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AXIAL FLOW COMPRESSOR, BLOWER OR VENTILATOR WITH REDUCED NOISE PRODUCTION

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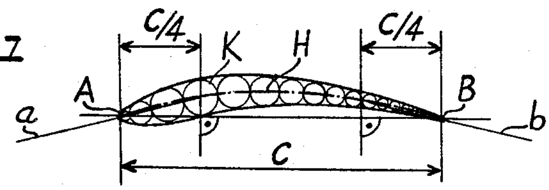
Fig-1



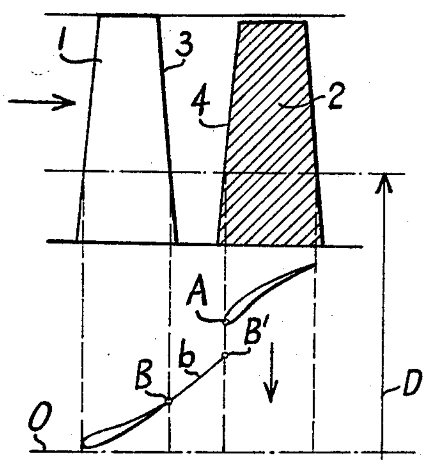


Fig-2

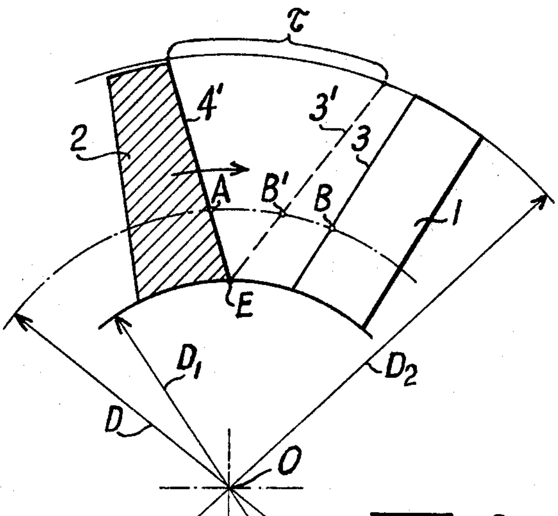


Fig-3

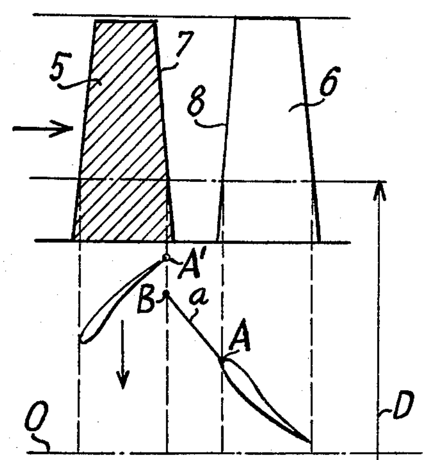


Fig-4

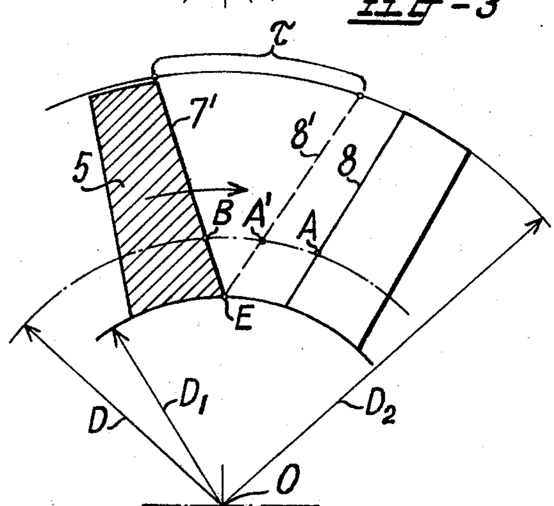


Fig-5

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AXIAL FLOW COMPRESSOR, BLOWER OR VENTILATOR WITH REDUCED NOISE PRODUCTION

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2 Claims. (Cl. 230—120)

This invention relates to a blade arrangement in axial-flow compressors, blowers, or ventilators which reduces the operating noise of these machines.

Axial-flow compressors and similar machines generate a so-called "siren noise" which is very unpleasant and may prevent their application in spite of their known advantages.

The siren noise originates in the blading of conventional compressors, blowers or ventilators.

We have found by theoretical and experimental work that the siren noise is produced when the blades pass through wakes behind the preceding blades and that the mutual position of the blades of axially adjacent rows is therefore closely related to this noise.

The invention provides two solutions of the noisiness problem in axial-flow compressors and like machines which may be applied simultaneously or separately.

In accordance with this invention, the operating noise of these machines is reduced by using a specific ratio of the number of rotor blades to the number of stator blades, and by selecting angular relationships of the edges of the rotor and stator blades which will be explained below in more detail. Each of these two noise reducing measures may be used separately or with the other one.

The numerical ratio of the rotor blades to the stator blades in accordance with this invention is either

$$\frac{Z_r}{Z_s}=\frac{1}{k}\frac{i}{2}$$

wherein Z_s and Z_r respectively are the numbers of stator and rotor blades, i is a positive, odd, integral number, and k is a positive, integral number; or

$$\frac{Z_r}{Z_s}=\frac{1}{k}\left(i-\frac{2}{3}\right)$$

or

$$\frac{Z_r}{Z}=\frac{1}{k}\left(i-\frac{1}{3}\right)$$

wherein i and k are integral positive numbers.

These ratios are generally valid, and reach an optimum value when Z_r is smaller than Z_s.

The relative position of the leading edges and the trailing edges of the blades of two adjacent blade wheels, that is, rotor and stator or vice versa, has been found to affect the noise level as a function of the parameter S

$$S=\frac{\tau}{\tau_0}$$

wherein τ is the characteristic value of blade crossing of the stator and rotor wheels, or of the rotor and stator wheels, and can be determined graphically as a distance in the circle defined by the blade tips and having a diameter D_2, and τ_0 is the pitch or spacing between circumferentially adjacent rotor or stator blades, also as measured on the circle of diameter D_2, whereby

$$\tau_0=\frac{\pi D_2}{Z_r}$$

or

$$\tau_0=\frac{\pi D_2}{Z_s}$$

For low machine noise, the parameter S should be greater than 0.65. It reaches its optimum value at $S=Z_r/Z_s$.

The invention will be best understood from the following description relating to the accompanying drawing which shows dimensional relationships relevant to blade crossing. FIGS. 1, 2, 3, are illustrative of conditions in the case of crossing of a stator blade by a rotor blade, and FIGS. 4 and 5 for a crossing of a rotor blade by a stator blade.

The manner of determining the characteristic crossing value τ will now be explained in more detail.

Referring more particularly to FIG. 1, there is shown a stator blade in airfoil section on a cylindrical surface of diameter D about the machine axis and developed in a plane. The mean or camber line H of the section is the locus of the centers of circles K inscribed into the contour of the blade profile. The points of intersection of the camber line H with the leading and trailing edges are at A and B respectively. The length of the chord between points A and B is C. Normal lines are drawn on the chord AB at the distance $C/4$ from the points A and B respectively, and their intersections with the mean line H are determined. Lines connecting the points of intersection with the points A, B respectively and extending outward through the last-mentioned points constitute a leading ray or line a and a trailing ray or line b. The function of these rays or lines will become presently apparent.

The direction of these rays is important in determining the blade cross-over.

FIGS. 2 and 3 illustrate the crossing of a stator blade by the leading edge of a rotor blade. The stator **1** is arranged ahead of the rotor **2** in the direction of fluid flow as indicated by arrows. FIG. 2 shows blades in section on a cylindrical surface of diameter D and developed in a plane. The trailing edge **3** of the stator **1** includes the points B of all cylindrical sections. The leading edge **4** of the rotor blade **2** includes the corresponding points A. The edge **4** generates a surface of rotation while rotating about the axis O of the rotor. The trailing ray b of the stator blade **1** on the selected diameter D intersects the surface of rotation at B′. The line connecting points of the surface of rotation analogous to B′ is projected axially on a plane perpendicular to the axis O and defines a projected line **3′**, as shown in FIG. 3. The leading edge **4** of the rotor blade **2** is projected in a similar manner on the perpendicular plane, whereby a line **4′** is defined. When the lines **3′** and **4′** are shifted angularly about the axis O by rotation of the rotor until they intersect at a point E of the circle of root diameter D_1, the circumferential distance of the lines **3′**, **4′**, as measured on a circle of tip diameter D_2 about the axis O is the characteristic crossing value.

Smiliar considerations hold also for the crossing of a rotor blade by a stator blade, as shown in FIGS. 4 and 5. FIG. 4 shows a rotor blade **5**, a stator blade **6**, the trailing edge **7** of the rotor blade **5**, and the leading edge **8** of the stator blade **6**. Projected lines **7′**, **8′** are derived from the edges **7**, **8** in a manner evident from the above description of FIGS. 2 and 3. The value τ is obtained from FIGS. 4 and 5 by the same method as described above.

τ_0, as mentioned above, is the pitch or circumferential distance of adjacent blades of the rotor or stator, and the machine noise is low when

$$S=\tau/\tau_0>0.65$$

and reaches a minimum at

$$S=Z_r/Z_s$$

Experiments have shown that an axial compressor meeting the afore-described conditions of numerical blade ratio and crossing characteristics either individually or simultaneously produces noise at a level harmless from the point of view of industrial health.

What we claim is:

1. An axial compressor, blower, or ventilator having a set of rotor blades and a set of stator blades, said blades satisfying the relationship $S=\tau/\tau_0>0.65$, wherein τ is the characteristic crossing value of one of said sets by the other set, and τ_0 is the pitch of the blades of said other set,

(1) the blades of each set being spaced about a common axis and extending radially between a root circle near said axis and a tip circle remote from said axis, said circles being centered in said axis, said pitch being the circumferential spacing of adjacent blades of the other set as measured on said tip circle,

(2) said characteristic crossing value being the circumferential spacing of two lines projected on a plane perpendicular to said axis, said spacing being measured on said tip circle, said projected lines intersecting in said root circle,

(3) one of said projected lines being an axial projection of a line of intersection between a surface of rotation about said axis and a plurality of radially spaced trailing rays of one of the blades of said other set, each trailing ray being defined by the point of intersection of the camber line of said one

blade with the trailing edge of said one blade in the airfoil section of said one blade and by a point on said camber line spaced from said trailing edge toward the leading edge of said one blade a distance equal to one fourth of the length of the chord between said camber line and said leading edge, said distance being measured along said chord,

(4) the other one of said projected lines being an axial projection of the leading edge of one blade of the other set,

(5) said surface of rotation being defined by said leading edge of the last-mentioned blade when said other set rotates about said axis.

2. A compressor, blower, or ventilator as set forth in claim 1, wherein the ratio of the number Z_r of said rotor blades to the number Z_s of said stator blades is

$$\frac{Z_r}{Z_s}=\frac{1}{k}\frac{i}{2}$$

wherein i is an integral positive odd number, and k is an integral positive number.

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