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SELECTED ASPECTS OF SIMULATION OF MULTI-MODULE MECHANISMS WITH THE USE OF MULTIBODY METHOD

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Abstract

The paper presents numerical analysis of a single segment of a floating bridge built in the form of a metal cassette with a movable bottom. An internal elastic container – a pontoon filled with the air was fixed in the cassette [4]. It enables a fluent change of displacement of a single segment and of a floating ribbon assembled from segments. A multibody analysis of cooperation of the cassette in the process of filling the pontoon and opening the cassette was discussed. Numerical analysis of a single cassette presented in the paper constitutes a part of tests including stand tests. The single floating cassette has a typical shelled construction consists of a tight deck, a pneumatic chamber closed with a reinforced movable bottom and sets of fastenings together with a mechanism of bottom opening. Each cassette is equipped with a highly resistant elastic or semi-elastic cushion hereinafter called a pontoon. The movement of the bottom and the process of opening the cassette module with a pneumatic air cushion realized under an influence of pressure of the compressed air. As a result of uneven filling the individual chamber of the pontoon with the air or their uneven emptying in the process of closing the cassette, there can occur the asymmetry of displacements of the bottom resulted even in seizing of telescopic mechanisms. In the paper were considered the cases of symmetrical and asymmetrical movement of the bottom corresponding to symmetrical and unsymmetrical pull out of the telescopic mechanism modules. Dynamical analysis of movement of cooperating subsystems of the floating cassette was carried out with the use of MSC.Adams code [5, 8].

Keywords*: *bridges, simulation of multi-component mechanism, rigid models, multibody numerical analysis

1. Introduction

A special bridges group includes floating pontoon bridges, which are military equipment [1-4, 6]. They are the constructions of a wide range of application enabling water crossings for both military and civil purposes. The bridges of this type are utilized, among others, as temporary crossings in the places excluded from exploitation of permanent bridges renovated due to service damages. A crossing composed of single floating segments in the shape of an appropriate ribbon (single, double, or mixed) constitutes a bridge of constructional system adjusted to the organized crossing [1-3, 7, 9]. Such constructions are also applied during evacuation of population or removing the effects of natural disasters, especially floods [1-3, 7, 9]. Unquestionable advantages of such constructions are high mobility, simplicity of construction, possibility of organizing various constructional systems depending on a water crossing. A special value of floating bridges is also their constructional elasticity and possibility of their adjustment and utilization independently on the width or depth of the obstacle as well as various field conditions.

Contemporary requirements concerning water crossings cause the fact that floating bridges should meet a number of conditions [1, 3, 6, 7]. They should enable easy and fast assembly and disassembly of a bridge construction, be characterized by small weight of segments and simultaneously enable crossing of equipment of high load capacity. They should have small dimensions enabling easy handling and transport not demanding a large number of transport vehicles. These criteria are met especially by an innovative construction of a ribbon assembled from floating cassettes – Fig. 1, proposed by the team of the Department of Mechanics and Applied Computer Science, Military University of Technology [4]. This construction connects possibilities and capabilities of a standard ribbon with additional possibilities of fluent regulation of displacement, depth of immersion and numerous service advantages including simplification of adjusting the constructional, transport, storage etc., configuration.

Numerical analysis of a single cassette presented in the paper constitutes a fragment of tests including stand tests, experimental material tests and loading tests of prototypical cassettes. Single floating cassettes assembled together with the use of mechanical buckle create a floating bridge of ribbon type. A fragment of a pontoon cassette bridge in the form of a repeatable floating segment of regulated displacement was subjected to multibody analysis. The single floating cassette has a typical shelled construction consists of a tight deck, a pneumatic chamber closed with a reinforced bottom and sets of fastenings together with a mechanism of bottom opening [4]. Each cassette is equipped with a highly resistant elastic or semi-elastic cushion hereinafter called a pontoon (Fig. 1b), which after filling with the air allows obtaining the accurate, required dependently on the organized crossing, buoyancy force. The change of the level of filling the elastic cushion, with compressed air, results in accurate opening of cassette bottom, thereby a possibility of regulation of the pontoon volume and adjusting it to buoyancy force and a construction draught.

Fig. 1. Prototypical cassette of a floating bridge; a) closed; b) open with lowered bottom and visible pontoon-container filled with the air

The paper presents numerical analysis of operation of a mechanism of lowering the cassette bottom during filling the elastic pontoon with the air. The movement of the bottom and the process of opening the module with a pneumatic air cushion realized under an influence of pressure of the compressed air. Displacement of the bottom is realized with the use of ten telescopes with built-in springs placed symmetrically on the both sides of the segment enabling folding the pontoon after reducing the pressure in the container and return to the state of closing the cassette. As a result of uneven filling the individual chamber of the pontoon with the air (the process of opening the cassette) or their uneven emptying in the process of closing the cassette, there can occur the asymmetry of displacements of the bottom resulted even in seizing of telescopic mechanisms.

The work presents a detailed analysis of cooperation of movable modules – telescopes consisted of four parts independently moving in respect to each other. There were considered the cases of symmetrical and asymmetrical movement of the bottom corresponding to symmetrical and unsymmetrical pull out of the telescopic mechanism modules. There were carried out simulations of three variants of asymmetrical displacement of the cassette bottom caused by unsymmetrical filling of individual sections of the pontoon. The values of reaction of interaction of individual modules of the telescopic mechanism in the process of bottom displacement – cassette opening were examined.

2. 3D rigid model of floating cassette

The prototypical construction of a single cassette of a pontoon bridge is developed by numerical tests and experimental studies. Possibility of carrying out numerical analyses significantly improves testing of a new construction and examinations of the influence of constructional modifications on strength and functionality of the object.

Dynamical analysis of movement of cooperating subsystems of the floating cassette was carried out with the use of MSC.ADAMS software [6]. This programme enables carrying out analyses of dynamics and kinematics of multi-module systems [5]. Three-dimensional models built of rigid bodies are used in multibody simulations.

A geometrical model of the floating cassette was carried out in CAD environment and imported to MSC.ADAMS code with the use of accurate extensions of files. A real object of the cassette was built on the base of constructional documentation of the prototypical cassette. All movable elements, being an object of dynamic analysis, were mapped in the model. They comprise, first of all, subsystems of ten elastic-telescopic mechanisms and buckle. Fig. 2 presents a three-dimensional model of the cassette, which was applied for dynamic analysis in ADAMS code.

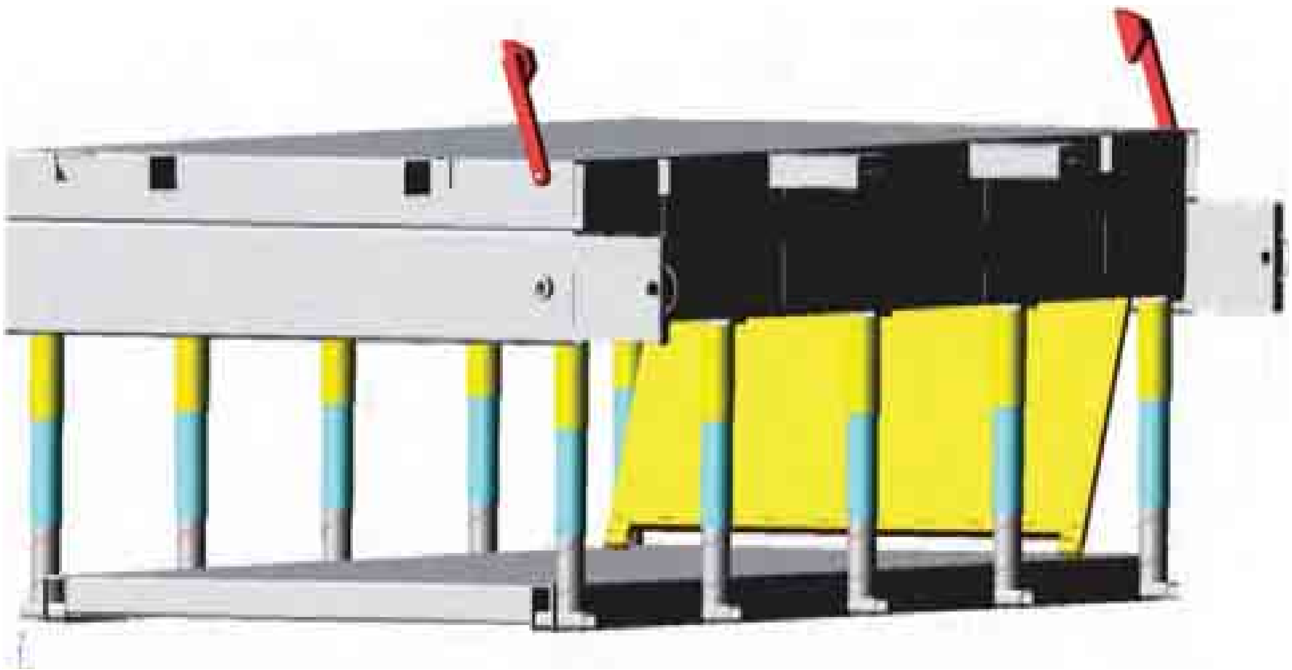

Fig. 2. 3D model of floating cassette with visible subsystems of mechanism of lowering the bottom and elements of movable lock (without elastic pontoon)

One of the main movable modules of the cassette is a set of ten elastic-telescopic mechanisms (Fig. 3). Each telescope was assembled from four cylindrical sleeves with accurately selected diameters so that during assembling individual sleeves were put one into another. Vertical translations of the sleeve are limited by rings placed inside the cylinders (Fig. 3). Thanks to this, after complete pulling of telescopic mechanism, further movement of cassette bottom is limited by contact of individual rings of the telescope. In order to model correct conditions of telescope work, there were modelled contacts between individual neighbouring cylinders and rings limiting movement of the telescope. Between subsequent sleeves, there was modelled slight radial clearance enabling correct assembling of individual telescopes and mutual free moving of cylinders in respect to each other during movement of the cassette bottom.

In the model for multibody simulation, besides telescopic mechanisms with springs, there were accurately modelled individual elements serving, among others, for fixing the springs or the telescope in the upper and lower part of the cassette (Fig. 2 and 3).

Fig. 3. Construction of telescopic-elastic mechanism of opening the cassette bottom: a) fastening the spring from the side of the roadway, b) spring, c), elements of fastening the upper cylinder, d) assembling the cylinders of telescopic mechanism, e) elements of fastening the spring and lower cylinder with movable bottom of the cassette

3. Asymmetrical spreading of the cassette

An elastic pneumatic pontoon built inside the cassette is divided with two tight separators into three isolated chambers according to Fig. 5. These sections are filled by the air from one gas main through two control valves (filling/emptying) fixed on the cassette stern - Fig. 1a. Such a construction of a pontoon and the method of its powering can result in uneven filling of individual sections, thus uneven distribution of pressures from individual sections of pontoons on the cassette bottom.

Asymmetric displacement of the cassette bottom was forced by distributing total force of pontoon pressure on component vertical forces affecting on parts of the cassette bottom as forces reduced from individual sections of elastic pontoon (Fig. 4). In the simulation, the movement of the bottom was extorted with the use of concentrated forces of relatively defined characteristics variable in time – Fig. 4. In all examined variants, the interaction of constant buoyancy force corresponding to immersion of the cassette with keeping free board was taken into consideration [2, 3].

There were carried out simulations of three variants of asymmetric displacements of the cassette bottom caused by uneven filling of individual pontoon sections:

– variant I – corresponding to the maximal difference of increasing of loading forces F_1, F_2 and F_3,
– variant II – with reduced, in relation to case II, difference of forces increasing time,
– variant III – with the minimal difference of forces increasing time.

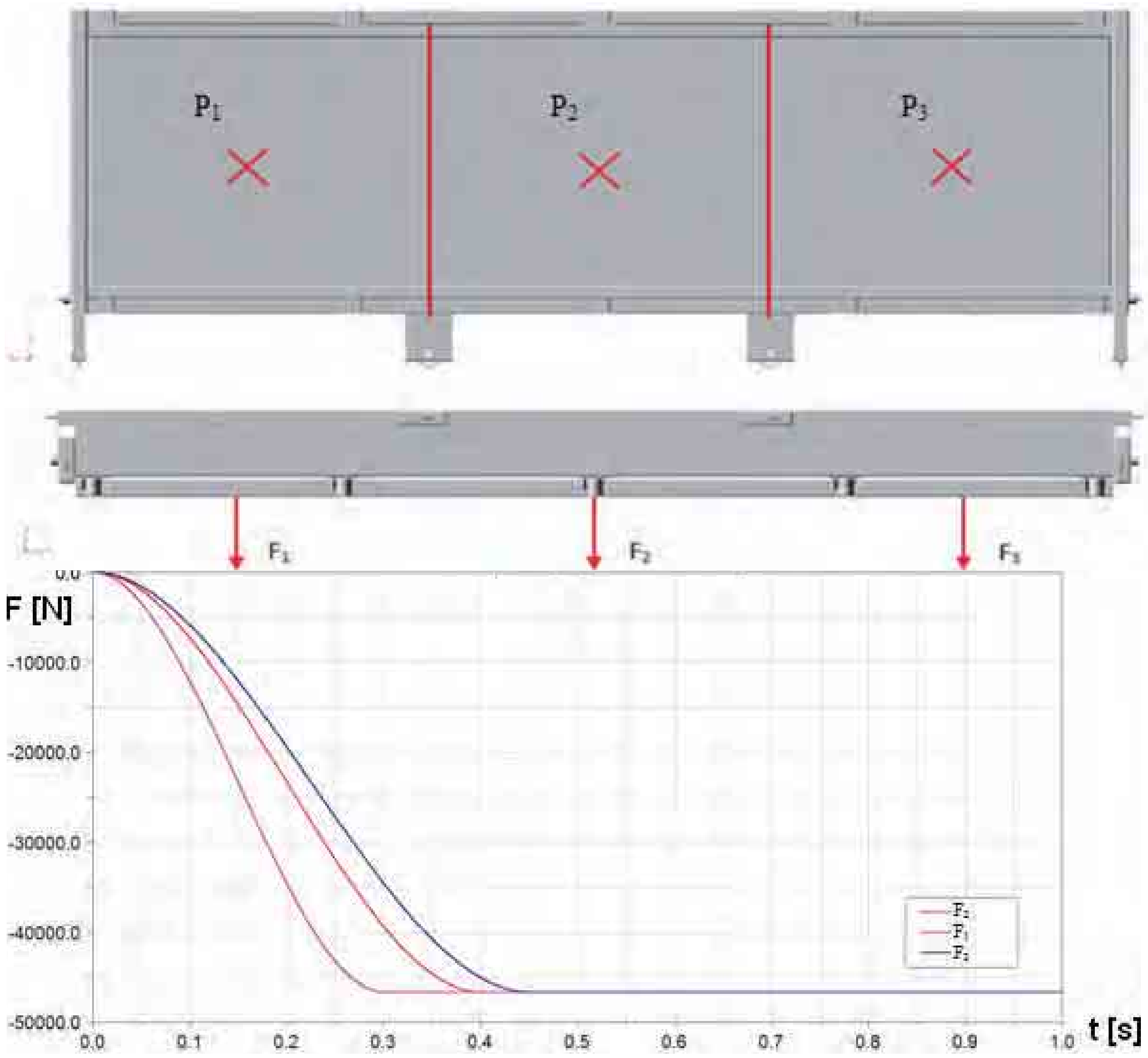

Fig. 4. Distribution of points of measuring displacements on the bottom of the cassette and reduced loadings F from pressure of the elastic pontoon filled with the air in time 1s – variant I

Individual variants differed with time in which reduced loading forces reached the maximum value. In variant I, P_1 reached, the maximum value after 30% of simulation duration time, P_2 after 40% while P_3 after 45% - Fig. 4. In variants II and III, the above-mentioned time differences were reduced. Variant II: P1 reached the maximum value after 35% of simulation duration time, P2 after 40% while P3 after 43%. Variant III: P1 reached the maximum value after 37% of simulation duration time, P2 after 40% while P3 after 42%.

In simulation variants II, untimely blocking of movement of the bottom was and I found out and simulation ended in the state of incomplete opening of the cassette. Variant III was determined as boundary one at which full-predicted constructional displacement of the cassette bottom is possible despite uneven filling of the pontoon.

Based on the simulations carried out with the use of MSC.ADAMS software, the values of contact forces occurring between individual movable mechanisms of the cassette was determined. The changes of values of interaction reactions of individual modules of the telescopic mechanism in the process of uneven displacement of the bottom/floor – opening of the cassette were examined. Fig. 5 presents distribution of vectors of contact forces between telescopic mechanisms cylinders corresponding to the state of seizing and incomplete displacement of the bottom/floor obtained in variant I of the simulation.

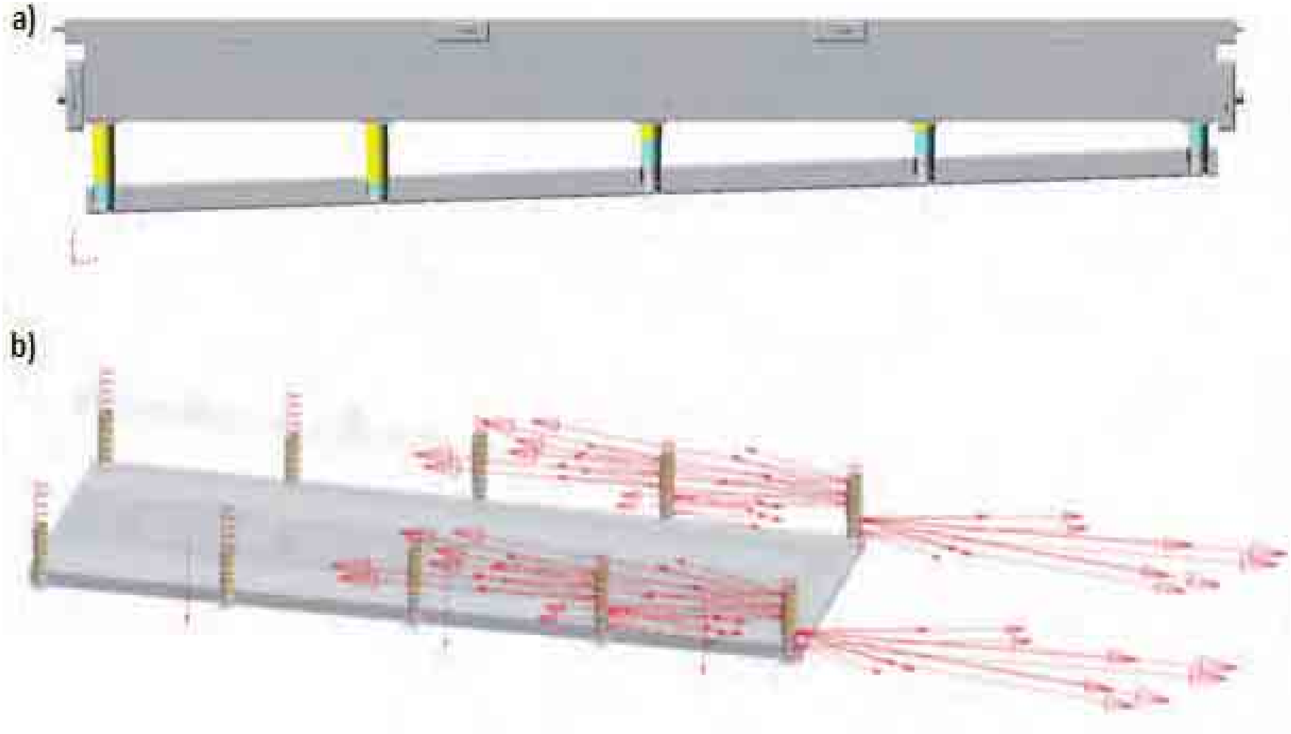

Fig. 5. Distribution of vectors of contact forces between telescopic mechanisms cylinder corresponding to the state of seizing and incomplete displacement of the bottom – variant I of the simulation

Based on the results of the carried out dynamical analyses it was found out that in variants I and II of asymmetric unfolding of the cassette the movement of the cassette bottom was blocked as a result of an excessive increase of contact forces between individual telescopes cylinders on the right side of the cassette, what is illustrated in Fig. 5b.

In variant III of the simulation no untimely stop of movement of cassette bottom caused by seizing of telescopic mechanisms occurred. The bottom was moving asymmetrically and a short time lost of its movement fluency was observed, however, eventually the complete opening of the cassette took place. Fig. 6 presents graphs illustrating changes of displacements of measurement points of the cassette bottom (P_1, P_2, and P_3 - Fig. 4) in variant III of the simulation.

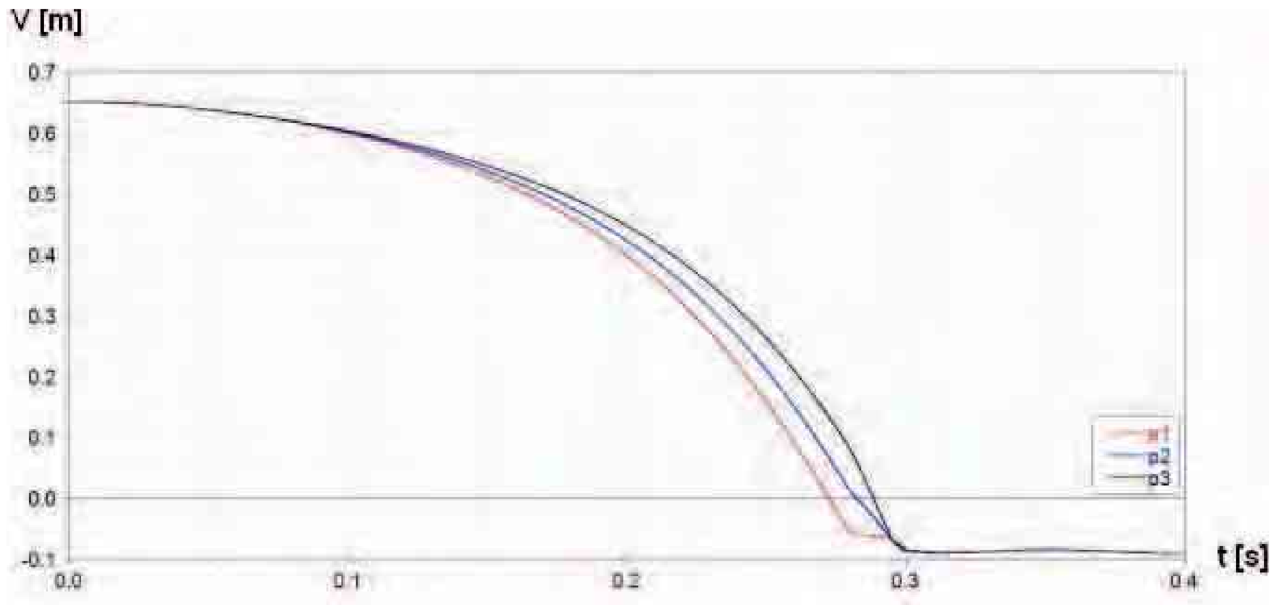

Fig. 6. Displacement of measurement points P_1, P_2 and P_3 on the cassette bottom – variant III

In the initial period of simulation in variant III, the cassette bottom moves unevenly – curves corresponding to individual measurement points on the graphs (Fig. 6) do not agree. However, after 0.3 s, the displacements reach approximately an identical maximal value equal to 0.74, what corresponds to the state of complete opening of the cassette.

5. Conclusions

The paper presents selected aspects of numerical investigations of a single prototypical cassette, which can serve for constructing a floating bridge of regulated deadweight and a value of immersion. The discussed construction was replaced with a complex system composed of rigid movable modules. A multibody methodology, enabling examinations of kinematics and dynamics of multi-module systems was applied. The presented analysis of prototypical cassette construction composed of movable modules allows estimation of cooperation of individual subsystems of mechanisms as well as determination of values occurring between the in various service conditions.

Based on the results of the presented multibody analysis, it can be concluded that the process of uneven filling of the individual sections of elastic cassette pontoon can be the reason of seizing of mechanism of controlling the cassette bottom movement. There were determined critical values of differences in the growth of pressures (forces of pressure) generated in individual sections of the pontoon on the bottom, at which the conditions for seizing of telescopic mechanisms and blocking of the movement of the cassette bottom in the process of its asymmetrical opening occur.

The presented model of a single cassette and realized simulations can serve for testing the operation of cassette mechanisms in the states corresponding to various service conditions without the necessity of executing or limiting the range of expensive experimental investigations.

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