Oct. 14, 1941. R. P. KROON 2,258,773

ELASTIC-FLUID TURBINE

Filed April 2, 1941

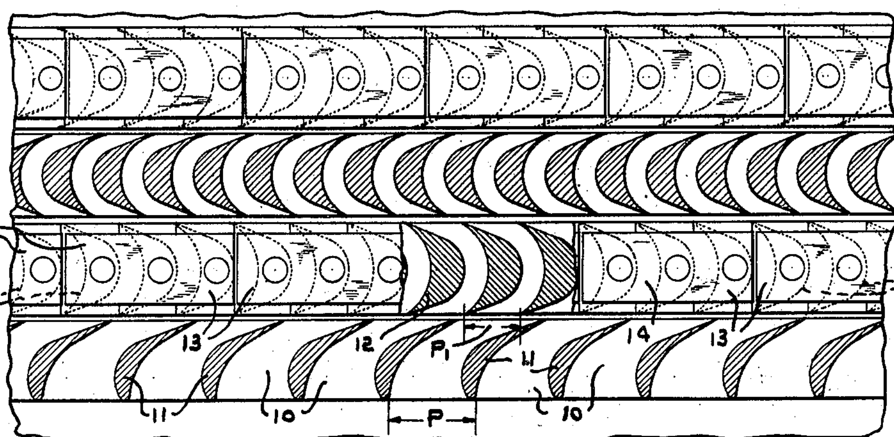

FIG. 1.

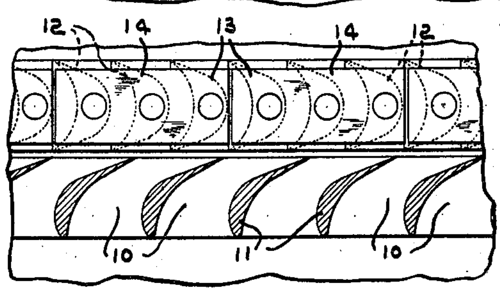

FIG. 2.

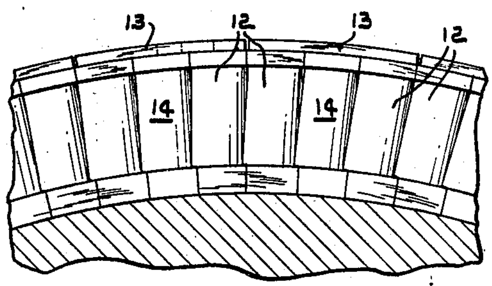

FIG. 3.

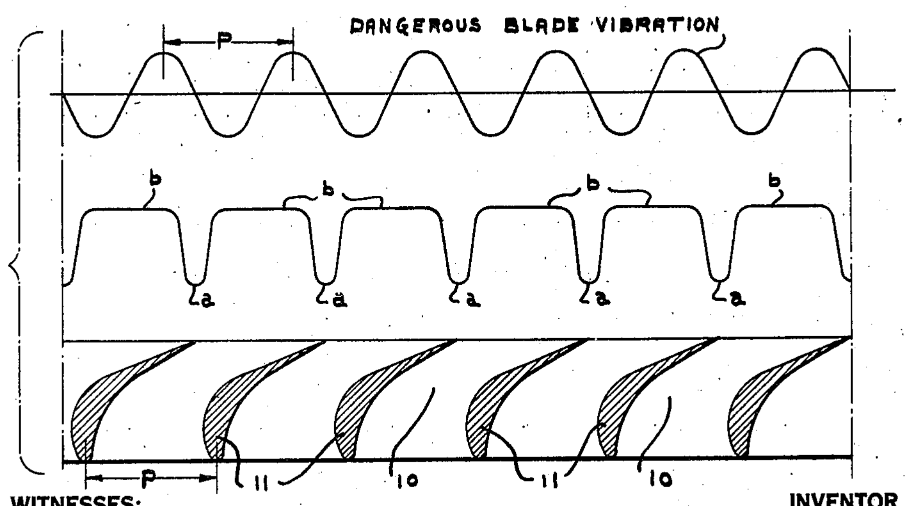

FIG. 4.

WITNESSES:

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Patented Oct. 14, 1941

2,258,773

UNITED STATES PATENT OFFICE

2,258,773

ELASTIC-FLUID TURBINE

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Application April 2, 1941, Serial No. 386,442

5 Claims. (Cl. 253—39)

The invention relates to stages of elastic fluid turbines, and it has for an object to resist effectively the inducement of blade vibration because of non-uniform flow of elastic fluid issuing from nozzle or vane passages.

Tests have shown, not only that the invention is effective for the purpose indicated, but also that it is particularly desirable to employ it where the pressure ratio across a stage is relatively high, the elastic fluid flow disturbances inducing blade vibration increasing as the velocity and the pressure ratio increase and such disturbances increasing quite rapidly when the acoustic velocity is exceeded. Accordingly, a further object of the invention is to provide a stage of the high-pressure ratio type and embracing vanes and blades, particularly short blades, and it has for an object to connect the blades together in groups and to provide such relation of nozzle or vane pitch, blade pitch, and the number of blades connected together in each group that blade vibration, due to irregularities in flow caused by the presence of vanes, is effectively resisted.

These and other objects are effected by the invention as will be apparent from the following description and claims taken in connection with the accompanying drawing forming a part of this application, in which:

Figs. 1 and 2 are diagrammatic views showing cooperating nozzles and blade groups;

Fig. 3 is a fragmentary view showing blade groups; and

Fig. 4 is a diagrammatic view.

Referring to Figs. 1 and 4, the flow of elastic fluid issuing from the vane or nozzle passages 10 is not uniform because of the wakes occurring in the flow behind each stationary vane 11. In Fig. 4, this non-uniform flow condition is diagrammatically shown, there being wakes, disturbances, or reduced velocity zones a back of each vane 11 and joined by zones b of more uniform velocity.

The non-uniformity of flow referred to is capable of exciting dangerous blade vibration, especially when the natural period of vibration of the moving blades is such that a blade goes through one cycle in exactly the distance required for it to travel from one nozzle to the next. While this capability of non-uniformity of flow to induce blade vibration is necessarily restricted to blades having high frequencies of vibration, nevertheless, the first moving blade row of an initial Curtis stage, the moving row of an initial Rateau stage, possibly the second moving row of a Curtis stage, and, in general, any short blade near the inlet end of the turbine, may come within the above frequency range. In Fig. 4, the top curve indicates the condition of dangerous blade vibration where a blade goes through one vibration cycle while traveling a distance equal the nozzle pitch p.

In accordance with the present invention, the blades 12 of the first moving row of an initial stage are connected by shroud elements 13 to form blade groups, at 14. In Fig. 1, showing an initial Curtis stage of the high-pressure ratio type, both the first and second moving rows of blades are connected together in such groups; and, in Fig. 2, showing an initial Rateau stage of the high-pressure ratio type, the moving blades are similarly connected together in groups. The number of blades connected in a group is such that the combined effect on all the blades in the group does not involve any exciting forces of dangerous frequencies. The blade pitch, nozzle or vane pitch, and number of blades connected together in each group are so arranged that the destructive forces on the individual blades balance each other. Balancing is secured when the nozzle pitch, the blade pitch, and the number of blades in each group have the following relation

$$p=p_1\frac{n}{m}$$

where

p is the nozzle pitch,

p_1, the blade pitch,

n, the number of blades connected together in each group, and

m is the number of vane passages covered by the blades in a group.

The number represented by m is a whole number, it is neither equal to nor a multiple of n, and it is preferably equal to $n-1$. If m is equal to $n-1$, then the above equation becomes

$$p=p_1\frac{n}{n-1}$$

Assuming that $n=3$ (3 blades per segment) and that the moving blade pitch p_1 is 1.20 inches, a stationary vane or nozzle pitch p of 1.80 inches may be used and blade vibration, due to irregularities in flow caused by the presence of the vanes, is effectively resisted or avoided.

Referring to Fig. 2, it will be noted that the vane pitch and the blade pitch are related so that two vane passages supply three blade passages; and that, in this view, m is equal to the number of nozzle passages 10 covered by the blades of a group 14, that is, m is equal to 2.

Having conceived of the possibility of disturbances making themselves felt on the blades as they pass the nozzle jets and of vibration or a dangerous resonant condition which might be built up, tests have shown the existence of such disturbances and the effects thereof. Furthermore, tests show the degree of disturbance, that is, up to the critical pressure ratio, the pressure ratio necessary for acoustic velocity, the influence of the wakes behind the nozzle vanes is not very important but it becomes of increasing consequence as the pressure ratio is further increased.

While the invention is shown as applied to two forms of turbine stages, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and it is desired, therefore, that only such limitations shall be placed thereupon as are specifically set forth in the appended claims.

What is claimed is:

1. In a turbine stage comprising stationary vanes, moving blades each having such natural frequency as to be likely to be resonant with elastic fluid flow disturbances due to the presence of the vanes, and means for connecting together in groups the blades of the first moving row of the stage; the vane pitch, the blade pitch and the number of blades connected together in each group having the relation,

$$p=p_1\frac{n}{m}$$

where p is the vane pitch, p_1 the blade pitch, n the number of blades connected together in each group, and m is a whole number which is neither equal to nor a multiple of n.

2. In an arrangement for resisting moving blade vibration of an elastic fluid turbine initial impulse stage having the elastic fluid pressure ratio thereacross sufficient to produce elastic fluid velocity which is acoustic or greater, said initial stage comprising stationary vanes and moving blades, the individual moving blades having such natural frequency as to be likely to be resonant with elastic fluid flow disturbances due to the presence of the vanes, and means for connecting together in groups the blades of the moving row of the initial stage; the vane pitch, the blade pitch and the number of blades connected together in each group having the relation,

$$p=p_1\frac{n}{m}$$

where p is the vane pitch, p_1 the blade pitch, n the number of blades connected together in each group, and m is a whole number which is neither equal to nor a multiple of n.

3. In a turbine stage comprising stationary vanes, moving blades each having such natural frequency as to be likely to be resonant with elastic fluid flow disturbances due to the presence of the vanes, and means for connecting together in groups the blades of the first moving row of the stage; the vane pitch, the blade pitch and the number of blades connected together in each group having the relation,

$$p=p_1\frac{n}{n-1}$$

where p is the vane pitch, p_1 is the blade pitch, and n is the number of blades connected together in each group.

4. In an arrangement for resisting moving blade vibration of an elastic fluid turbine initial impulse stage having the elastic fluid pressure ratio thereacross sufficient to produce elastic fluid velocity which is acoustic or greater, said initial stage comprising stationary vanes and moving blades, the individual moving blades having such natural frequency as to be likely to be resonant with elastic fluid flow disturbances due to the presence of the vanes, and means for connecting together in groups the blades of the moving row of the initial stage; the vane pitch, the blade pitch and the number of blades connected together in each group having the relation,

$$p=p_1\frac{n}{n-1}$$

where p is the vane pitch, p_1 is the blade pitch, and n is the number of blades connected together in each group.

5. In an arrangement for resisting moving blade vibration of an elastic fluid turbine initial impulse stage comprising a row of stationary vanes providing vane passages, a row of moving blades providing blade passages receiving elastic fluid issuing from the vane passages, the individual moving blades having such natural frequency as to be likely to be resonant with elastic fluid flow disturbances due to the presence of the vanes, said vanes and blades being spaced circumferentially so that the blade pitch is two-thirds of the vane pitch, and means for connecting the blades together in groups of three.

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