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SOLVING PROBLEMS USING THE DALAMBER PRINCIPLE FOR MECHANICAL SYSTEM AND MATERIAL POINTS.

[1]Kholbekov Toshturdi Qudratovich, [2]Bobomurodov Sardor Sodiq ugli

Termez Institute of Technology and Innovative Development Storage, processing and mechanization of agricultural products Assistant of the department[1], Termez Institute of Agrotechnology and Innovative Development Student of agricultural mechanization[2]

ABSTRACT

The meaning of the D'Alembert principle is that the motion of an object is stopped "imaginatively" and the problem of dynamics is reduced to the problem of statics by adding the forces of inertia to the forces acting. In mechanics, this method is called "kinetostatics" - the method of "stopping motion".

Suppose a non-free material point moves under the influence of active and reaction forces. Its differential equation of motion is:

$$m\vec{a} = \sum_{k=1}^{n} \vec{F}_k^{\,a} + \vec{N}.$$

Move the expression on the left to the right, $m\vec{a}$

$$\sum_{k=1}^{n} \vec{F}_k^{\,a} + \vec{N} - m\vec{a} = 0,$$

and for inertial forces

$$\vec{F}^{in} = -m\vec{a}$$

by entering the designation,

$$\sum_{k=1}^{n} \vec{F}_k^{\,a} + \vec{N} + \vec{F}^{in} = 0$$, or in short

$$\vec{F} + \vec{N} + \vec{F}^{in} = 0.$$

This means that if we add the forces of inertia to the number of forces acting on a material point, the resulting system of forces is balanced. equality represents the Dalamber principle for the material point. According to the rules of statics, it is possible to create conditions of equilibrium for these forces:

$$F_x + N_x + F_x^{\,in} = 0; \qquad F_y + N_y + F_y^{\,in} = 0; \quad F_z + N_z + F_z^{\,in} = 0;$$

projection equations and

$$\begin{cases} m_x(\vec{F}) + m_x(\vec{N}) + m_x(\vec{F}^{in}) = 0; \\ m_y(\vec{F}) + m_y(\vec{N}) + m_y(\vec{F}^{in}) = 0; \\ m_z(\vec{F}) + m_z(\vec{N}) + m_z(\vec{F}^{in}) = 0, \end{cases}$$

moment equations are constructed and the unknowns are determined.

The Dalamber principle for the k-ni point of a mechanical system is written as follows:

$$\vec{F}_k^{\,e} + \vec{F}_k^{\,i} + \vec{F}_k^{\,in} = 0,$$

It's there: $\vec{F}_k^{\,e}$ – external forces acting here; $\vec{F}_k^{\,i}$ – influencing internal forces;

$\vec{F}_k^{\,in}$ – inertial forces acting.

Based on the properties of the internal forces for the whole mechanical system,

$\sum_{k=1}^{n} \vec{F}_k{}^{i} = 0$, then

$$\sum_{k=1}^{n} \vec{F}_k{}^{e} + \sum_{k=1}^{n} \vec{F}_k{}^{in} = 0.$$

This means that if we add inertial forces to the list of external forces acting on a mechanical system, these systems of forces will be in equilibrium.

Equations (5.3) and (5.4) for a mechanical system are as follows:

$$\begin{cases} \sum_{k=1}^{n} F_{kx}{}^{e} + \sum_{k=1}^{n} F_{kx}{}^{in} = 0; \\ \sum_{k=1}^{n} F_{ky}{}^{e} + \sum_{k=1}^{n} F_{ky}{}^{in} = 0; \\ \sum_{k=1}^{n} F_{kz}{}^{e} + \sum_{k=1}^{n} F_{kz}{}^{in} = 0, \end{cases}$$

moment equations

$$\begin{cases} \sum_{k=1}^{n} m_x(\vec{F}_k{}^{e}) + \sum_{k=1}^{n} m_x(\vec{F}_k{}^{in}) = 0; \\ \sum_{k=1}^{n} m_y(\vec{F}_k{}^{e}) + \sum_{k=1}^{n} m_y(\vec{F}_k{}^{in}) = 0; \\ \sum_{k=1}^{n} m_z(\vec{F}_k{}^{e}) + \sum_{k=1}^{n} m_z(\vec{F}_k{}^{in}) = 0. \end{cases}$$

We will consider the application of the above theoretical information to practical problems.

Problem 1: A point M with mass m = 2 kg at the end of a rod of length l = 0.981 m rotates at a right velocity burchak = 4.47 rad / s around a vertical axis OA = 1.5 l (Figure 5.1). OA and MA find the horizontal reaction forces at the bases and the angle formed by the rod vertically, without taking into account the mass of the rods. The distance between the bases is 0.5l.

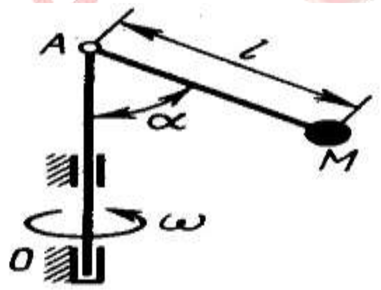
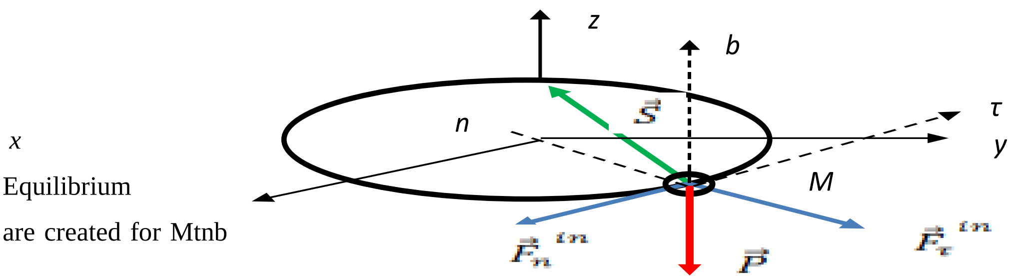


Figure 1.

Solution: The diagram describes the external forces acting on a material point, the force of gravity, the tension of the rod, and the forces of inertia (Figure 2).



Equilibrium conditions are created for Mtnb axes:

$$\begin{cases} \sum_{k=1}^{n} F_{k\tau} = 0; & -F_{\tau}^{\ in} = 0; \\ \sum_{k=1}^{n} F_{kn} = 0; & -F_{n}^{\ in} + S \cdot sin\alpha = 0; \\ \sum_{k=1}^{n} F_{kb} = 0; & S \cdot \cos\alpha - P = 0, \end{cases} \qquad (1)$$

the centrifugal inertial force here

$$F_n^{\ in} = m \cdot a_n = m \cdot l \cdot \sin\alpha \cdot \omega^2 = 2 \cdot 0{,}981 \cdot 0{,}866 \cdot 4{,}47^2 = 33{,}94\ N,$$

from equation 2 of the system

$$S = m \cdot l \cdot \omega^2.$$

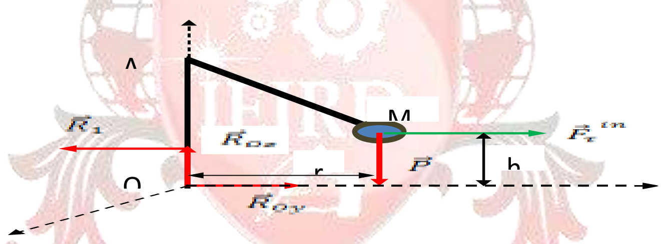
from equation 3 of the system

$$\cos\alpha = \frac{P}{S} = \frac{g}{l \cdot \omega^2} = \frac{9{,}81}{0{,}981 \cdot 4{,}47^2} = 0{,}5$$

$$\alpha = 60°.$$

3) Taking the material point OA and MA as a system and the point M as a system, we add the forces of inertia to the number of external forces acting and create the conditions of equilibrium (Figure 5.3). MA sternal stress remains an internal force for the system.

3-shakl.



$$\begin{cases} \sum_{k=1}^{n} F_{ky} = 0; & F_{\tau}^{\ in} - R_1 + R_{Oy} = 0; & (d) \\ \sum_{k=1}^{n} F_{kz} = 0; & R_O - P = 0; & (e) \\ \sum_{k=1}^{n} m_O(\vec{F}_k) = 0; & -F_{\tau}^{\ in} \cdot h - P \cdot r + R_1 \cdot 0{,}5l = 0; & (f) \end{cases}$$

Where $h = OA\text{-}MA \cdot \cos\alpha = 1{,}5l - l \cdot cos60° = l;$

$r = MA \cdot \sin 60° = 0{,}866l,$

then from the third equation

$$R_1 = \frac{m(l \cdot \sin\alpha \cdot \omega^2 + 0{,}866g)}{0{,}5} = \frac{2 \cdot (0{,}981 \cdot 0{,}866 \cdot 4{,}47^2 + 0{,}866 \cdot 9{,}81)}{0{,}5} = 101{,}88\,N$$

from the first equation

$$R_{Oy} = R_1 - F_\tau^{in} = 101{,}88 - 33{,}94 = 67{,}94\,N.$$

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