March 29, 1927. T. VON KÁRMÁN ET AL 1,622,930

TURBO MACHINE

Filed Aug. 21, 1924 2 Sheets-Sheet 1

Fig. 1.

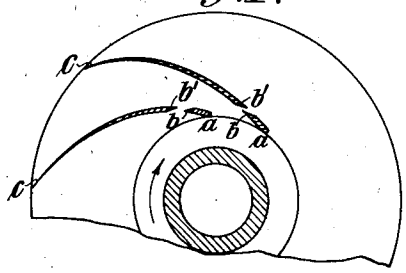


Fig. 1a.

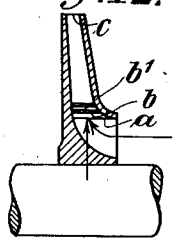


Fig. 2.

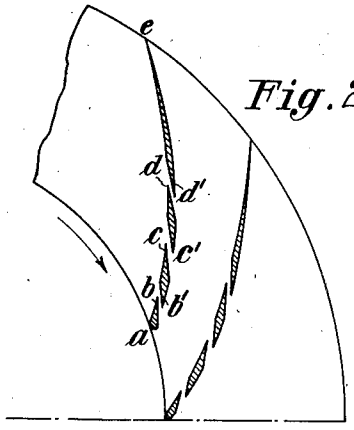
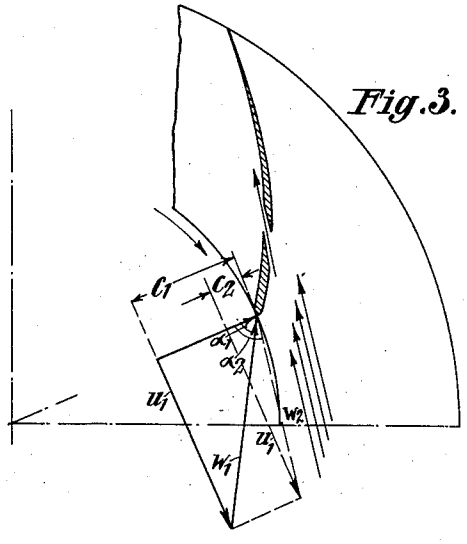


Fig. 3.



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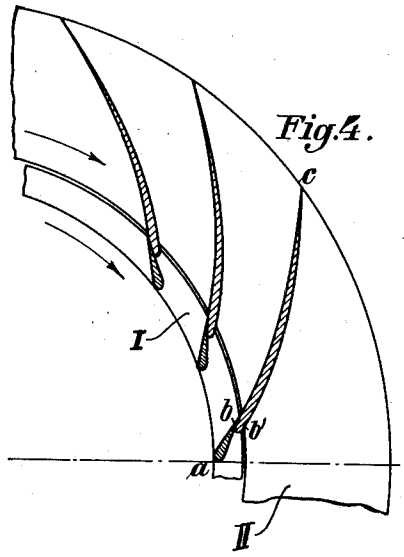


Fig.4.

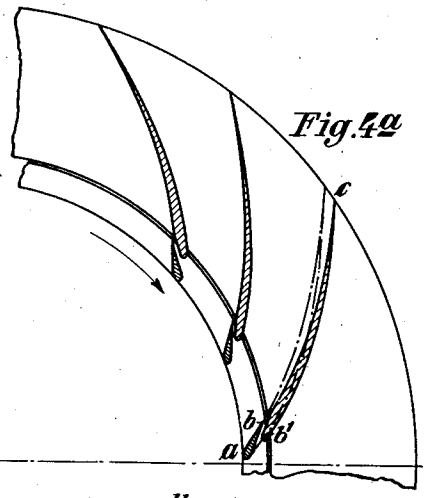


Fig.4a

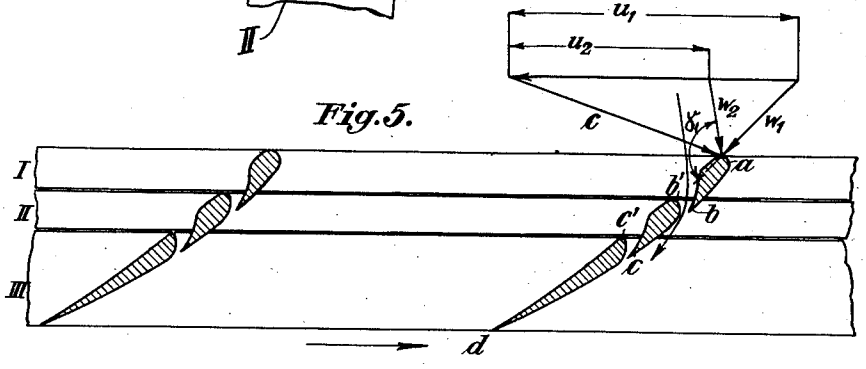


Fig.5.

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UNITED STATES PATENT OFFICE.

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TURBO MACHINE.

Application filed August 21, 1924, Serial No. 733,418, and in Germany October 8, 1921.

This invention relates in general to turbo machines and more particularly to the blades in such machines. Its object is to reduce the losses due to the shock between the fluid and the blades and to increase the efficiency by improving the conditions of flow of the fluid in the machine. The word "turbo machine" is intended to mean for the purposes of this specification all machines which take in and deliver a fluid and in so doing alter its condition, as for example ventilators, compressors, pumps, propellers, screws, etc. and also turbo power machines which convert the energy in a fluid into mechanical energy, such machines being for example water and steam turbines, air motors etc.

The invention consists in building up each of some or all of the blades of a turbine in sections divided by gaps that are adapted to give rise to collateral currents which carry the main current of fluid along with them and prevent the main current from leaving the blade surface. The blade sections may be assembled on different circular members which may be adapted to be displaced with respect to each other. The blade sections are so constructed that when the gaps between neighbouring blade sections are closed a continuous or connected blade contour is formed of each series of associated blade sections on the sides of lower and higher pressure when the sections abut upon each other so as to close the intervening gaps. The regulation of said gaps may be accomplished in any suitable manner, as by hinged or sliding gaps or by turning the rings with their blade sections relatively to each other.

The invention is shown by way of example in the drawing in which—

Fig. 1 is a section through two adjacent blades of the rotor of a turbo compressor while Fig. 1ª is a radial section through the rotor.

Fig. 2 is a section similar to Fig. 1 except that each of the blades is divided into several instead of only two sections.

Fig. 3 is a speed diagram of the blade arrangement of Fig. 1.

Fig. 4 shows a blade arrangement in which the blade sections are arranged on concentric circular members, Fig. 4ª showing the circular members of Fig. 4 displaced with respect to each other so as to form gaps between the blade sections belonging to each blade.

Fig. 5 shows a development of the blades of an axial turbine.

In accordance with Figs. 1 and 1ª the blades are generally constructed so that at a certain speed of revolution and at a certain output the fluid enters the rotor without any shock occurring between the fluid and blade. This is illustrated in Fig. 3 in which the speed w_1 relatively to the rotor is the resultant of the speed c_1 at which the fluid passes radially through the machine and of the speed of revolution u_1. But if the output or quantity of fluid delivered by the machine is reduced, as by a throttling device, the relative speed w_2 in relation to the radial direction will form a greater angle α_2, which would result in a loss through shock. Consequently the pressure which could be obtained by means of the compressor without this loss will be reduced. A further increase of the angle α will even result in the current of fluid leaving the blade, which becomes noticeable during operation of the machine by a sudden drop of head. These drawbacks are overcome by the invention by sub-dividing the blades a, c in blade sections a, b, b', c as shown in Fig. 1. If, with this arrangement, the angle grows, a part of the air or fluid passing through the machine will rush through the gaps b, b' and prevent the shock and divert the entire current so that it will follow the form of the blade or contact therewith up to the point c. By this means a greater rise of pressure, particularly in the case of small outputs, is obtained. A further advantage of the arrangement is that in consequence of the current of fluid being caused to contact with the blades under different operating conditions, the number of blades can be reduced, so that a saving of material and a reduction of losses through friction results. By increasing the pressure in turbo compressors the number of steps in the same can also be lessened.

As shown in Fig. 2 each blade may be subdivided into several sections a, b, b', c, c', d, d', e with intervening gaps b, b', c, c', d, d'.

In the modification shown in Figs. 4 and 4ª each blade is divided into two sections, the smaller sections being attached to a circular carrying member and the larger sections being attached to a second circular carrying member. The circular members I, II may be fixed relatively to each other or

they may be arranged to be displaced relatively to each other during operation as indicated in Fig. 4a such displacement enabling regulation of the machine. In many cases it is advantageous to arrange the blade sections so that in a certain position of the rotating circular members the gaps b, b', etc. are completely closed and associated blade sections form a single more or less smooth blade as shown in Fig. 4.

Another modification consists of an axial turbine with blades spaced comparatively far apart as in modern high speed machines. Fig. 5 shows a development of the blade system for an axial turbine. In this figure the speeds in relation to the rotor, which is imagined to be stationary, are shown. When the fluid enters the machine running at its normal speed of operation without shock, the current passing into the machine when it runs at a reduced speed will form an obtuse angle α with the initial tangent of the blade so that the current will tend to leave, or tear away from, the convex side of the blade and this will give rise to a reduction of output or efficiency. In accordance with the invention the blade system is subdivided so that the fluid that passes through the gaps b, b' regulates the total current in such a way that, even when the current entering the machine deviates still further from the angle at which normally no shock arises, the current will contact properly with the blade so that the second or third section b', c, c', d will become effective, which would not be the case if the current were to tear away or leave the blade. By displacing the various series of blade sections I, II, III a regulation can be obtained which is as good as that accomplished by turning the individual blades and which is far simpler in structural design. Instead of regulating the gaps b, b', c, c', etc., by turning the circular blade section carriers, the same result may be obtained by closing the gaps by hinged or slidable members or any other suitable device. The blade sections could also be rotated.

The invention may be applied in a similar manner to rotary pumps, screw ventilators, wind wheels, steam turbines, etc.

We claim:—

1. In turbo machines, blades co-operating with the fluid passing through the machine, each of said blades being made with uniform continuous contours at either sides of its body and having comparatively small gaps provided therein whereby said blade is divided into sections, said gaps being adapted to pass a comparatively small portion of the fluid from one side of the blade to the other one and to so produce auxiliary streams to draw the main stream between two blades unto and alongside of the contour of the respective blade, said blade sections being carried by circular carrying members.

2. In turbo machines, blades co-operating with the fluid passing through the machine, each of said blades being made with uniform continuous contours at either sides of its body and having comparatively small gaps provided therein whereby said blade is divided into sections, said gaps being adapted to pass a comparatively small portion of the fluid from one side of the blade to the other one and to so produce auxiliary streams to draw the main stream between two blades unto and alongside of the contour of the respective blade and said blades being formed of adjustable blade sections adapted to be positioned to divide said blades by producing the aforesaid gaps.

3. In turbo machines, blades co-operating with the fluid passing through the machine, each of said blades being made with uniform continuous contours at either sides of its body and having comparatively small gaps provided therein whereby said blade is divided into sections, said gaps being adapted to pass a comparatively small portion of the fluid from one side of the blade to the other one and to so produce auxiliary streams to draw the main streams between two blades unto and alongside of the contour of the respective blade, the blade sections being adjustable to vary the widths of the aforesaid gaps.

4. In turbo machines, blades co-operating with the fluid passing through the machine, each of said blades being made with uniform continuous contours at either sides of its body and having comparatively small gaps provided therein whereby said blade is divided into sections, said gaps being adapted to pass a comparatively small portion of the fluid from one side of the blade to the other one and to so produce auxiliary streams to draw the main stream between two blades unto and alongside of the contour of the respective blade, adjustable gaps being produced by making said sections movable.

5. In turbo machines, blades co-operating with the fluid passing through the machine, each of said blades being made with uniform continuous contours at either sides of its body and having comparatively small gaps provided therein whereby said blade is divided into sections, said gaps being adapted to pass a comparatively small portion of the fluid from one side of the blade to the other one and to so produce auxiliary streams to draw the main stream between two blades unto and alongside of the contour of the respective blade, said sections being made adjustable so as to form at will in the closed position a single smooth blade, or in open position one divided by gaps.

6. In turbo machines, blades co-operating with the fluid passing through the machine.

each of said blades being made with uniform continuous contours at either sides of its body and having comparatively small gaps provided therein whereby said blade is divided into sections, said gaps being adapted to pass a comparatively small portion of the fluid from one side of the blade to the other one and to so produce auxiliary streams to draw the main stream between two blades unto and alongside of the contour of the respective blade, said blade sections being carried by members adapted to be arranged in adjustable spaced relation to one another so as to have at will a blade subdivided by gaps or closed into a continuous single blade, said carrying members corresponding in number to that of the sections in a blade and each carrying one and the same particular section of each blade.

In testimony whereof we affix our signatures.

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KARL FROMM.