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DYNAMICS OF FINE MECHANICAL EMBARKED SYSTEMS IN CHANNEL OF (RHSO) LAUNCHER

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Abstract: The motion of pieces system takes place when a device is moving in the launcher to be continuing on the flying on a trajectory. General theorems of dynamics lead to the differential system of equations to move the pieces. One considers the moving of a device in channel of the launcher as a rotation with translation, so that; the centre of mass is translated in direction of OX axis. With the help of a numerical simulation the paperwork presents the particular movement with its associated velocity of a safety cylinder.

Key-Words: mechanical embarked systems, launcher, dynamics, safety cylinder.

1. Introduction

Embarked pieces of board apparatus of the rockets are any motion in time during displacement in channel of launcher tube or guiding runner. The functions of these systems are in connection with reference time for a preciously time computing or other works. Moreover, these functions are safe properties of any other systems to enter in working of any steps. To obtain motion of any embarked pieces is a hard problem in the motion of a rocket. This is the reason of any embarked pieces motion in the channel of launcher tube so, where we have a great acceleration of rockets, only in launcher or runner guiding. Many safety-embarked pieces are of special form configuration and as a system, are combined of big number, because the forces applied on are very small and for a good work these pieces must be very sensitive. In this case, that means of a reduced force, with any pieces working on the principal of safety facilities' piece.

In this way, we shall treat the motion of embarked systems on rockets board with only applying basic law of dynamics. The items will be completed with graphs of motion and explanations. For the first time we insist especially, on translation motion of embarked safety pieces as cylinders with special forms used in safety systems. We chose these systems because in all parts of rockets these have only translation motion without rotation.

2. Theoretical aspects

Cylinders with translation motion are very important safety pieces in many systems of embarked board apparatus on the rockets.[3] They are especially, of a hard configuration because they couldn't move in normal form. This configuration is a channel or any channels, which are practised on external or inner surfaces. During the translation of cylinder with the channel, it is moving on an axe that is going in channel. So, the cylinder is working in translation displacement and the channel is forced to go on this axe. These cylinders have only translation motion, but in this case are two channels or only translation with rotation motions of one channel on cylinder. In safety systems, these cylinders have one or two phases of functions. In many systems, the second phase of function is produced after combustion of rockets engines, at the ending of active portion of trajectories. In the following figures we shall illustrate any safety systems with cylinders.[4]

In Figure 1 we see the spring of cylinder 2 in position 4 and safety balls 3 for blocking spindle 1. We observe the forces, which are working on cylinder with appliance of the second Newton's law or basic law of dynamics. The single action is axial force of inertia under direction of Ox axis of orthonormal system of co-ordinates taken with origin in mass centre C of cylinder.[5]

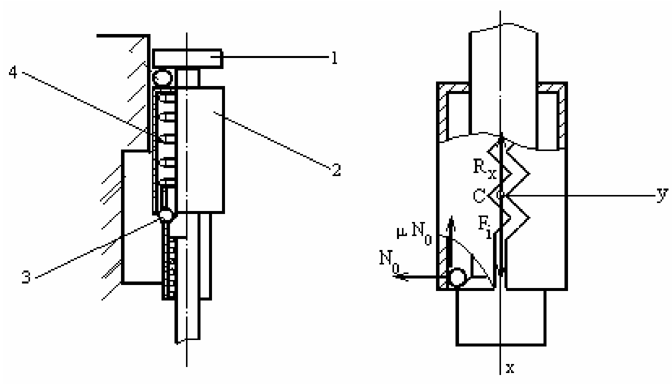

Figure 1 Safety cylinder

This represents displacement direction of cylinder. We have also, the pressure N_0 on inner surface of cylinder by safety balls and action of helicoidal spring R_x.

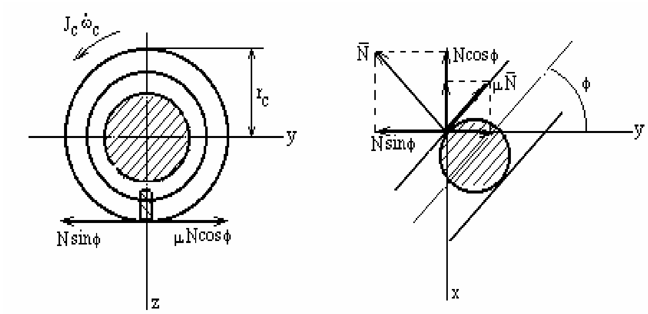

Figure 2 The axe in profile channel

In Figure 2 we illustrated the axe in profile channel practice on cylinder surface. As we see in the above picture this channel is in form of zigzag.

So, we find the axial moment of inertia J_c of cylinder in proper rotation of this piece round direction of Ox axis.

The reaction $\overline{N}$ of channel to the axe in section as we see, determins appearance of friction $\mu\overline{N}$ with the components on direction of motion in channel and this perpendicularly on. The projections of these reactions lead to a moment of rotation cylinder round axis. After we presented these its forces and moments work on cylinder, we can write the relations to prepare differential system of equations of motion in the channel of launching tube. The equation of cylinder translation with mass m, is as below [2]

$$F_i - R_x - \mu N_0 - N\cos\varphi - \mu N\sin\varphi - m\ddot{x} = 0 \qquad (1)$$

In this equation we don't have any $\overline{N}$ reaction. This problem was solved easily with an equation of moments through Ox axis. As in above figure we observe

$$r_c N\sin\varphi - r_c \mu N\cos\varphi - J_c\dot{\omega}_c = 0 \qquad (2)$$

We do not know the rotation motion with angular velocity ω_c of cylinder. Though, we know this velocity in formula of peripheral velocity.

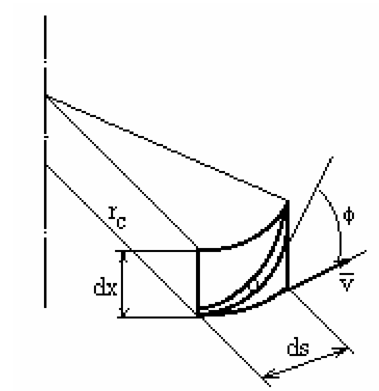

Figure 3 Solid element

In the Figure 3 we took a solid element $ds \times dx \times r_c$ of cylinder with channel of angle φ. We can write the peripheral velocity as

$$v = r_c \cdot \omega_c = \frac{ds}{dt} \qquad (3)$$

The problem is what size the angular velocity ω_c has got? We observe that we can put relation of

$$tg\varphi = \frac{dx}{ds}\cdot\frac{dt}{dt} = \frac{dx}{dt}\cdot\frac{1}{\frac{ds}{dt}} = \frac{1}{r_c\omega_c}\cdot\frac{dx}{dt} \qquad (4)$$

From this relation we find angular velocity expression, as

$$\omega_c = \frac{1}{r_c}\frac{dx}{dt}ctg\varphi \qquad (5)$$

Angular acceleration can easily be obtained in form of

$$\dot{\omega}_c = \frac{1}{r_c}\frac{d^2x}{dt^2}ctg\varphi \qquad (6)$$

After substitution in relation (2) we have the following formula of reaction $\overline{N}$

$$N = \frac{J_c}{r_c^2}\cdot\frac{ctg\varphi}{\sin\varphi - \mu\cos\varphi}\cdot\frac{d^2x}{dt^2} \qquad (7)$$

In relation (1) we shall have translation motion with differential equation

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$$m\ddot{x} = F_i - R_x - \mu N_0 - \\ - \frac{J_c}{r_c^2} \cdot \frac{ctg\varphi}{\sin\varphi - \mu\cos\varphi} \cdot \\ \cdot \frac{d^2x}{dt^2}(\cos\varphi + \mu\sin\varphi)\cdot\ddot{x} \tag{8}$$

With any simple operations we obtain

$$\dot{x} = v$$

$$\dot{v} = \frac{F_i}{m+m_1} - \frac{R_x}{m+m_1} - \frac{\mu N_0}{m+m_1} \tag{9}$$

In relation we have

$$m_1 = \frac{J_c}{r_c^2} \cdot \frac{ctg\varphi}{\sin\varphi - \mu\cos\varphi}(\cos\varphi + \mu\sin\varphi) \tag{10}$$

Axial force of inertia $F_i = m\dot{V}$ is depending on translation acceleration $\dot{V}$.

Resistance of spring R_x is depending on displacement x of cylinder. So, we observe that in mounting state of system, resistance of spring we noted with R_0, after translation $x = a$, shall have a new resistance of spring R_a. Now, knowing initial and final resistance for a displacement x, we shall have resistance R_x as, below

$$R_x = R_0 + \frac{R_a - R_0}{a}x \tag{11}$$

With these substitutions the system of relation (9) becomes

$$\dot{x} = v$$

$$\dot{v} = \frac{m}{m+m_1}\dot{V} - \frac{R_0}{m+m_1} - \frac{R_a - R_0}{m+m_1}\cdot\frac{x}{a} - \frac{\mu N_0}{m+m_1} \tag{12}$$

With initial conditions

$$t = t_0 = 0\,, x_0 = 0\,, v_0 = 0 \tag{13}$$

If we note any terms of these equations with

$$C = \frac{m}{m+m_1}\,, \mathrm{K}_0 = \frac{R_0}{m+m_1} - \frac{\mu N_0}{m+m_1}\,, \\ \mathrm{K}^2 = \frac{R_a - R_0}{m+m_1}\frac{1}{a} \tag{14}$$

In this way we have

$$\dot{x} = v \\ \dot{v} = C\dot{V} - K^2x - K_0 \tag{15}$$

with the same initial conditions as in (13). This equation represents the oscillations of cylinder in motion on portion of channel. In each part of channel we shall have other initial conditions. The analytic solution is in form of relation [1]:

$$x(t) = -\frac{1}{\omega_0}\cos\omega_0 t\int_0^t \sin\omega_0 t dV + \frac{1}{\omega_0}\sin\omega_0 t\int_0^t \cos\omega_0 t dV - \\ \frac{K_0}{\omega_0^2}(1-\cos\omega_0 t);$$

$$v(t) = \sin\omega_0 t\int_0^t \sin\omega_0 t dV + \cos\omega_0 t\int_0^t \cos\omega_0 t dV - \\ \frac{K_0}{\omega_0}\sin\alpha\omega_0 t$$

with difference that we have the term of constant C instead of unit 1. In any case of axe concussion in each ending part of channel for the following parts of channel we shall take a negative velocity v_0.

3. Numerical simulation

In the following example we shall give the graphs with simulation of motion for a part of channel of length $a_i = 2{,}5\,mm$ for a cylinder of mass $m = 15g$.

The spring was taken with values: $R_0 \approx 1{,}5N$, $R_a \approx 2{,}5N$.

For motion of a rocket we shall take a mean acceleration of $\dot{V} = 260\frac{m}{s^2}$.

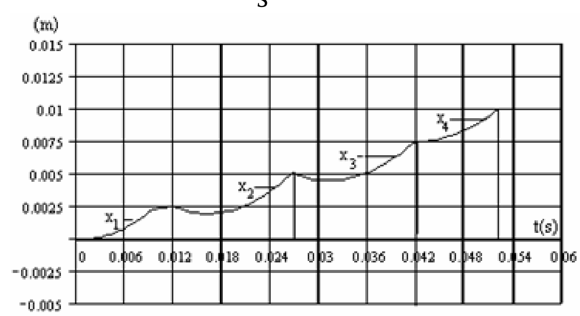

Figure 4 Displacement of cylinder on each part of channel

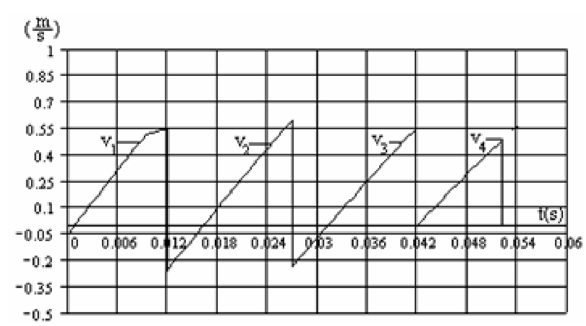

Figure 5 Velocity in translation of cylinder on each part of channel

In Figure 5 we give graph of velocity in translation of cylinder on each part of channel, going with negative values. In this simulation we had elevation angle of each part of channel measured after Oy axis was $60\deg$.

The figure below represents the diagram of cylinder's angular round translation axis velocity.

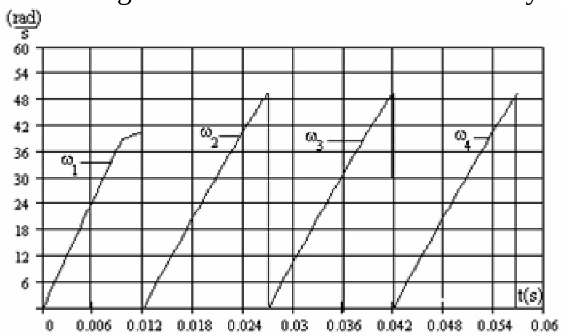

Figure 6 - Angular velocities on each part of the zigzag channel

Angular velocities on each part of the zigzag channel have big values as we see in graph of Figure 6.

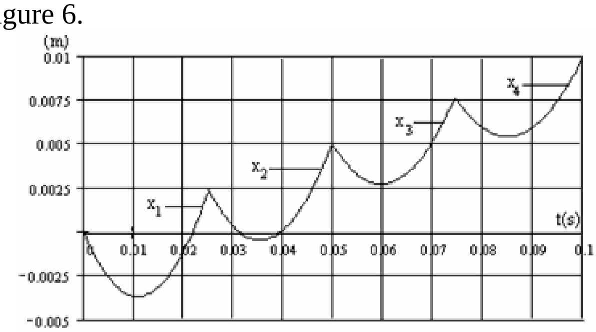

Figure 7 Displacement of cylinder on each part of channel.

In Figure 7 we have the same system, which is working with almost double variable acceleration as in Figure 6. So, we see any zones of concussions with recoil of cylinder.

In Figure 8 we observe diagrams of velocities and their greater negative values as in previous figures.

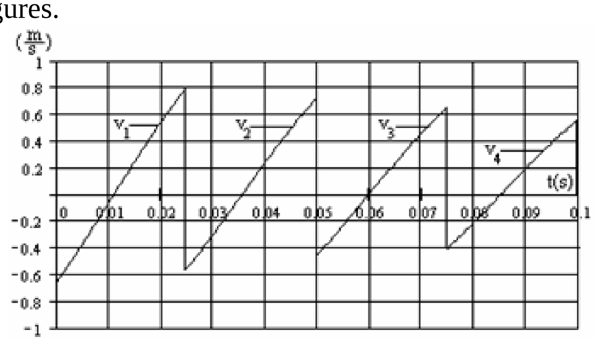

Figure 8 Diagrams of velocities

4. Conclusions

The present paperwork frames the theoretical works that study the motion of mechanical embarked systems in channel of launcher.

Due to special geometry of the safety cylinder the mouvment of a mechanical embarked system is very particular. (see Figures 4 and 7)

As a direct result of the particular mouvment of the mechanical embarked system studied, the longitudinal and angular velocities gain a special profile. (see Figures 5, 6 and 8)

References:

[1] Cristescu R., *"Functional Analyses"*, Didactical and Pedagogical Publishing House, Bucharest, 1979.

[2] Voinea Radu., Voiculescu D., Ceausu V., "*Mechanics"*, Didactical and Pedagogical Publishing House, Bucharest, 1975.

[3] Moraru F., „*Numerical analysis charters. Aplications for ballistics and flinght dynamics"*, Military Technical Academy, Bucharest, 2002

[4] Bucur P., Postolea D., Enache C., „*Mechanics*. *Embarked systems*", Ed. Pro Transilvania, Bucharest, 2004.

[5] Balasoiu S., „*Teoria sistemelor mecanice imbarcate*", Ed. ATM, Bucharest, 2001.