

Fig. 7. Dynamical flexibility of the fixed rod system rotating with angular velocity equal 500 rad/s

Fig. 8. Dynamical flexibility of the free-free beam system rotating with angular velocity equal 500 rad/s

Fig. 9. Dynamical flexibility of the free-free rod system rotating with angular velocity equal 1500 rad/s
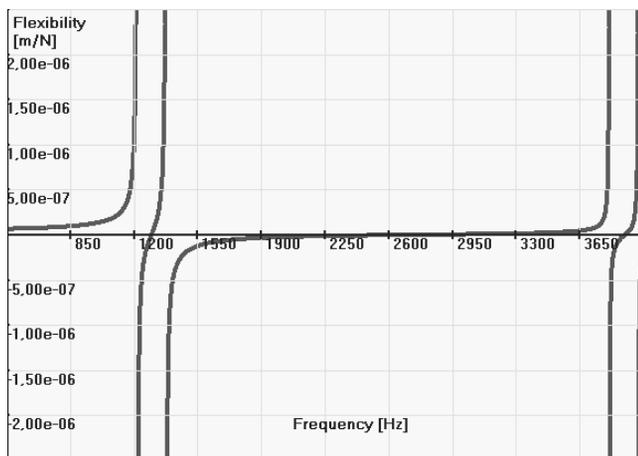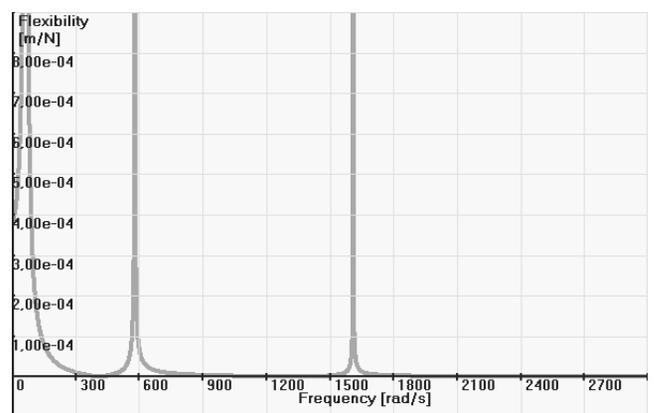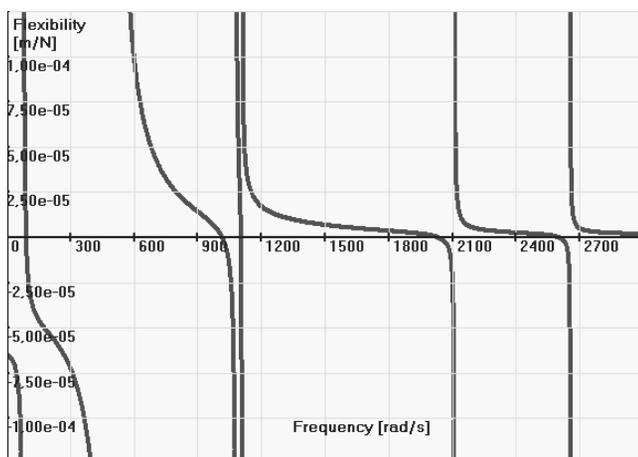

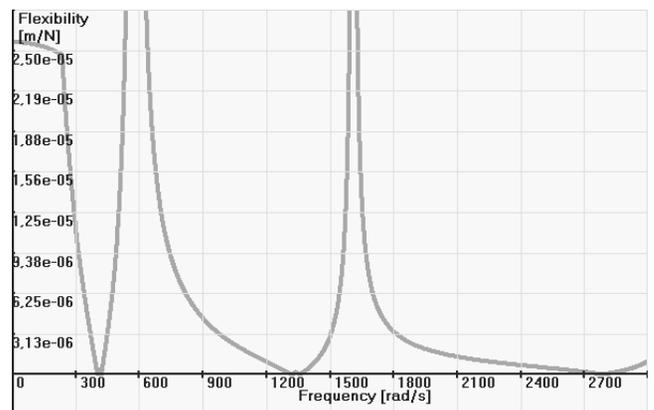Fig. 10. Dynamical flexibility of the fixed stationary beam system

Fig. 11. Dynamical flexibility of the fixed stationary beam system with limited range of the chart

The Figure 12 shows the second form of vibrations in a juxtaposition of different materials. The chart enables for users changing the material parameters for example for steel,

aluminium alloy, brass, bronze, lead, etc. Users can also define own values of material parameters, such as the Young modulus, moment of inertia, mass-density, etc.

In the Figure 13 the second form of vibrations was presented. The chart shows the change of eigenfrequencies and dynamical flexibility after changing the type of cross-section of analyzed system. These figures present only the example numerical characteristics without a deeper analysis and without drawing the conclusions from analysis.

The analysis of effect of angular velocity onto dynamical characteristics can be done in the program. Example analysis for velocities from zero to 100 rad/s was presented in Figure 14. The chart was presented in absolute quantities. In Figure 15 there was presented the chart of second and third modes of vibrations of dynamical flexibility of the fixed beam also as in Figure 14 for velocities from zero to 100 rad/s.
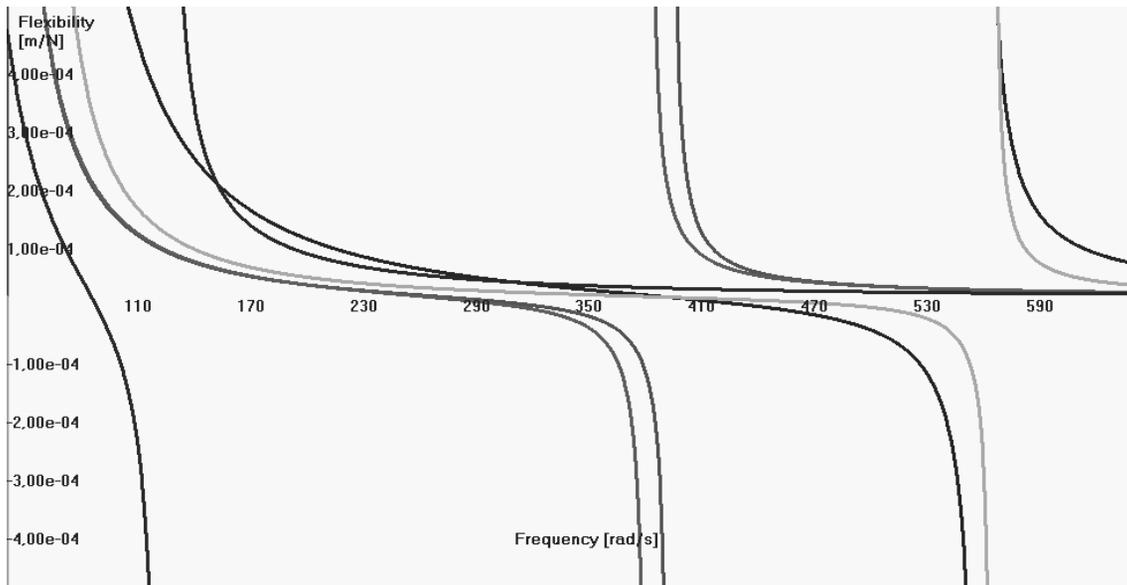

Fig. 12. Second mode of vibrations of the fixed beam system, the red line for brass, the orange line for steel, the black line for aluminium alloy, the green line for bronze, the blue line for lead
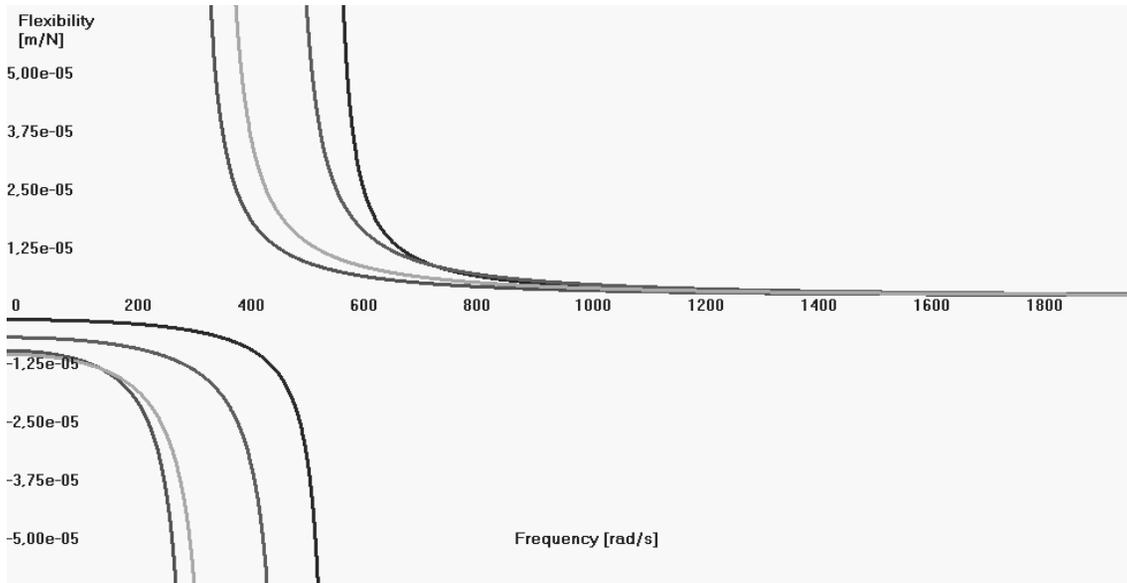

Fig. 13. Second mode of vibrations of the fixed beam system made by steel material, the red line for round cross section (0.01 m diameter), the blue line for round drifted cross section (0.01 m external diameter and 0.005 m internal diameter), the orange line for rectangle drifted cross section (0.01x0.01 m and the hole dimensions 0.005x0.005 m), the green line for square cross section (0.01x0.01 m)
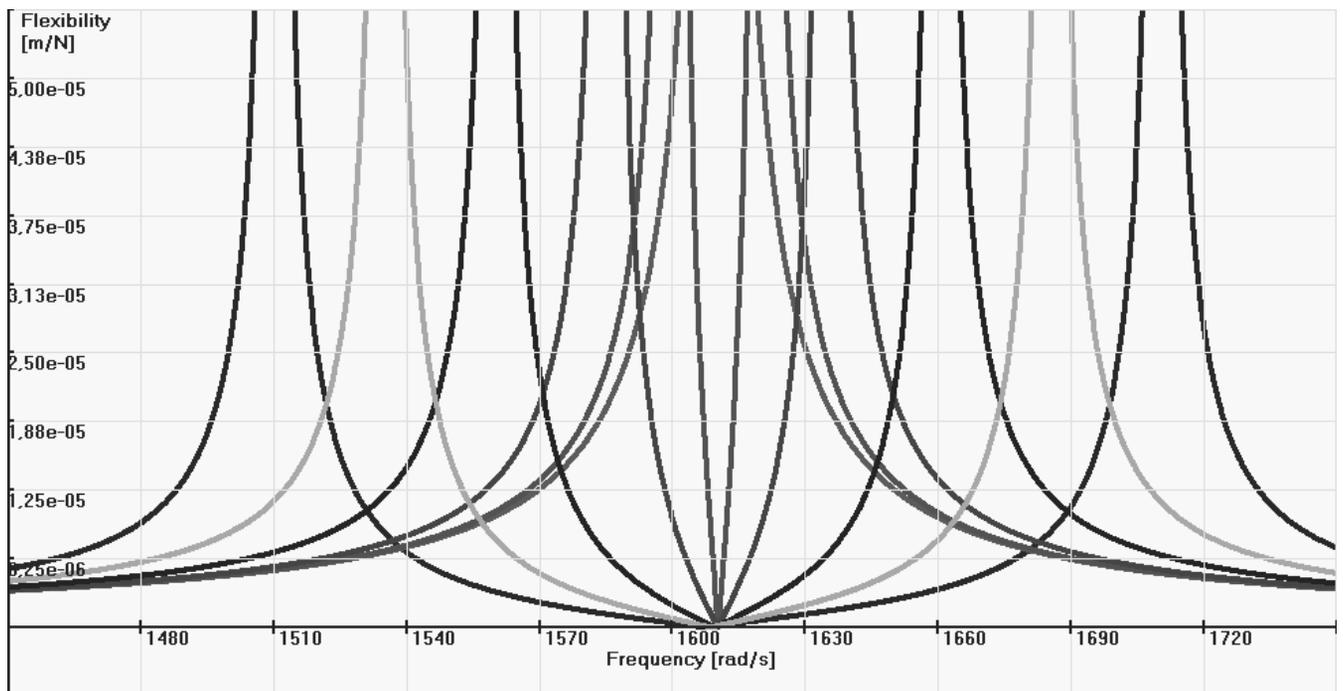
Fig. 14. Analysis of third mode of vibrations of the fixed beam system, undergoing increasing the angular velocity from zero's velocity to angular velocity equals 100 rad/s (absolute of dynamical flexibility)
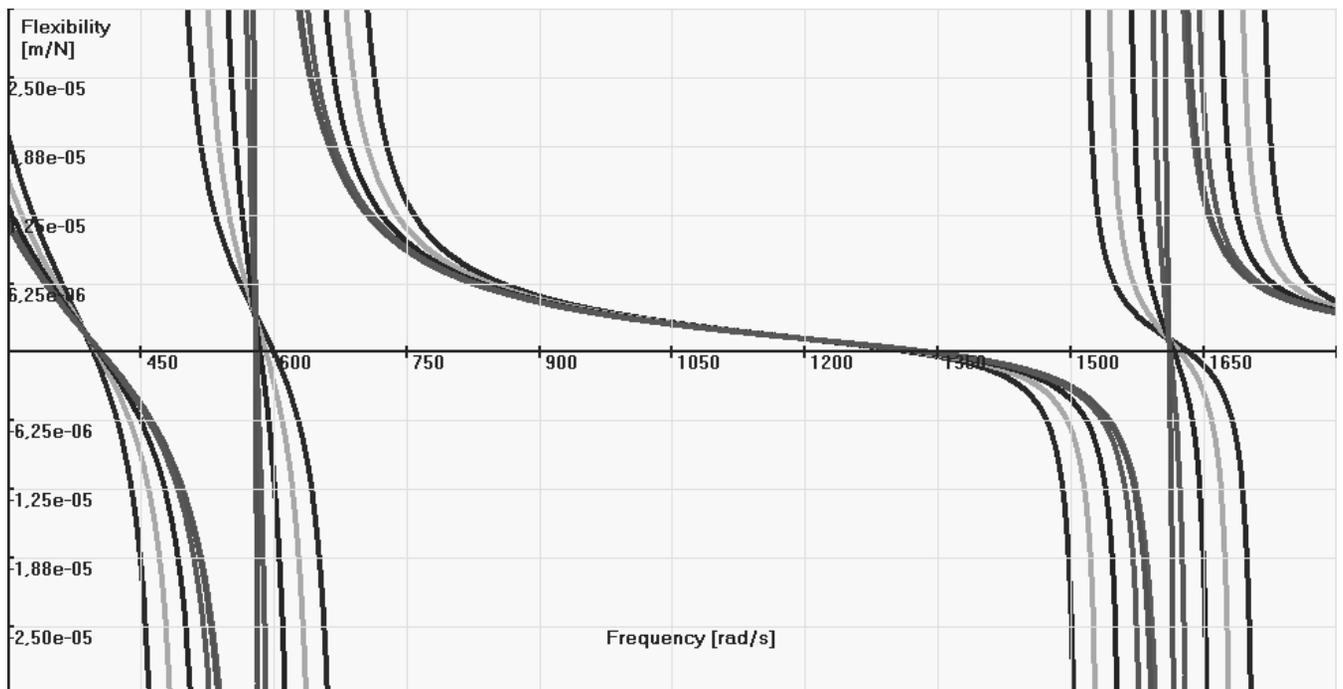

Fig. 15. Second and third modes of vibrations of the fixed beam system, undergoing increasing the angular velocity from zero's velocity to angular velocity equals 100 rad/s

3.2. Forms of vibrations

The Modyfit enables generating arbitrary form of vibrations and optional number of forms of vibrations presented as the chart of sum of these forms. In this subsection example forms of vibrations of analyzed systems generated in the application were shown.

In the Figure 16 there were presented twelve forms of vibrations of the free-free rod and in the Figure 17 there were presented twelve forms of vibrations of the fixed beam.
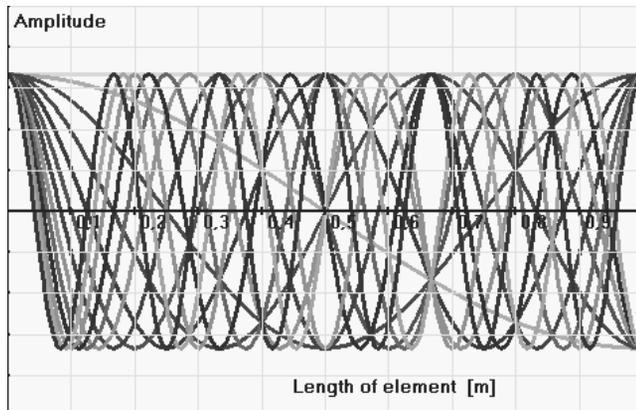

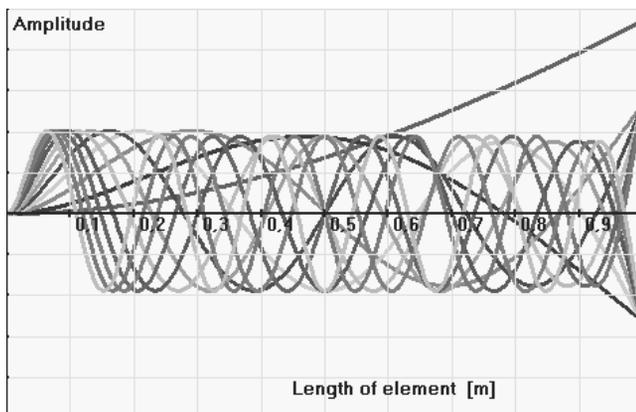Fig. 16. Forms of vibrations of the free-free rod

Fig. 17. Forms of vibrations of the fixed beam

4. Conclusions

In this work the numerical application MODYFIT (abbr. **M**odelling **O**f the **DY**namic **F**lexibility **I**n **T**ransportation [20]) was presented. This application is a numerical program based on derived in other works mathematical models of vibrating systems in transportation. The program is dedicated for generating dynamical characteristics of rod and beam systems. Fundamental calculations such as volume, cross-section area, mass-moment of inertia, geometrical dimensions, velocity of wave propagation can be done in this environment. Modyfit code uses the implemented mathematical models enclosing systems of equations of motion, forms of vibrations, eigenfunctions of displacement and dynamical flexibilities of simple and complex beam and rod systems in rotational motion treated as transportation. The program makes possible a more straightforward of simple rotational beams and rods. Users can very easily aid their designing processes by observing responses of systems after changing the fundamental parameters by performing in some cases very arduous computations many times. In the program many of parameters applying to analyzed systems are default and can be treated as symbolic values that do not effect on final results of calculations and users can change only interesting themselves values neglecting others. There is also a possibility for modelling of geometrical parameters of systems such as type of cross section (for example full round cross section, rectangle, square and drifted ones) and of course overall dimensions. Those facilities provide for time savings in dynamical analysis. All numerical quantities were used with compatible SI system units. The code of the Modyfit application was written in MS Visual Basic.

Acknowledgements

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