SUBSECTION 3.2.
COMPOSITE THIN-WALLED STRUCTURES

DESCRIBING THE DIFFUSION OF ELASTIC AND SOLITARY WAVES IN LAYERED STRUCTURAL ELEMENTS WITH LINEAR-ELASTIC AND VISCO-ELASTIC CONTACT INTERACTION FORCES USING PRECISE ROD MODELS

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It is shown that rod models can be used to describe dynamic processes in layered structural elements. An example of a two-stratum rod with longitudinal oscillation is given.

The compound rod considered is a combination of two bars contacting each other. The contact interaction force is assumed to be linear-elastic. The motion of the rods is described by a system of equations: at an initial time, a pulse of the cinematic or force nature is applied to the left end of the rods, the right end being free.

The above system can be reduced to a single equation in terms of the median line displacement of one of the rods. A similar equation can be derived in Mindlin-Herrmann's model describing longitudinal oscillations of the rod. Thus, longitudinal oscillations of a compound rod can be described by Mindlin-Herrmann's equation of longitudinal oscillations of a hypothetical rod. Reduction to Mindlin-Herrmann's model is possible if the parameters of the compound rod satisfy the following condition: the product of the density and the cross-section area of the first rod are thrice as much as that of the second one. For the system of parameters to be simultaneous, it is also necessary that the longitudinal and shear wave velocities are equal. In that case, the thickness of the equivalent rod will increase with increasing the force of elastic interaction of the rods and will decrease with decreasing the linear density of the first rod. The correcting coefficients in Mindlin-Herrmann's model are related with the parameters of the initial rods, allowing one to derive the expression for the shear wave velocity in the following form:

In the particular case, if the density of one of the rods is considered to be small, the equation set will be reduced to the equation of longitudinal oscillations of a rod in Bishop's model. In that case, the parameters of the compound rod have to satisfy the following condition: the relation of Young modulus of the second rod to that of the first one is to be bigger than the relation of the cross-section area of the first rod to that of the second one, while the polar radius of inertia and Poisson's coefficient of the equivalent rod are to be determined by relations.

The longitudinal and shear wave velocities in a rod in Bishop's model are expressed in terms of the longitudinal wave in the initial rod.

The wave energy in homogeneous dispersing systems is known to be transferred at a group velocity [1].

A dynamic equation of a rod characterized by a Lagrangian depending on the longitudinal displacements and their partial derivatives was derived. The energy density and the flow density of the wave energy are derived from the energy transfer equation and phase-averaged. The notion of the wave energy transfer velocity is introduced, representing the ratio of the average value of the energy flow density to the average value of the wave energy density. The displacements obey the progressing harmonic wave law, which is used to determine frequency, wave number and group velocity. Thus, the wave energy velocity and the group velocity are shown to be equal; hence the elastic wave energy is transferred over layered structural elements at the group velocity as well.

A compound rod is then considered; the contact interaction force is assumed to be linear visco-elastic. The motion of the rods is also described by a system of equations. The system can be reduced to a single equation in terms of the median line displacement of one of the rods. It is noted that an analogous equation can be derived in Mindlin-Herrmann's system.

Thus, the longitudinal vibrations of a compound rod, both for the elastic and visco-elastic contact interaction, are described by Mindlin-Herrmann's equation of longitudinal oscillations of a hypothetical rod.

A nonlinear-elastic compound rod is also considered. The motion of the rods is described by an equation system: with elastic and viscous interaction forces. As in the above cases, the system is reduced to a single equation in terms of displacements of one of the rods.

Then notation in dimensionless values is introduced, partial derivatives are expressed and the notations are used. After the transformations, the equation for the dimensionless value is obtained. This equation can be reduced to non-linear generalized Mindlin-Herrmann's equation, which later, following the transformations, will be rewritten in the form of a differential equation describing the oscillations of a non-harmonic oscillator with quadratic nonlinearity [2]. The parameters of the differential equation are evaluated, and the roots of the denominator are determined.

Two cases are considered: that of a positive and that of the negative soliton [3]. In each case, the amplitude and the oscillation time are determined. Each form of these solutions is represented on the diagrams. It can be concluded that: in the case of a positive soliton, the oscillation amplitude increases and the oscillation time decreases with the velocity, which is characteristic of a classical soliton; whereas in the case of a negative soliton, the oscillation amplitude decreases and the oscillation time increases with the velocity, which is characteristic of a non-classical soliton.

In the case of a classical soliton, the investigation of the behavior of the oscillation amplitude showed that, if its parameters in the formula are related in such a way that one of them contained in the numerator increases, the rest of them contained in denominator decrease, then the oscillation amplitude increases.

For the case of a non-classical soliton, the behavior of the oscillation amplitude was also studied. It was found that, if the parameters in the formula are related in such a way that, one of them contained in the numerator increases, the rest of them contained in denominator decrease, then the oscillation amplitude increases.

Thus, the propagation of solitary waves in a nonlinear elastic compound rod has been demonstrated. Depending on the velocity, waves are divided into classical and non-classical ones. The behavior of the oscillation amplitude for a classical and a non-classical soliton has also been studied.

References

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РАЗРАБОТКА И ИЗГОТОВЛЕНИЕ ШПАНГОУТОВ И ДРУГИХ ИЗДЕЛИЙ СИЛОВОГО НАБОРА ИЗ КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ

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Одним из наиболее распространенных методов изготовления конструкций из композиционных материалов является метод намотки. В зависимости от применяемого оборудования и структуры армирования на сегодняшний день известны следующие технологии намотки: спирально-кольцевая; орбитальная (плоскостная); продольно-поперечная; совмещенная; зонная; косослойная продольно-поперечная (КППН).

За счет непрерывности намотки, управления параметрами натяжения и содержания связующего можно достичь высокой прочности и жесткости материала конструкции. На сегодняшний день достигнуты характеристики прочности армирующих волокон в микропластике ~ 600 кг/мм^2, модуля упругости ~16000 кг/мм^2 (Русар-С).

Метод намотки и программное обеспечение для станков с ЧПУ наиболее разработаны для изготовления оболочек вращения типа цилиндр, конус, сфера, овалоид и их комбинаций. Для траекторий намотки используются геодезические линии и траектории с отклонением от геодезических линий в пределах конуса трения.

В качестве элементов подкрепления тонкостенных оболочек, выполненных методом намотки, наиболее широкое применение нашли шпангоуты сплошного поперечного сечения, изготавливаемые послойной тканой или нитяной намоткой. Масса таких шпангоутов является весьма значительной, до 30% массы подкрепленной оболочки, а конструкция нерациональной. Поэтому весьма актуальна задача замены сплошных шпангоутов на более эффективные в весовом отношении - профильные (тавровые, коробчатые и др.).

Анализ научно-технической литературы и патентный поиск позволили