From a Magic Wallet to an Adaptive Wing

Levsha [Leftie] (supplement to the magazine *Junyj Tekhnik* [Young Technician]) №08, 2020.
By Alexey V. Ivchenko
(translated, from the Russian, by Yana Mohanty)

Can you imagine that a technical idea depicted in 16th-century paintings (**Fig. 1**), and exhibited as a curiosity in an 18-19th century collection of a Swiss museum (**Fig. 2**) has evolved into an engineering invention in modern-day aviation? This is hard to imagine, but such an idea exists. In all these cases, the common element is a mechanism built on the principle of a reversible hinge joint with a variable axis of rotation.

The object we see in the hands of the infant is identical to the one held by the middle-aged man in the old paintings (see **Fig.1**). In the literature, this object appears under the name of a “magic wallet”.

a)

b)

Figure 1

In order to better explain the mechanism of this magic wallet, we will show you how to make it yourself at home. The process is quite simple. You will need

1. 4 identical rectangles made of cardboard or some other firm material. These should be just a little larger than the size of paper currency in the country where you live.
2. Ribbons—these will be used to construct our reversible hinge joint.
3. Glue

First, you need to connect the two cardboards in the rear of **Fig. 3** with ribbons. The ribbons should be glued as shown in **Fig. 2(b)**.

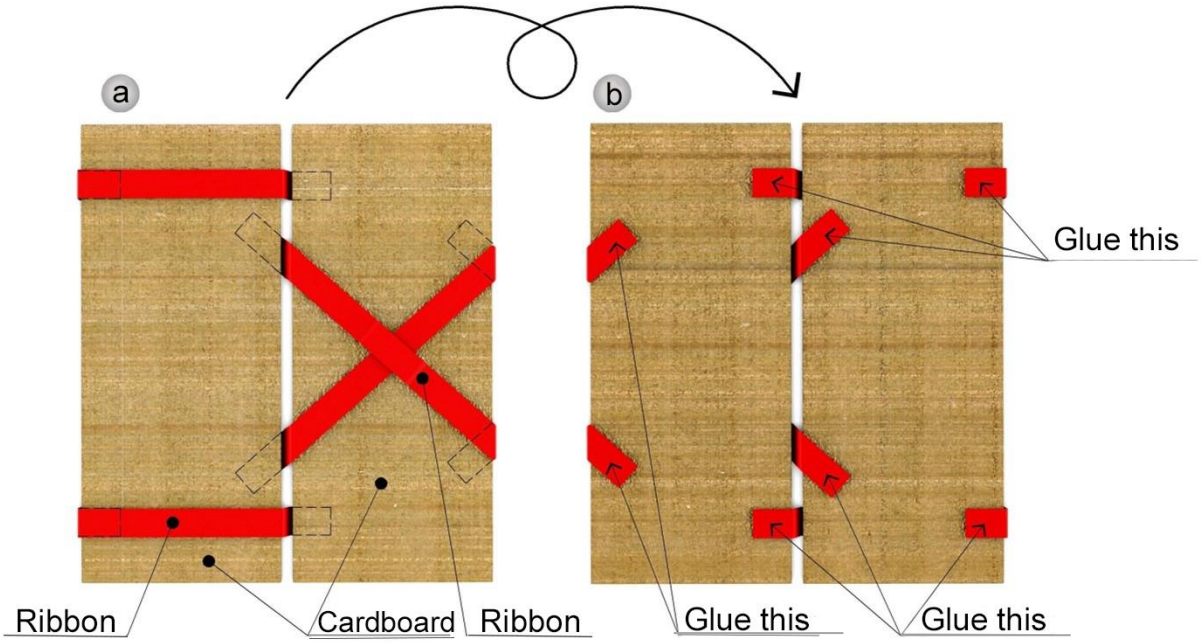

Figure 2

In order to give your wallet a finished look, we suggest that you glue the remaining two pieces of cardboard (front of **Fig. 3**) to the sides where the ends of the ribbons are visible.

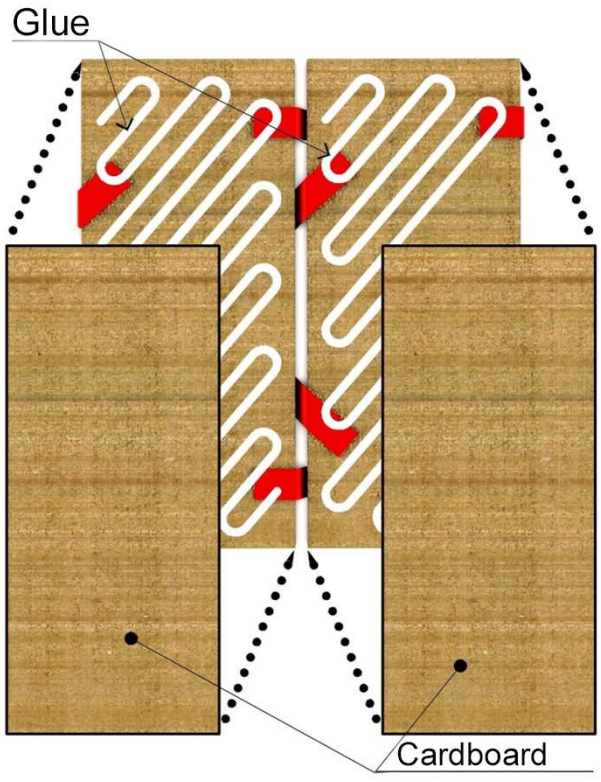

Figure 3

After inserting a paper bill (or, in our case, a picture) in the wallet compartment with the crossed ribbons (see **Fig. 4**), and flipping over the empty compartment as illustrated, you can observe a magical transfer of the paper bill into the compartment with parallel ribbons. We suggest that you experiment some more to acquaint yourself further with the properties of this unusual object. For example, you can use more than one picture, or bill, in the wallet.

Figure 4

Another historical object which we touched upon earlier is a toy known as “Jacob’s Ladder". In this case, it is a 6-panel Jacob’s Ladder from the Winterthur Art Museum in Switzerland, which dates between 1770 and 1820 (see **Fig. 5**).

The historical name of this object has to do with an apocryphal theme from the Old Testament. It refers to the ladder connecting heaven and earth from Jacob’s dream.

Figure 5

As in the case of the magic wallet, we offer the reader instructions for making Jacob's ladder. (See **Figure 6**). For this you will need to go through the sequence of steps to connect ribbons with the 12 wood blocks with slightly rounded edges.

The glue you choose needs to be strong enough to hold the toy together as you are playing with it. Any wood glue would be a good choice.

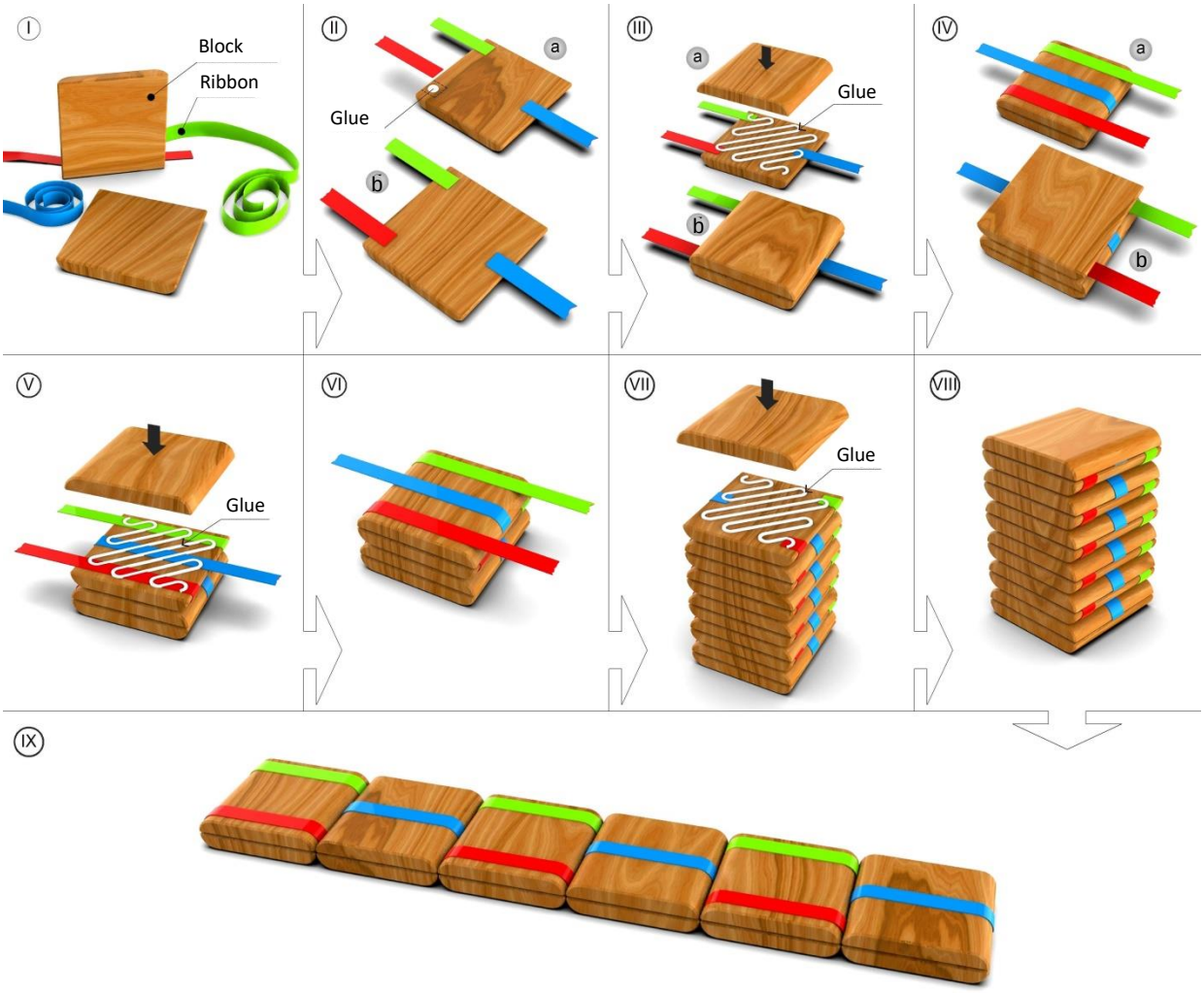

Figure 6

Jacob's Ladder is a mechanical toy which gives a visual illusion of a wooden block descending along the entire assembly as you play with it. (see **Fig. 7)** In reality**,** the wooden blocks turn sequentially one after the other, without changing their position within the chain of the other elements. The only thing that changes as the block "travels" down is the front and back side of all the blocks—they switch sides.

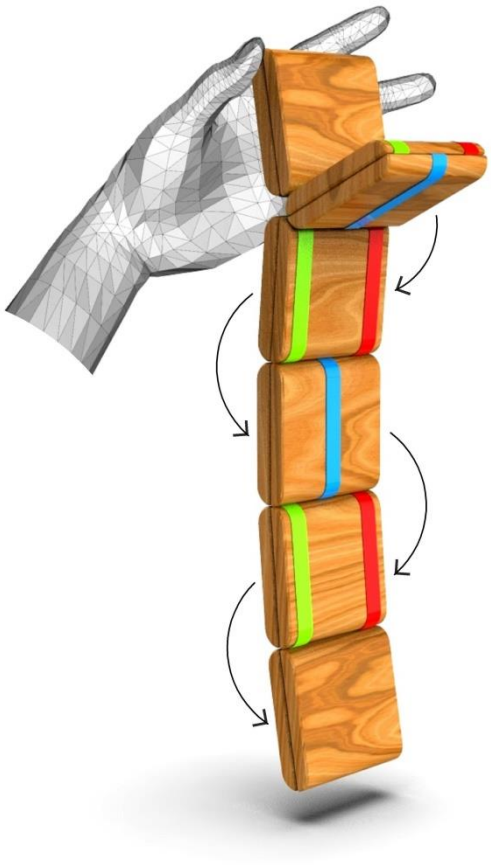

Figure 7

Our next example will be the tri-tetraflexagon, which, as our previous examples, uses the principle of a reversible hinge joint with a variable axis of rotation.

A tri-tetraflexagon is a flat model which is which has three types of exposed surfaces. One of these is always hidden in the folds of the construction. In the process of playing with the tri-flexagons, this surface gets revealed, and one of the previously exposed surfaces gets hidden in the folds

At the top of **Fig. 8** you can see the tri-tetraflexagon in its unfolded form. It can be made out of regular paper. We denote the “front side” with the letter “a” and the “back side” with the letter “b”. The sequence of making the tri-tetraflexagon is shown with Roman numerals I, II, III. The asterisk “*” in the upper right-hand corner of one of the squares with the number **2** on the “front face” is a marker which allows us to follow the position of the corner in the process of all the transformations that the tri-tetraflexagon undergoes. It is not necessary for the construction itself.

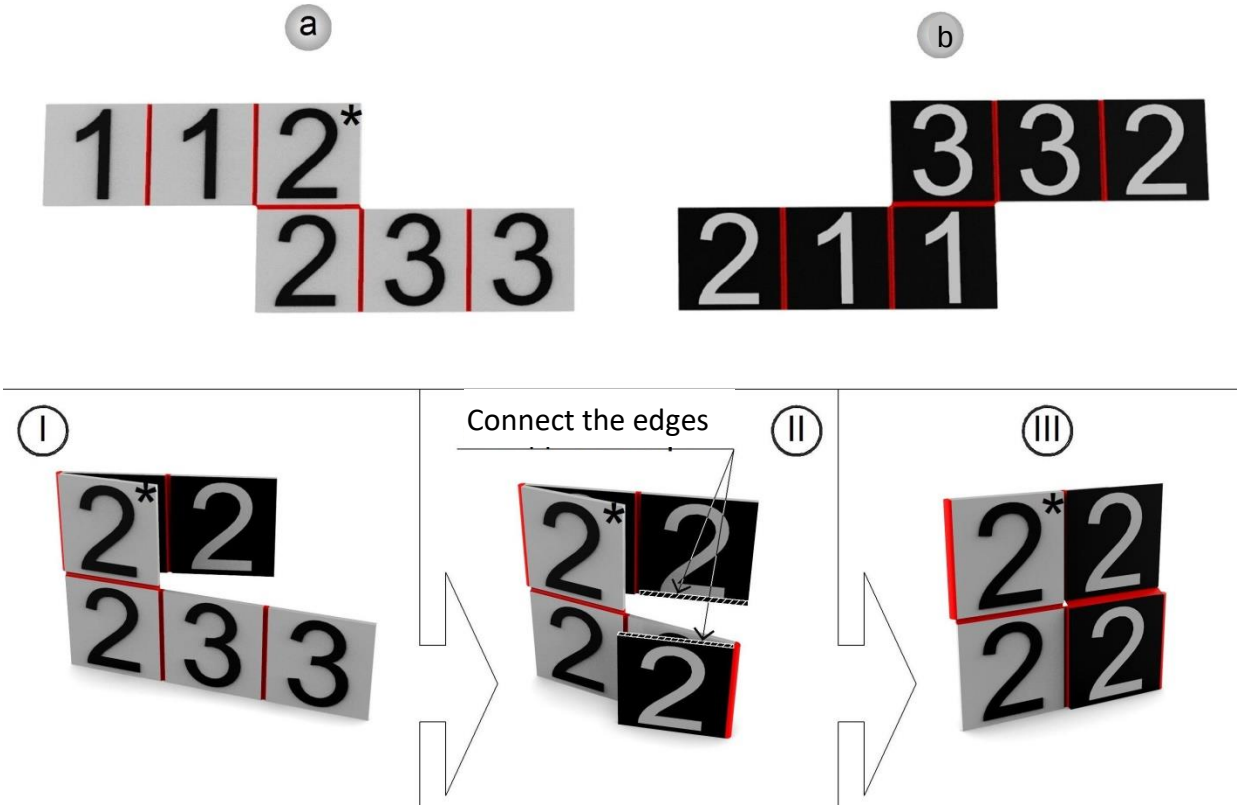

Figure 8. Tri-tetraflexagon: unwrapped state and preparation for gluing.

The principle behind the operation of a tri-tetraflexagon is shown in **Fig. 9.**

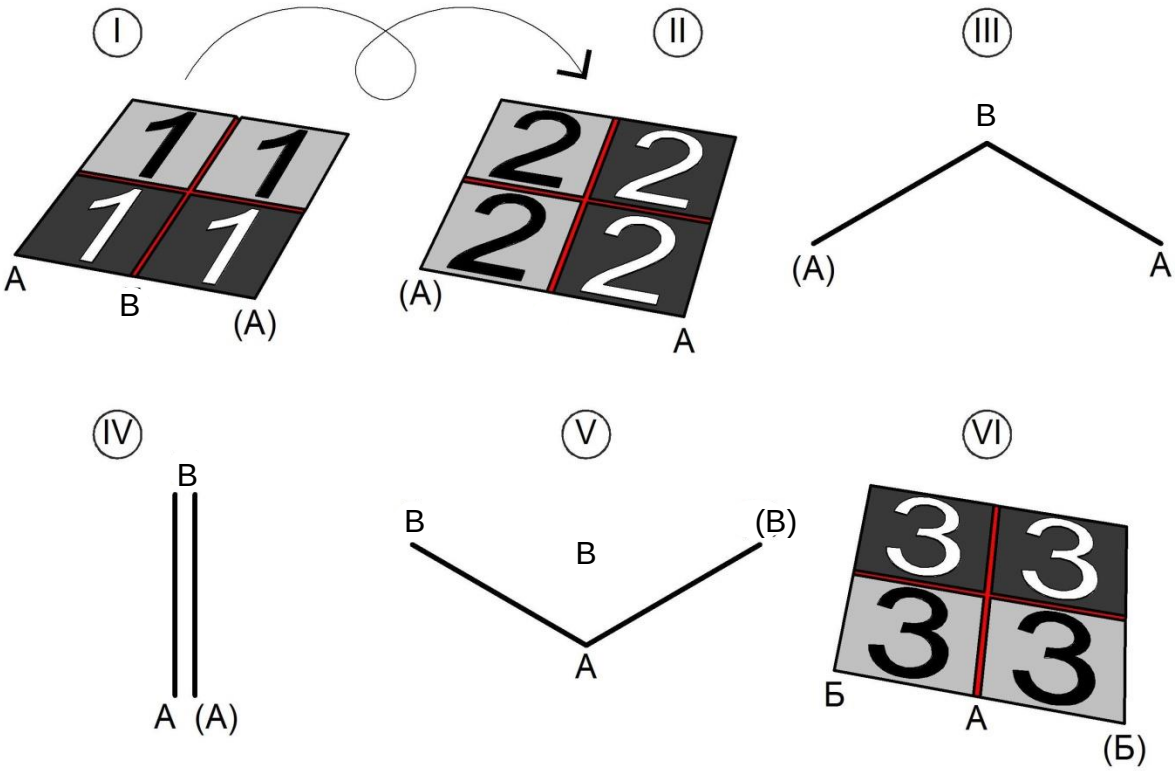

Figure 9. The principle behind operating a tri-tetraflexagon.

The tri-tetraflexagon realized in the form of a hinged assembly acts as a moveable joint with a variable axis of rotation (see **Fig. 10**). The hinge in question can take on three states, marked (**a**), (**b**), and (**c**), with a smooth transition from one state to another.

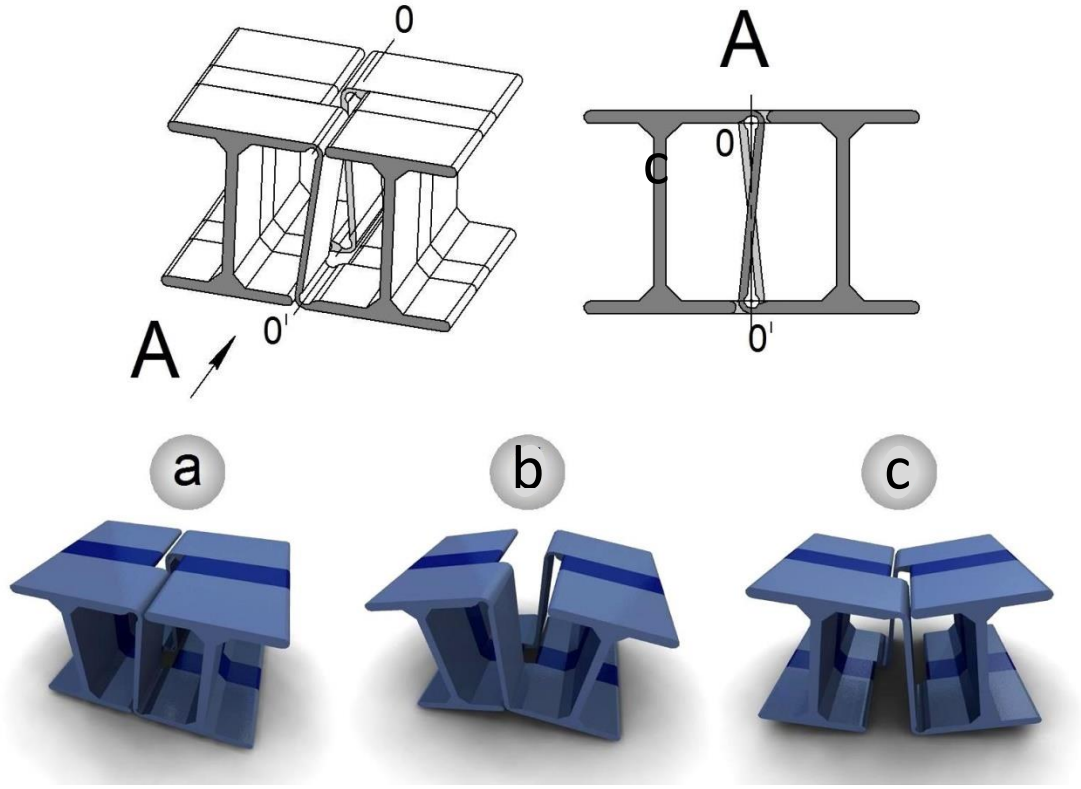

Figure 10. Assembly of the moveable joint with a variable axis of rotation.

Going sequentially along the chord of the wing, if we combine the hinges with a variable rotary axis, ensuring the follow the contour of the wing profile, we will get the reconfigurable part of the aerodynamic elastic-deformable panel. (see **Fig. 11**).

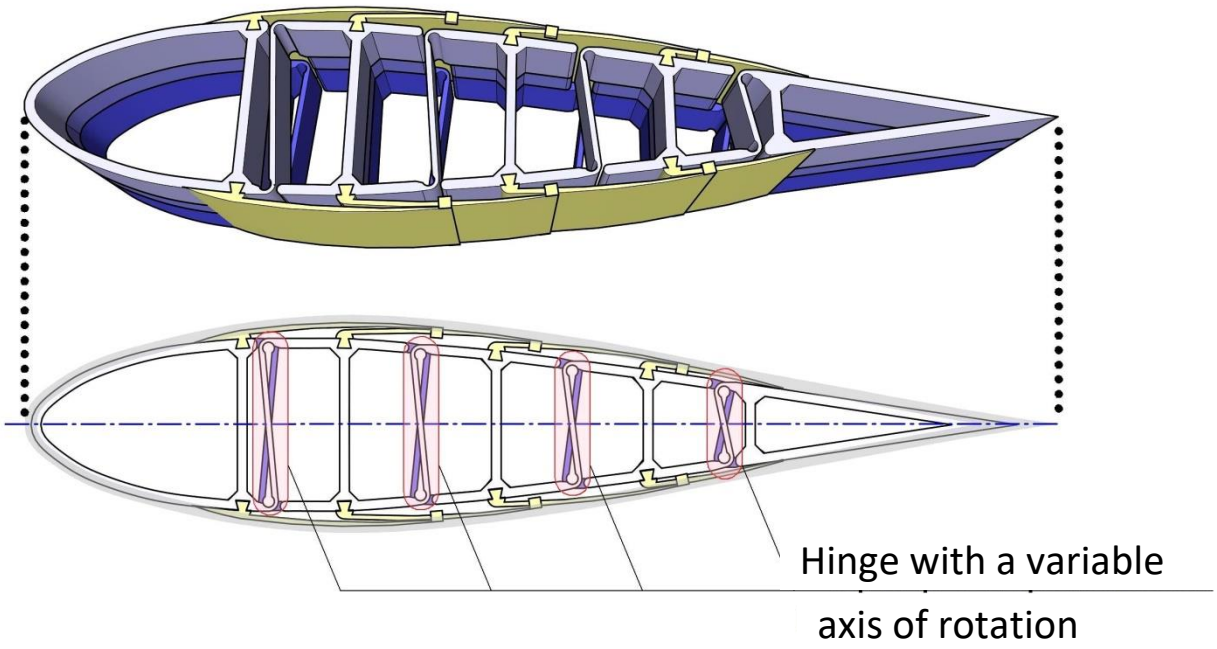

Figure 11. Profle of the adaptively controlled aircraft wing.

The solution described in this article leads to improvements in the aerodynamic characteristics of the aircraft. The profile of the adaptive controlled wing takes on a shape that is optimal at every flight mode. The construction of such a wing allows the smooth deflection of the nose and tail part of the wing, thus changing the curvature along the span, depending on the altitude, flight speed and load.

We have attempted a brief introduction to an example of how a historical technical idea got a chance to be reborn and contribute to significant progress after many centuries. This idea now forms a basis for the creation of a new modern technology. This is possible only with inquisitive and creative attention to phenomena and objects. We encourage our readers to develop these qualities.

About the author

Alexey Ivchenko is a Russian engineer who has been gaining wide recognition for his expertise in reconfigurable structures. His design of an adaptive, reconfigurable airplane wing was recently recognized as one of the Top 10 innovations at the international air show MAKS held biannually near Moscow. Alexey has a number of publications in Russian popular science magazines, including *Nauka i Zhizn'* [Science and Life]. He is a special correspondent for the children's magazine *Junyj Tekhnik* [Young Technician] and he has written for the journal *Levsha* [Leftie] which focuses on guiding children in the inventive process.

Author contact:

+7-937-719-89-96

+7-904-433-05-11 (WhatsApp)

https://www.facebook.com/flexagonstructures

https://vk.com/geneta77

--

E-mail: ge7net7a@yandex.ru