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Catastrofical changes of shape of folded systems.

The folded systems are considered which consist of rods, plates or shells connected by hinges along their long edges. Such systems may be represented by aircraft and ship designs of wing or tail unit type which have controls, ailerons, flaps, slats.

The development of aircraft engineering is historically connected with a constant struggle for increasing speed and decreasing weight. Simultaneous solving of these problems contradicts the structural strength of an aircraft. Increasing speed requires decreasing relative thicknesses of the wing, while the loads on it grow. For this utilising high-strong materials leads to the wing being more flexible.

Strength calculations when assuming deflections to be small may lead not only to quantitative errors but to qualitative ones as well. Firstly, the large displacements may change the outer loads and cause the known pfenomena of flatter, divergence etc. Secondly, the elastic calculation scheme requires taking account of geometrical nonlinearity the influence of which on the wing mathe- matical model will open new laws of its behaviour in a flow.

The interest to the problem of taking acconunt of geometrical nonlinearity took effect only recently [1-6] after the calculations of compound wing (a wing with aileron, a tail unit with control etc.) which detected a large loading of the middle plane when linking the separate units being statically undefinable. The loading is defined by the number of brackets of suspensions and their designs [6,7].

The planes of separate units of the folded systems are not parallel and arranged under some angles of adjacency (for example, the angle of deflection of control created by the control wheel). When the folded system being bended their separate units become loaded in the middle plane by interaction forces transformed via connected hinges. The more is the stiffness of bending the unit in its plane, the more are these forces.

It is known from the literature that beams loaded in the plane of its more stiffness can loose the stability of its flat shape. This phenomenon was studied as to the isolated rods loaded by bending in the plane of the most stiffness.

The investigation of the behaviour of the fold in a flow of gas (of a wing with ailerons in a wind tube) is suggested.

It is found that when the folded system being laterally bended it may transit in jump to a new equilibrium state not connected with the original one - a catastrofical change of shape occurs. The investigation of this phenomenon on the mathematical model has been carried out which describes the equilibrium state of the fold consisting of two rods (beams), as well as on the physical model consisting of two rods (metal strips) connected by discrete hinges. It has been shown that according to Rene Tom classification presented in the theory of catastrophes the behaviour of such folded system one may relate to the catastrophes of "assemble" type.

Refining the mathematical model of compound wing has led to nonlinear equations the solving of which in statics showed that several values of parameters of damping cannot correspond to a single outer load [8] that itself implies "a catastrophe" - a jump transition from one equilibrium state to another one. Such deflection of twisting angles of the rudder or aileron was found and confirmed experimentally [9], and called "rudder snap-through"[1,2].

This phenomenon is possible only in the case when the interaction of the separate units of compound construction (of wing, aileron) causes large loades in their middle plane. if this interaction occurs through the brackets with short lug, then the control surface snap-through may not occur because of stability loss of one of compressed brackets - the phenomenon was called "rudder mounting bracket snap-through" [7].

"Rudder catastrophes" change general load on tail unit (wing) which results in changing its bending in axis curvature. "Catastrophe" decreases the load and the curvature which causes the reverse catastrophe, that is transition of the rudder to the original deformed state and the cycle repeates again - vibrations are started studied theoretically and confirmed experimentally in the wind tube of Kazan aeronautical institute and called "vibrations of catastrophic change of the wing shape" [2,3,9].

The mentioned experimental investigations showed that "snap-through vibrations" have the more amplitude, the better the rudders are trimmed, and the vibrations almost disappear if the rudders are not trimmed. The found phenomenon is called "reverse effect of rudder trimming", if to consider that the expected effect from trimming is the elimination of vibrations of rudder flutter [9].

Standing the problems of mechanics of compound design we happened to be witnesses of an accident when break-down of flap carriadge from a rail occured during aircraft IL-76 landing. This resulted in interpreting and describing the phenomenon [10] led to the break-down of the carriadge. This phenomenon is characteristic of multi-railed flaps, if the number of flap extending mechanisms is less than the number of rail. The carriadge of the rail not having the extending mechanism in the near place is moved along the rail when the wing bending and this displacement is as more as the curvature of wing axis is more.

The materials on phenomena and effects described in the present article as well as assumptions for creating a new mathematical model and theory of obtaining its resolving equations were published openly and interpreted in USA during 1974-1985.

The author considers these phenomena to be new ones and would like to know the opinion of world scientific public concerning them. Having found the phenomena specific for modern and especially future aircraft designs, the phenomena which may cause losing effectiveness of rudders, carriadge break-downs from the rails, vibrations and catastrophes, we want to make them the property of all world aircraft designers, wishing to be honest before the people and God and notify in advance those innocent victims which may happen if engineers do not know about them and undertake the appropriate measures [11].