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KINETOSTATICS OF A NON-AXISYMMETRIC WEDGE

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Abstract. The equations of kinetostatics are compiled and the reaction forces of constraints of a non-axisymmetric (triangular) wedge are determined according to the d'Alembert principle. A mathematical expression is obtained for the reaction force of the kinetostatics problem of a non-axisymmetric wedge under the action of a non-constant force. The research methods are based on the classical methods of theoretical mechanics of deriving the equation of dynamics based on the d'Alembert principle and the analytical method for determining the reaction force of constraints.

Keywords: reaction forces, wedge, kinetostatics problem.

КИНЕТОСТАТИКА НЕОСЕСИММЕТРИЧНОГО КЛИНА

Аннотация. Составлены уравнения кинетостатики и определены силы реакции связей неосесимметричного (треугольного) клина по принципу Даламбера. Получено математическое выражение для силы реакции задачи кинетостатики неосесимметричного клина при действии непостоянной силы. Методы исследования основаны на классических методах теоретической механики вывода уравнения динамики на основе принципа Даламбера и аналитическом методе определения силы реакции связей.

Ключевые слова: силы реакции, клин, задача кинетостатики.

INTRODUCTION.

Determination of the reaction forces of constraints of composite wedge pairs is the foundation for the study of the dynamic processes of many mechanisms used in mechanical engineering. Agricultural machines are equipped with V-belts and wedge friction gears, wedge valves are used in oil products transportation lines, freight car bogies are equipped with wedge spring-friction sets. Wedge pairs are widely covered in the literature [1, 2].

Using the method of addition of forces between two infinitesimal sections of the rod, in accordance with the d'Alembert principle, a differential equation of longitudinal vibrations of a wedge pair was compiled [3]. The general and particular solutions of the differential equation of longitudinal oscillations of a wedge pair are presented and their propagation under the action of a constant force corresponding to the given initial and boundary conditions is studied.

A generalized model of a spring-friction set of a freight car bogie was created in [4]. Critically discussing the lack of methods of classical mechanics in multiple publications, according to the principle of the release of constraints, an equation for the equilibrium of friction wedges was compiled and an analytical expression for the reaction of a friction wedge was obtained in [5].

In this article, a mathematical expression is obtained for the reaction force of constraints for the dynamic problem of a non-axisymmetric wedge.

METHODS

The research methods are based on the classical methods of theoretical mechanics for compiling the equations of dynamics according to the d'Alembert principle and the analytical method for determining the reaction force of constraints.

MATERIALS.

Let force $\bar{P}$ make an effort to move a homogeneous wedge (Fig. 1). It is necessary to determine the dynamic reaction forces of constraints on the wedge.

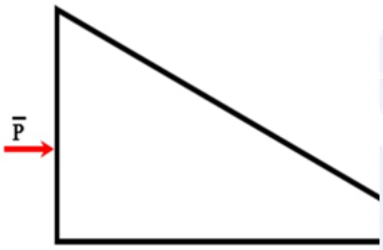

Fig.1. Wedge shape

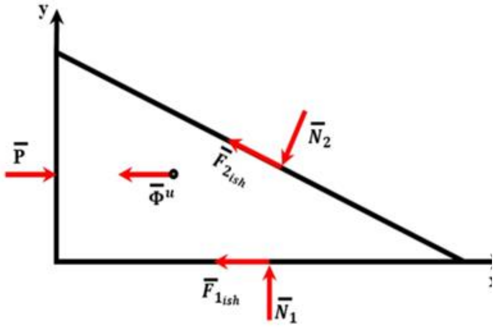

Fig.2. Acting forces

To do this, we use the d'Alembert principle [6]. The equation of dynamics according to the d'Alembert principle has the following form

$$\bar{\Phi}^u + \bar{F}^a + \bar{R} = 0,$$

where $\bar{\Phi}^u$ is the force of inertia, expressed as $\bar{\Phi}^u = -m\ddot{x}$, $\bar{F}^a$ is the active force, expressed by force $\bar{P}$, $\bar{R}$ is the passive force, which consists of the forces of friction $\bar{F}_{ish}$ and the forces of normal reaction $\bar{N}$.

To determine the reaction force, we set a coordinate system and determine the projections of all forces along the coordinate axes of this coordinate system (Fig. 2). Normal reaction forces $\bar{N}$ of the working planes are directed perpendicular to these planes. Friction forces $\bar{F}_{ish}$ of these surfaces lie in the working planes. The force of inertia $\bar{\Phi}^u$ is directed in the opposite direction of force $\bar{P}$ direction.

Let us derive an equation for the projections of all wedge forces along the x-axis:

$$\Phi^{u}+P-fN_2\cos\alpha-N_2\sin\alpha-fN_1=0 \qquad (1)$$

Let us derive an equation for the projections of all wedge forces along the y-axis:

$$N_1-N_2\cos\alpha+fN_2\sin\alpha=0.$$

(2)

Then we determine N_1:

$$N_1=N_2(\cos\alpha-f\sin\alpha).$$

(3)

Taking into account relation $F_{ish}=fN$ for the friction force (where f is the coefficient of friction), from the last equation we obtain:

$$P-fN_2\cos\alpha-N_2\sin\alpha-fN_2\cos\alpha-f^2N_2\sin\alpha-m\ddot{x}=0,$$

Then we determine

$$\ddot{x}=\frac{P}{m}-\frac{N_2(-f\cos\alpha-\sin\alpha-f\cos\alpha-f^2\sin\alpha)}{m}. \qquad (4)$$

By integrating over time t in (4), we obtain an expression for the velocity:

$$\dot{x}=\frac{P}{m}t-\frac{N_2}{m}t(f^2\sin\alpha-2f\cos\alpha-\sin\alpha)+C_1.$$

Thus, the forces of normal reaction N_1 and N_2 of the working planes have the following form:

$$N_2=\frac{m\ddot{x}-P}{f^2\sin\alpha-2f\cos\alpha-\sin\alpha},$$

$$N_1=N_2(\cos\alpha-f\sin\alpha).$$

RESULTS AND DISCUSSION.

In a particular case, if the law of motion of the wedge is given in the following form:

$$x=\sin kt,$$

then, differentiating this expression twice, we obtain:

$$\ddot{x}=-k^2\sin kt.$$

$$N_1=\frac{-(mk^2\sin kt+P)(\cos\alpha-f\sin\alpha)}{f^2\sin\alpha-2f\cos\alpha-\sin\alpha},$$

$$N_1=\frac{-(mk^2\sin kt+P)(\cos\alpha-f\sin\alpha)}{f^2\sin\alpha-2f\cos\alpha-\sin\alpha}$$

where f is the coefficient of friction. Then we determine the expression for the normal reaction force

$$N = \frac{P}{2(\sin\alpha + f\cos\alpha)}, \qquad (5)$$

which, unlike the formulas, found in the literature, more accurately expresses the nature of the reaction force of real constraints. Note that in textbooks on the theory of mechanisms and machines [1], the normal reaction force is determined by the following formula

$$N = \frac{P}{\sin\alpha},$$

Here, for $\sin\alpha = 0$, the reaction force tends to infinity, which does not correspond to the physics of the phenomenon.

CONCLUSION.

Thus, a refined expression for the reaction force of constraints of a triangular wedge for a dynamic problem was obtained. The resulting analytical expression for the normal reaction force of the wedge constraints corresponds to the physics of the phenomenon under any conditions of application of active forces.

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