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MOTION OF A CYLINDRICAL NET WITH A MASS AT THE END

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Abstract. The motion of a semi-infinite cylindrical net with a mass at one end is examined. The cylindrical net, with a mass at one end, is initially stretched. Addressing the problem of wave propagation in deformable filament systems, accounting for significant deviations from their original rectilinear shape, presents considerable mathematical complexity, as the equations of motion constitute a system of nonlinear partial differential equations. The solution, derived using characteristic equations, reveals the occurrence of traveling waves. This solution is constructed by satisfying conditions at the point of contact between the net and the load. The results are presented in the form of graphs and tables.

Keywords: Cylindrical net, motion equation,deformation, wave propagating.
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1 Introduction

Net systems are utilized in various fields of modern technology, including aviation, fishing, and construction. And these systems are subjected to the effects of intensive short-term loads.

The equation of net motion was first written down in Rakhmatulin (1947). Based on the theory of H.A. Rakhmatullin the equations of motion of the net were obtained.

In Agalarov et al. (2019), a study on the unloading wave in a cylindrical mesh of nonlinear elastic fibers was conducted. Various shapes of waves propagating in the net were investigated. The distribution of constant deformation along the characteristics is determined based on the velocity distribution at the boundary.

In Rustamova (2019), unloading waves in a cylindrical net of nonlinear elastic fibers were examined. An attempt was made to address the problem of continuous waves, considering multiple options for wave propagation in cylindrical nets.

A study on the flat form of nets was conducted in Agalarov & Rustamova (1998). In Agalarov & Efendiev (1988), a motion of a continuous model network is investigated under a transverse impact caused by a point load and by a rigid cone. The nonlinear differential equations obtained are solved analytically and with the finite difference method. The network consists of two sets of flexible filaments, the elements of which are fixed at the intersection points. The equations,

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describing the front of the plane waves, are derived, and solved for two cases: the net a) without b)with prestressing before shock. The results confirm the theoretical solutions.

Articles Seyfullayev & Rustamova (Gulieva) (2000); Rustamova (Gulieva) (2002); Agalarov & Rustamova (2002); Agalarov et al. (2022) focus on the investigation of nets in a rectangular Cartesian coordinate system. Both non-one-dimensional dynamic problems and net equilibrium were examined. To study wave propagation, the equations of motion for the net are provided in both rectangular Cartesian coordinates and natural coordinates.

In Eremeev (2018), a continuum model was proposed for a specific class of elastic shells undergoing finite deformations. This model utilizes the equations from the six-parametric theory of shells. Within this framework, the shell's kinematics is described using six kinematically independent scalar degrees of freedom, including displacement and rotation fields. This characteristic resembles the Cossera continuum, leading to the model being referred to as the theory of micropolar shells.

The work Azarov (2018), which is a review, focuses on the problem of designing mesh composite structures extensively utilized in domestic rocket and space technology. It discusses the design and technological concepts, methods of design, and primary applications of mesh aerospace structures. The results achieved in this field by the scientific school of Academician V.V.Vasiliev are highlighted.

The work Vasiliev (2020) explores mesh cylindrical shells fabricated from modern composite materials using the automatic continuous winding method, known for their high degree of weight efficiency and extensive utilization in aerospace engineering. It addresses the optimal design problem of these shells, focusing on minimizing mass while adhering to strength and stability constraints. By employing a method that minimizes safety factors for potential forms of failure, an analytical solution is derived to determine the optimal design parameters of the composite mesh shell.

In recent years, precise equations describing the motion of a deformable thread under large deviations have garnered significant attention. This interest is partly driven by the technical applications of the physical phenomena elucidated by these equations. For instance, Kerimov (1960)addressed the transverse impact problem using exact solutions of the simple wave type, demonstrating that these equations furnish a fundamental theoretical framework for conducting experimental studies on material behavior under substantial dynamic deformations and high strain rates.

In Lopatin & Khakhlenkova (2018), a design for the connecting compartment of a spacecraft (adapter) was proposed. It consists of two mesh composite conical shells and a three-layer load-bearing panel, intended to accommodate three spacecraft. A finite element model of the adapter has been developed, and a program generating it has been created. An analysis was conducted on the influence of the parameters of the three-layer panel and the parameters of the mesh structure of the shells on the main frequency of transverse vibrations. A set of parameters has been determined to ensure a given oscillation frequency.

2 General equations of motion of the net

In practice, there may be a stretched cylindrical net with a load at one end that is initially motionless. Here, the motion of such a cylindrical net with a mass at one end is investigated.

Suppose that the cylindrical net with a mass at the end is in a stretched state. At a certain point in time, the load is released, and both the load and the net begin to move. Waves arise within the net, and it is necessary to determine their intensity. It is assumed that the net maintains its initial cylindrical shape, which is feasible with certain supports. Such pipes are used, in particular, when drilling and flushing wells. In practice, these phenomena can occur in flexible pipelines.

In Figure 1, the components are labeled as follows: 1 – net, 2 – porous filler, 3 – mass.

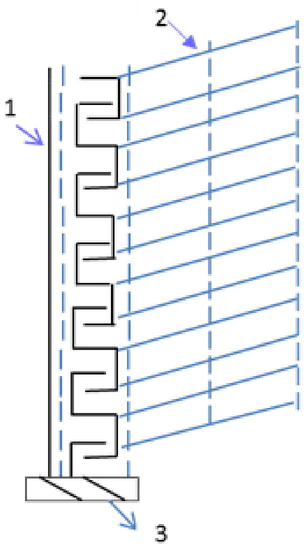

Figure 1. 1 – net, 2 – porous filler, 3 – mass.

The equation of motion of the net in space, constructed based on the theory of Rakhmatullin H.A., takes into account the reaction of the supporting body and the geometric relations. This form contrasts with that of (Rakhmatulin, 1947).

$$\begin{gathered}\frac{\partial}{\partial s_1}\left(\sigma_1 \overrightarrow{\tau_1}\right)+\frac{\partial}{\partial s_2}\left(\sigma_2 \overrightarrow{\tau_2}\right)=2\rho \frac{\partial^2 \vec{r}}{\partial \tau^2}+p\,\vec{n}, \\ \left(1+e_1\right) \overrightarrow{\tau_1}=\frac{\partial \vec{r}}{\partial s_1} ; \quad\left(1+e_2\right) \overrightarrow{\tau_2}=\frac{\partial \vec{r}}{\partial s_2} .\end{gathered} \tag{1}$$

Here $\vec{r}$ is the radius vector of the net particle, p is the reaction force of the support; $e_1,\ e_2$ are relative elongations of the corresponding threads; $s_1,\ s_2$ are the Lagrangian coordinates of the thread particles; $\sigma_1,\ \sigma_2$ are the conditional stresses, ρ is the mass of the net coming per unit area in the initial state; $\tau_1,\ \tau_2$ are the unit vectors tangent to the threads; $\vec{n}$ is the normal to the surface of the base.

The following are taken as the basis of the cylindrical system: the unit vector $\bar{i}$ is parallel to the axis of the cylinder, $\bar{j}$ is a unit vector tangent to the cross section of the cylinder, $\bar{k}$ is a unit vector perpendicular to the previous ones.

Then

$$\bar{\tau}_1=\cos\gamma_1\ \bar{i}+\sin\gamma_1\ \bar{j};\quad \bar{\tau}_2=\cos\gamma_2\ \bar{i}+\sin\gamma_2\ \bar{j},$$

where $\gamma_{1,2}$ are the thread angles formed with the axis of the cylinder.

Derivatives

$$\frac{\partial\bar{\tau}_1}{\partial s_1}=\cos\gamma_1\ \frac{\partial\bar{i}}{\partial s_1}+\bar{i}\frac{\partial\left(\cos\gamma_1\right)}{\partial s_1}+\sin\gamma_1\ \frac{\partial\bar{j}}{\partial s_1}+\bar{j}\frac{\partial\left(\sin\gamma_1\right)}{\partial s_1},$$

$$\frac{\partial\bar{\tau}_2}{\partial s_2}=\cos\gamma_2\ \frac{\partial\bar{i}}{\partial s_2}+\bar{i}\frac{\partial\left(\cos\gamma_2\right)}{\partial s_2}+\sin\gamma_2\ \frac{\partial\bar{j}}{\partial s_2}+\bar{j}\frac{\partial\left(\sin\gamma_2\right)}{\partial s_2},$$

or considering

$$\frac{\partial\bar{i}}{\partial s_1}=\frac{\partial\bar{i}}{\partial s_2}=0;\quad \frac{\partial\bar{j}}{\partial s_1}=-\frac{\sin\gamma_1}{r}\bar{\kappa};\ \frac{\partial\bar{j}}{\partial s_2}=-\frac{\sin\gamma_2}{r}\bar{\kappa}.$$

It follows that:

$$\frac{\partial\bar{\tau}_1}{\partial s_1}=\frac{\partial\left(cos\gamma_1\right)}{\partial s_1}\bar{i}-\frac{\left(\sin\gamma_1\right)^2}{r}\bar{\kappa}+\frac{\partial\left(\sin\gamma_1\right)}{\partial s_1}\bar{j},$$
$$\frac{\partial\bar{\tau}_2}{\partial s_2}=\frac{\partial\left(cos\gamma_2\right)}{\partial s_2}\bar{i}-\frac{\left(\sin\gamma_2\right)^2}{r}\bar{\kappa}+\frac{\partial\left(\sin\gamma_2\right)}{\partial s_2}\bar{j}. \tag{2}$$

Also considering $\overrightarrow{r}=x\overrightarrow{i}+r\overrightarrow{\kappa}$ then,

$$\frac{\partial\overrightarrow{r}}{\partial t}=\frac{\partial x}{\partial t}\overrightarrow{i}+r\frac{\partial\overrightarrow{\kappa}}{\partial t}=\frac{\partial x}{\partial t}\overrightarrow{i}+r\omega\overrightarrow{j},$$

$$\frac{\partial^2\bar{r}}{\partial t^2}=\frac{\partial^2 x}{\partial t^2}\overrightarrow{i}+r\frac{\partial\omega}{\partial t}\overrightarrow{j}+r\omega\frac{\partial\overrightarrow{j}}{\partial t}\ \text{ or }\ \frac{\partial^2\bar{r}}{\partial t^2}=\frac{\partial^2 x}{\partial t^2}\overrightarrow{i}+r\varepsilon\overrightarrow{j}+r\omega^2\overrightarrow{\kappa}. \tag{3}$$

x is the coordinate along the axis of the cylinder, ω is the angular velocity, ε is the angular acceleration.

When substituting equations (2) and (3) into equation (1), the following is found:

$$\frac{\partial}{\partial s_1}\left(\sigma_1\cos\gamma_1\right)+\frac{\partial}{\partial s_2}\left(\sigma_2\cos\gamma_2\right)=2\rho\frac{\partial^2 r}{\partial t^2},$$

$$\frac{\partial}{\partial s_1}\left(\sigma_1\sin\gamma_1\right)+\frac{\partial}{\partial s_2}\left(\sigma_2\sin\gamma_2\right)=r\varepsilon, \tag{4}$$
$$-\frac{\sigma_2}{r}\sin^2\gamma_2-\frac{\sigma_2}{r}\sin^2\gamma_2=p+2\rho r\omega^2.$$

Next, the symmetrical arrangement of right and left fibers is considered. Then, equations (4) are considered:

$$\sigma_1=\sigma_2=\sigma,\gamma_1=-\gamma_2=\gamma,\omega=0,\varepsilon=0$$

will take the form:

$$\frac{\partial}{\partial s}\left(\sigma cos\gamma\right)=\rho\frac{\partial^2 r}{\partial t^2},$$
$$-2\sigma\sin\gamma=p. \tag{5}$$

Let the derivative of the radius vector be defined by r with respect to s. Denoting:

$$\overrightarrow{r}=x\overrightarrow{i}+r\overrightarrow{k},$$

$$\frac{\partial\bar{r}}{\partial s}=\frac{\partial x}{\partial s}\bar{i}+\frac{\partial\kappa}{\partial s}r=\frac{\partial x}{\partial s}\bar{i}+\frac{\partial y}{\partial s}\bar{j},$$

y is the circular coordinate, where according to (1) and (2):

$$(1+e_1)\cos\gamma_1\overrightarrow{i}+(1+e_1)\sin\gamma_1\overrightarrow{j}=\frac{\partial r}{\partial s_1},$$

$$(1+e_2)\cos\gamma_2\overrightarrow{i}+(1+e_2)\sin\gamma_2\overrightarrow{j}=\frac{\partial r}{\partial s_2}.$$

Taking into account the above, the following will be written:

$$(1+e)\cos\gamma=\frac{\partial x}{\partial s}, \tag{6}$$

$$(1+e)\sin\gamma=\frac{\partial y}{\partial s}. \tag{7}$$

Since the set does not rotate, y is constant, then (over time)

$$\frac{\partial\left((1+e)\sin\gamma\ \right)}{\partial t}=0 \quad \text{or} \quad (1+e_0)\sin\gamma\ _0=(1+e)\sin\gamma\ , \tag{8}$$

where e_0 and γ_0 are the values of the parameters in the initial state.

Considering that the material of the set is linearly elastic, i.e. $\sigma=E\cdot\varepsilon$. From (5) follows:

$$\frac{\mathrm{E}}{1+e}\cdot\left(1-\frac{e}{1+e}\right)\cdot\frac{\partial e}{\partial s}\frac{\partial x}{\partial s}+\frac{\mathrm{E}\cdot e}{1+e}\cdot\frac{\partial^2 x}{\partial s^2}=\rho\cdot\frac{\partial^2 x}{\partial t^2}. \tag{9}$$

From equations (6) and (8), it is obtained that:

$$(1+e)^2=\left(\frac{\partial x}{\partial s}\right)^2+(1+e_0)^2\sin^2\gamma_0, \tag{10}$$

where from

$$\left(\frac{\partial x}{\partial s}\right)^2=(1+e)^2-(1+e_0)^2\sin^2\gamma_0, \tag{11}$$

$$(1+e)\,\frac{\partial e}{\partial s}=\frac{\partial x}{\partial s}\frac{\partial^2 x}{\partial s}. \tag{12}$$

Substituting (12) into (9),

$$\frac{E}{1+e}\left(1-\frac{e}{1+e}\right)\frac{1}{1+e}\left(\frac{\partial x}{\partial s}\right)^2\frac{\partial^2 x}{\partial s^2}+\frac{E}{1+e}\frac{\partial^2 x}{\partial s^2}=\rho\frac{\partial^2 x}{\partial t^2}$$

or

$$\frac{{a_0}^2}{1+e}\cdot\left[\frac{\left(\frac{\partial x}{\partial s}\right)^2}{(1+e)^2}+e\right]\frac{\partial^2 x}{\partial s^2}=\frac{\partial^2 x}{\partial t^2}, \tag{13}$$

where $a_0^2=\frac{E}{\rho}$.

Substituting (11) into (13), the following is obtained:

$${a_0}^2\cdot\left[1-\frac{(1+e_0)^2\sin^2\gamma_0}{(1+e)^3}\right]\frac{\partial^2 x}{\partial s^2}=\frac{\partial^2 x}{\partial t^2} \tag{14}$$

or

$$a_0^2\left[1-\frac{(1+e_0)^2\sin^2\gamma_0}{\left(\sqrt{\left(\frac{\partial x}{\partial s}\right)^2+(1+e_0)^2\sin^2\gamma_0}\right)^3}\right]\frac{\partial^2 x}{\partial s^2}=\frac{\partial^2 x}{\partial t^2}, \tag{15}$$

where x is displacement, s is Lagrangian coordinates, t is time, e is fiber deformation. $\frac{\partial x}{\partial s}=x_s$ is axial deformation of the net, γ is angle of inclination of the fiber to the axis.

The last equation is a quasi-linear partial differential equation. The characteristics method is used here.

$$x|_{s=\infty}=0.$$

The equation of motion of mass M has the following form.

$$M\left.\frac{\partial^2 x}{\partial t^2}\right|_{s=0}=f\,\sigma\cos\gamma\ |_{s=0}, \tag{16}$$

where σ is the stress caused by the tension of the fibers, f -is the cross-sectional area of the net. In the initial state $\sigma=\sigma_0$.

3 Equations of characteristics

The equations of characteristics have the form:

$$ds = adt, \quad ds = -adt. \tag{17}$$

Characteristics conditions

$$dx_t = a(x_s)\,dx_s, \quad dx_t = -a(x_s)\,dx_s, \quad \left(x_t = \frac{\partial x}{\partial t}, x_s = \frac{\partial x}{\partial s}\right). \tag{18}$$

$$a = a_0 \sqrt{1 - \frac{(1+e_0)^2 \sin^2\gamma_0}{\left(\sqrt{\left(\frac{\partial x}{\partial s}\right)^2 + (1+e_0)^2 \sin^2\gamma_0}\right)^3}}. \tag{19}$$

Consider the plane $s - t$ (Fig.2). There are two points, A and B on the line s and at which the deformation is equal to x_s^0, i.e. the characteristics have a slope $a(x_s^0)$. As a result, this state extends to ACB, i.e., to the region FOS. (i.e. in the resting state area FOS).

The state of the net in the tOF region is being considered.

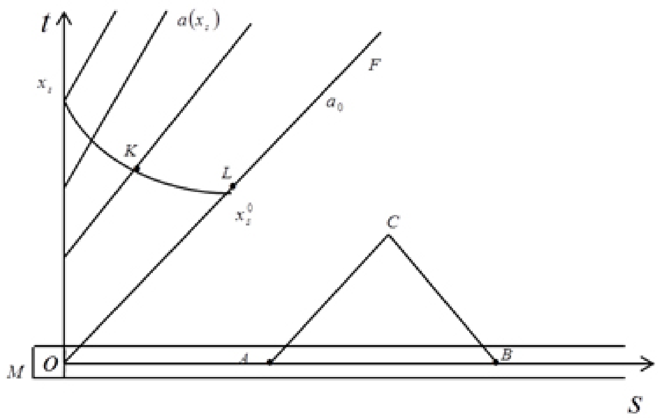

Figure 2. Description of wave speed.

The equation of the negative characteristic is integrated from a point on the front L to K in the tOF region

$$x_t = -\int_{x_s^0}^{x_s} a(x_s)dx_s. \tag{20}$$

Next, we differentiate (18) in the direction of the positive characteristic. Considering that on the line OF $x_s = x_s^0$ is constant:

$$dx_t = -adx_s. \tag{21}$$

From (20) and condition (18) for a positive characteristic, it follows:

$$dx_t = 0, dx_s = 0. \tag{22}$$

In other words, positive characteristics are linear everywhere ($x_t = const, x_s = const$). Thus, the solution in the area of FOt has the following form

$$x_t = \varphi\left(t - \frac{s}{a(x_s)}\right); \quad x_s = \psi\left(t - \frac{s}{a(x_s)}\right). \tag{23}$$

4 Solving the equation of motion of a cylindrical net

Differentiating (20) with respect to t is obtained:

$$\frac{\partial^2 x}{\partial t^2} = -a\frac{\partial x_s}{\partial t}. \tag{24}$$

By satisfying the condition at the boundary s=0, from equations (16) and (24) is defined:

$$-Ma\frac{\partial x_s}{\partial t} = f\sigma\cos\gamma. \tag{25}$$

Considering that the material of the set is linearly elastic, i.e., $\sigma = Ee$, where (Agalarov et al., 2019):

$$e = \sqrt{\left(\frac{\partial x}{\partial s}\right)^2 + (1+e_0)^2\sin^2(\gamma_0)} - 1,$$

$$\cos\gamma = \frac{1}{1+e}\frac{\partial x}{\partial s},$$

$$\sigma = E\left(\sqrt{\left(\frac{\partial x}{\partial s}\right)^2 + (1+e_0)^2\sin^2(\gamma_0)} - 1\right). \tag{26}$$

Substituting (26) into (25), the following is obtained ($s = 0$):

$$M\frac{\partial x^2}{\partial t^2} = \left[E\left(\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)}\right) - 1\right]\frac{\psi}{\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)}}, \tag{27}$$

where $\left(\psi = \frac{\partial x}{\partial s}\right)$.

On a negative characteristic $dx_t = -a dx_s$. Considering $x_t = \varphi\left(t - \frac{s}{a}\right)$; $\quad x_s = \psi\left(t - \frac{s}{a}\right)$. $\left(\varphi = \frac{\partial x}{\partial t}\right)$, when $s = 0$, it is obtained.

$$dx_t = d\varphi, \quad dx_s = d\psi,$$

$$\left(\frac{\partial x}{\partial s} = x_s, \quad \frac{\partial x}{\partial t} = x_t\right),$$

or

$$\frac{\partial \varphi}{\partial t} = -a\frac{\partial \psi}{\partial t}.$$

Substituting in (27), the following is obtained.

$$-a\frac{\partial \psi}{\partial t} = \frac{\left[fE\left(\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)} - 1\right)\right]}{M\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)}}\psi \tag{28}$$

or taking into account (19):

$$-a_0\left(\sqrt{1 - \frac{(1+e_0)^2\sin^2(\gamma_0)}{\sqrt{\left(\psi^2 + (1+e_0)^2\sin^2(\gamma_0)\right)^3}}}\right)\frac{\partial \psi}{\partial t} = \frac{\left[fE\left(\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)} - 1\right)\right]}{M\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)}}\psi.$$

And accordingly

$$-\frac{a_0 M}{fE}\frac{\sqrt{1 - \frac{(1+e_0)^2\sin^2(\gamma_0)}{\sqrt{\left(\psi^2+(1+e_0)^2\sin^2(\gamma_0)\right)^3}}}}{\left(\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)} - 1\right)}\sqrt{\psi^2 + (1+e_0)^2\sin^2(\gamma_0)}\,\frac{\partial \psi}{\psi} = dt. \tag{29}$$

Integrating (29), the following is obtained

$$t = M\int_{x_s^0}^{x_s} \frac{(1+e)\,a}{\sigma}\frac{\partial\psi}{\psi}. \tag{30}$$

The integral (30) is approximated as a sum.

$$t_0 = \Phi(\psi_0)\Delta\psi,$$

$$t_1 = (\Phi(\psi_0) + \Phi(\psi_1))\,\Delta\psi,$$

$$t_2 = (\Phi(\psi_0) + \Phi(\psi_1) + \Phi(\psi_2))\,\Delta\psi,$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$t_n = (\Phi(\psi_0) + \Phi(\psi_1) + \cdots + \Phi(\psi_n))\,\Delta\psi_n$$

or

$$\Phi(\psi) = t$$

that is, the inverse dependence of $\psi \to t$ on the boundary. Since the positive characteristics are rectilinear, it is possible to determine ψ in the entire area of motion. Here:

$$\Phi\left(\psi\right) == \frac{a_0 M}{fE}\frac{\sqrt{1-\frac{(1+e_0)^2\sin^2(\gamma_0)}{\sqrt{\left(\psi^2+(1+e_0)^2\sin^2(\gamma_0)\;\right)^3}}}}{\left(\sqrt{\psi^2+\left(1+e_0\right)^2\sin^2\left(\gamma_0\right)}\;-1\right)}\sqrt{\psi^2+\left(1+e_0\right)^2\sin^2\left(\gamma_0\right)}\;\frac{1}{\psi}.$$

By specifying the speed of movement of the end of the network at the boundary as a function of time, it is possible to determine the deformation as a function of time at the end of the network and throughout the SOt region in the same manner (Fig.2).

Examples are viewed (Fig.3 and Fig.4):

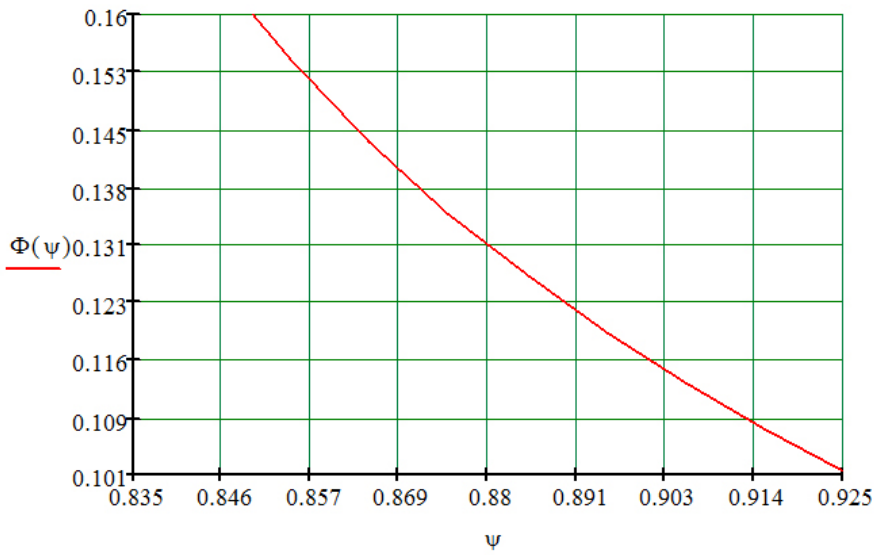

Figure 3. The distribution of constant deformation on the characteristics at the boundary. ($\gamma_0 = \frac{\pi}{4},\ M = 10kq,\ E = 2\cdot 10^5 MPa,\ a_0 = 5000,\ \Delta\psi = 0.01$).

The graph $\psi(t) = t$ is shown in Fig.4.

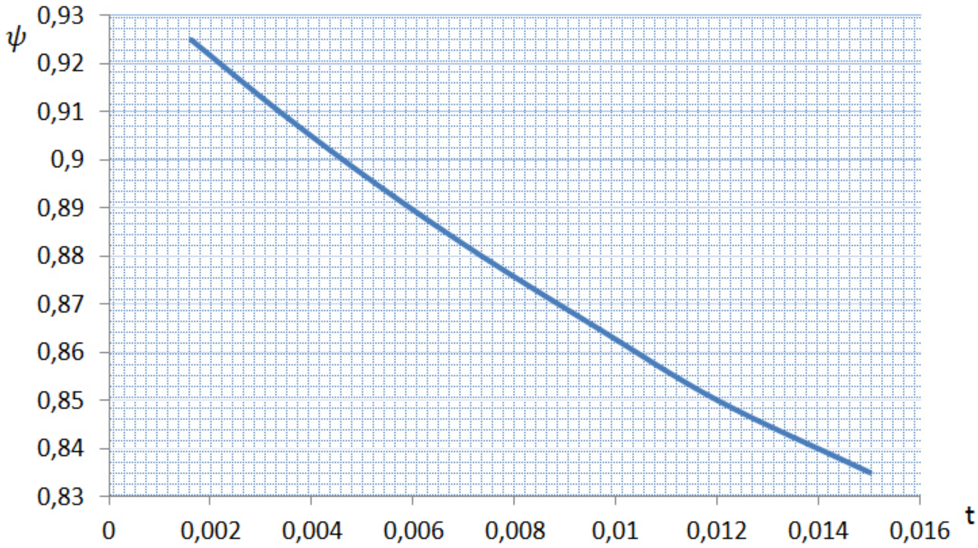

Figure 4. $\psi(t) = t$.

5 Conclusion

The solution using characteristic equations shows the occurrence of traveling waves. The solution is constructed by meeting the conditions at the point of contact between the net and the mass.

When the end of a stretched cylindrical net (pipe) with mass is released, it accelerates, causing the end of the net to move at an increasing speed. Points at a distance exhibit a delayed increase in velocity and lesser acceleration.

Table 1. Calculated values of the parameters utilized.

ψ_0	ψ_1	ψ_2	ψ_3	ψ_4	ψ_5	ψ_6	ψ_7	ψ_8	ψ_9	ψ_{10}
0.925	0.915	0.905	0.895	0.885	0.875	0.865	0.855	0.845	0.835	0.825
$e(\psi_0)$	$e(\psi_1)$	$e(\psi_2)$	$e(\psi_3)$	$e(\psi_4)$	$e(\psi_5)$	$e(\psi_6)$	$e(\psi_7)$	$e(\psi_8)$	$e(\psi_9)$	$e(\psi_{10})$
0.169	0.161	0.153	0.145	0.137	0.129	0.122	0.114	0.106	0.099	0.01
t_1	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
0.00102	0.00209	0,00322	0.00441	0.00568	0.00703	0.00847	0.01	0.012	0.014	0.016
$\Phi(\psi_0)$	$\Phi(\psi_1)$	$\Phi(\psi_2)$	$\Phi(\psi_3)$	$\Phi(\psi_4)$	$\Phi(\psi_5)$	$\Phi(\psi_6)$	$\Phi(\psi_7)$	$\Phi(\psi_8)$	$\Phi(\psi_9)$	$\Phi(\psi_{10})$
0.102	0.107	0.113	0.119	0.127	0.135	0.144	0.154	0.166	0.18	0.20

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