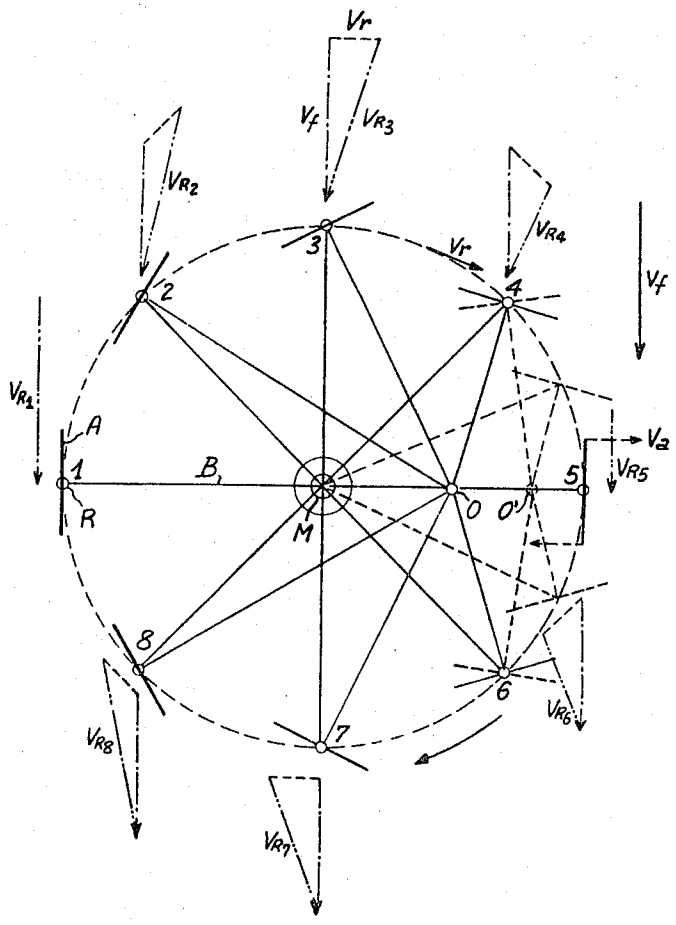
May 14, 1968 P. DEJUSSIEU-PONTCARRAL ET AL 3,382,931

FLUID-DRIVEN ENGINE HAVING ANGULARLY ADJUSTABLE BLADES

Filed March 11, 1965 4 Sheets-Sheet 1

Fig. 1

PRIOR ART



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Fig. 2

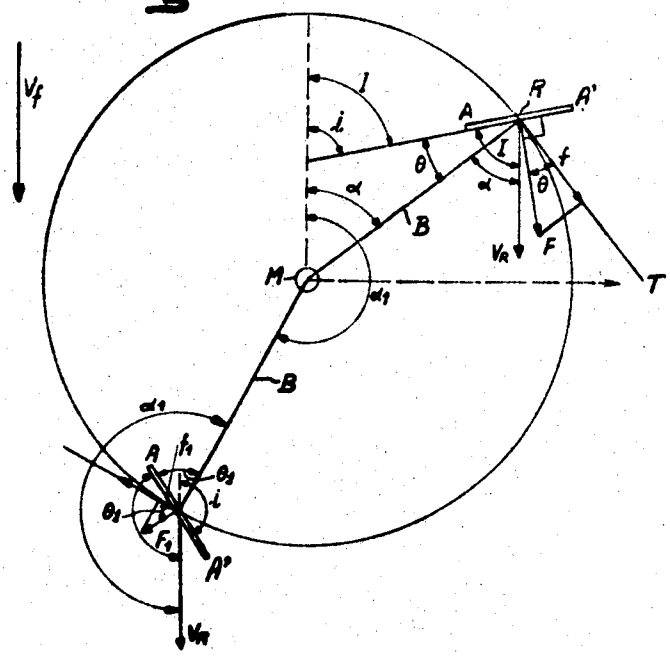
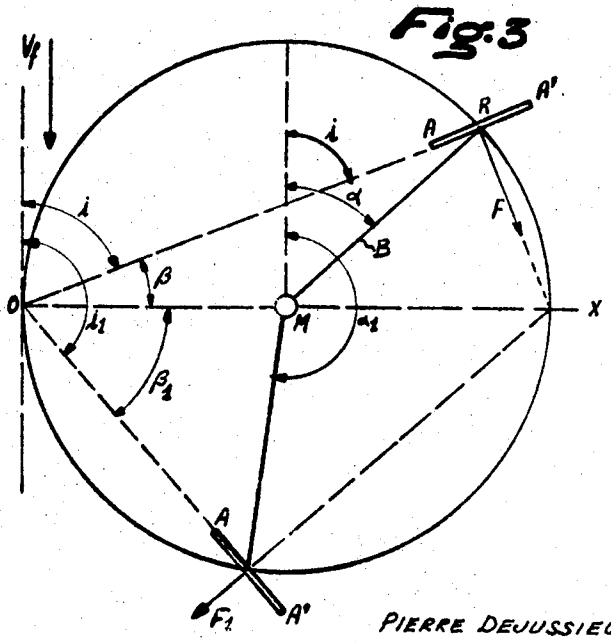


Fig. 3



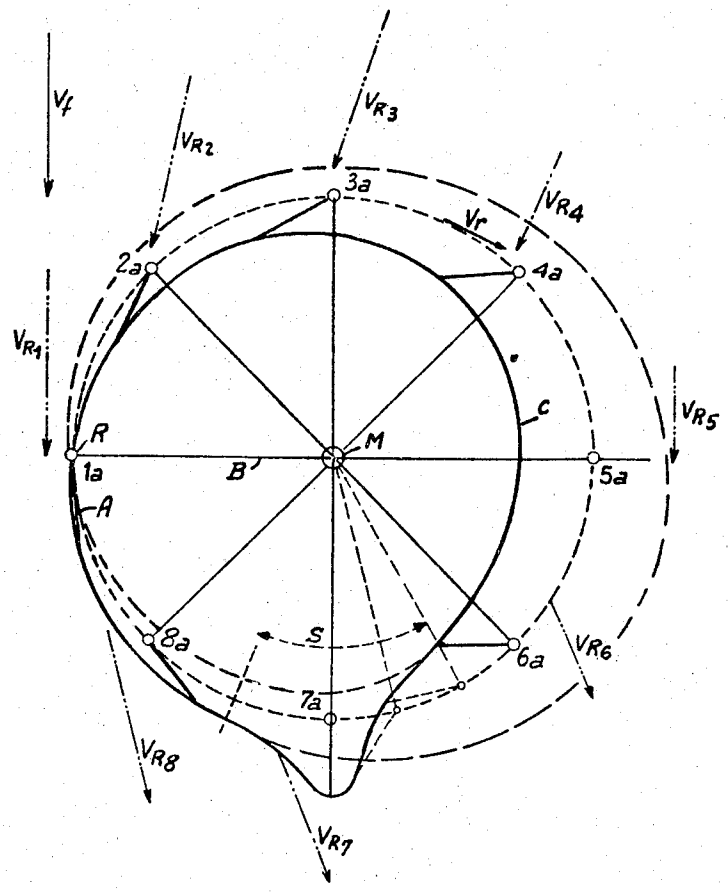
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Filed March 11, 1965 4 Sheets-Sheet 3

Fig. 4



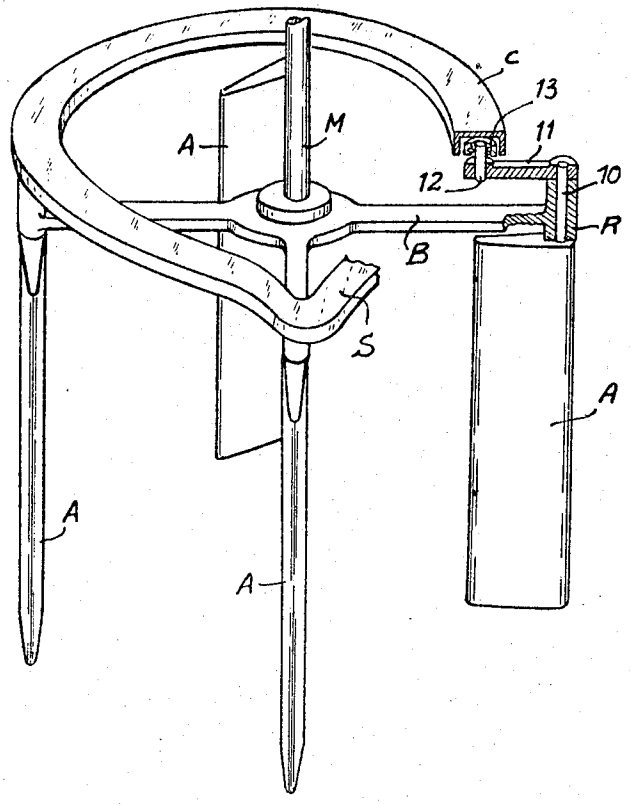
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Fig. 5



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FLUID-DRIVEN ENGINE HAVING ANGULARLY ADJUSTABLE BLADES

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2 Claims. (Cl. 170—24)

ABSTRACT OF THE DISCLOSURE

A fluid-driven engine whose axis is perpendicular to the direction of fluid flow, has an eccentrically mounted rotatable blade swingable about a second axis parallel to the first axis. The blade is guided to swing so that it is substantially perpendicular to the fluid flow when it is being pushed about the downstream side of its path, and feathers on the return side. To do this, the blade flops over to reverse its position at the most downstream point in its path.

Engines driven by a fluid stream and including at least one vertical blade of which the medial axis moves along a cylindrical path having a vertical axis are well-known in the art, the angular setting of the plane of the blade with reference to the direction of flow of the driving fluid depending on the position of the blade on said cylindrical path having a vertical axis.

Thus, an embodiment of such an engine has already been described, wherein the blade may, for instance, be carried by an arm, keyed to the shaft extending along the rotary axis and forming the power transmitting shaft, to be pivotally secured to said arm along an axis registering with the medial axis of said blade in which case the blade is angularly set by an arm of an adjustable length which is perpendicular to the blade surface and passes through a point which is stationary for a predetermined rate of running and is located on a perpendicular to the direction of flow of the fluid passing through the rotary axis.

In such an embodiment, the blade shows at two points an incidence angle equal to zero with reference to the direction of flow of the driving fluid, said two points lying at the two ends of the diameter passing through the axis of rotation and the directing axis. At said two points, the blade produces on the power-transmitting shaft a torque which is equal to zero since the blade has a zero incidence with reference to the driving fluid. This is very objectionable for the blade moving along with the stream, i.e. the downstream blade which is located at such a moment in the fluid stream under the most favorable conditions for the production on the shaft of a substantial driving torque. This is true in the vicinity of the point at which the downstream blade is tilted and in fact throughout an area in which the blade has an incidence which is very different from optimum incidence. To remove this drawback, it has been proposed to shift to a maximum the directing axis as near as possible the cylindrical path of the blade, which blade is substantially perpendicular to the direction of flow of the driving stream over a large development of the downstream area so as to show a detrimental incidence only on a more reduced area while it shows a lower more favorable incidence in the so-called upstream area, which has been found to increase the power. However, the tilting of the downstream blade is obtained very speedily and its speed of rotation around its vertical axis leads to the production of a resistance and of eddies the presence of which influences the action of the driving fluid on the blades reaching subsequently the same point and also during their progression.

Our invention has for its object to eliminate the above drawbacks and to provide an engine of the type having a vertical axis and angularly shiftable blades, which engine driven by a fluid stream has improved efficiency.

According to our invention, the angular setting of the blade is defined as a function of the ratio between the speed of flow Vf of the driving fluid and the rotary speed of the engine Vr and of the angle of the blade in order to provide at each point a maximum torque on the power shaft.

According to a first approximation, the guiding of the blade is executed in a manner such that the slope of the blade with reference to the reference axis extending in the direction opposed to the direction of the flow of the fluid may be equal at each point to

$$i=\frac{\pi}{4}+\frac{\alpha}{2}$$

α being the angle of the radius passing through the blade with the reference axis.

The guiding of the blade is ensured by a guideway constituted by a cam stationary with reference to the blades and completely independent of the latter. Said stationary guideway is preferably constituted by a race having a U-shaped cross-section cooperating with a roller or cam follower carried by a crank keyed to the end of the vertical spindle carried by the blade and passing through the end of the arm rigid with the power shaft.

The crank is preferably parallel at each point to the plane of the blade but it may also be perpendicular to said plane or form with the latter any desired angle, the outline of the cam being modified as required for this purpose.

The guiding of the blade may include either a single guiding roller guided itself by two curved guides crossing each other and following in alternation said guides during any two successive revolutions of the engine or else two guiding rollers lying symmetrically with reference to the pivotal axis of the blade, the cams corresponding to one of said curves and each guiding roller ensuring in alternation the actual guiding during one revolution.

According to a further feature, the blade is subjected to a reversal of its position in the vicinity of the point of its path lying on the upstream or on the downstream side of the engine axis, the guide being constituted by elements of the two guiding curves between their point of intersection and the tilting point, said elements merging into each other in registry with said tilting point.

Further features of our invention will appear from the reading of the following description, incorporating a comparison between prior art and our improved fluid-controlled engine, reference being made to the accompanying drawings wherein:

FIG. 1 is a diagrammatic showing in plan view of an engine of a prior known type.

FIG. 2 is a vectorial diagram illustrating the theoretical calculation of the useful force for a zero speed of rotation of the engine.

FIG. 3 is a diagram illustrating the angular setting of the blade producing the maximum static torque.

FIG. 4 is a diagram applicable to the case of our improved engine, ensuring a guiding of the blade producing a reversal of the latter.

FIG. 5 is a diagrammatic perspective view of an embodiment of the engine wherein the guiding is obtained in accordance with FIG. 4.

Turning to FIG. 1, we have illustrated eight positions of a blade A revolvably secured at R to the end of an arm B rigid with a power shaft M, said blade being subjected to a program defining its angular setting, in a manner such that the perpendicular to the blade may always pass

through a stationary point O. The engine thus executed is positioned inside a fluid stream progressing with a speed Vf. Since the blade revolves with a peripheral speed Vr, we obtain at each point a different relative speed V_R of the fluid with reference to the blade.

It is apparent that such a blade may be subjected at each point to a force which is a function of a polar, of the incidence of the flow of fluid with reference to the surface of the blade and of the square of the relative speed of flow V_R, said force being perpendicular to the plane of the blade. The speed V_R being defined by the operative speed Vf and by the speed Vr, it is possible to consider the torque on the shaft as being chiefly a function of the polar, of the angular setting of the blade with reference to the direction of flow and finally of the tangential component of the force obtained, said tangential component defining the torque acting on the shaft.

The resultant acting on the blade being a function of the polar which is an unvarying function for the selected blade and of the incidence of the blade with reference to the vector V_R which varies at each point and is defined in space as disclosed, the maximum power is obtained when the tangential component of the resultant is at a maximum at each point. Furthermore, the torque exerted on M should always suitably face the direction of rotation; in other words, the tangential component of the resultant should always face said direction of rotation.

In the case of FIG. 1, it is apparent that for the position **1**, the torque is very small and is produced by the resistance opposing the progression of the blade in a stream progressing at a speed V_{R1} of which the absolute value is equal to the sum of the absolute values of Vf and Vr. At **2**, **3** and **4** the blade is subjected to a resultant passing through O, which produces a driving torque the tangential component of which is properly set with reference to the direction of rotation. However, since the incidence is defined by the position of the blade with reference to the circle along which it moves by a mathematical equation, it is apparent that, although the resultant torque forms a driving torque, the angular setting of the blade is not in practice that which produces a maximum torque on the shaft under the best hydrodynamic or aerodynamic conditions because the incidence is not that which provides a maximum tangential component of the resultant while the polar is taken into account.

Between the points **4** and **6** and more accurately between two points lying on a line perpendicular to M_O, the blade is tilted through 180° and passes from a position perpendicular to V_R into a position parallel to V_R after which it returns to a reversed position which is also perpendicular to V_R. The torque remains a driving torque but, at **5**, only the friction V_{R5}, exerted by a stream and of which the absolute value is equal to the difference between the absolute values of Vf and Vr, produces a driving torque. At this point and more accurately in the vicinity of said point throughout the area in which the blade is tilted, said blade is shifted out of an incidence perpendicular to V_R which is itself substantially perpendicular to a radius and lies in a direction which leads to the production of a driving torque so that the incidence out of which the blade is shifted is that which produces the maximum tangential component for the resultant. The actual torque is consequently throughout said area much lower than the theoretical torque which is then at a maximum.

In order to eliminate such a drawback, and to obtain maximum power, it has been proposed to shift the point O away from M into a position O' so as to reduce the amplitude of the tilting area and to increase thereby the torque for the positions **2**, **3**, **4** since the tangential component of the resultant is generally higher. However, the blade is subjected to a tilting movement and the speed Va of the end of the blade increases and said speed which is perpendicular to V_{R5} disturbs the flow of fluid, this disturbance continuing its action on the blades reaching the positions **6** and **7**. Furthermore, the large resistant torque obtained through this tilting movement has to be deduced from the driving torque.

For the positions **6**, **7** and **8**, the setting of the blade produces a driving torque which is again lower than the theoretical torque, the incidence of the blade being associated with its angular position on the circle along which it moves by the same mathematical equation as that referred to for the points **2**, **3** and **4**.

When searching for the optimum angular setting of the blade, we will first consider FIGS. 2 and 3 for which the engine has a zero speed Vr. It is possible to calculate the angular setting of the blade giving at each point the maximum useful force. The useful tangential force is a tangential force f.

Assuming F is constituted by the thrust exerted on the blade A—A', C the coefficient of thrust and θ the angle between the direction of application of the force F, which is perpendicular to the blade and the tangent, the following equation is true:

$$f=CF\cos\theta \text{ (FIG. 2)}$$

On the other hand, the value of F is variable and may be taken with a large approximation in the case of water as equal to $SV_{R2}\sin I$, S designating the area of the blade, V_R the relative speed of the fluid which is a resultant of the combination of Vf and Vr and lastly I designating the actual angle between the plane of the blade and direction of V_R. The equation becomes thus $f=CSV_R^2\sin I\cos\theta$.

In the case illustrated in FIG. 2 where the speed of the engine Vr is equal to zero V_R is the same as Vf. Assuming α designates the angle between the arm B passing through the center of the blade and the reference radius lying in a direction opposed to the direction of flow and i the angular setting of the blade with reference to said reference radius $I=i$ and consequently

$$f=CSV_R^2\sin i\cos\theta$$

Furthermore, it is apparent from FIG. 1 that

$$f=CSV_R^2\sin i\cos(i\pm\alpha)$$

and this value should be a maximum for all the values of α which condition is satisfied for

$$i=\frac{\pi}{4}+\frac{\alpha}{2}$$

Geometrically, this means that the blades should be angularly set so that their extensions may pass through the point O (FIG. 3) which is at 270° on the guiding circle described by the point R; as a matter of fact, if β designates the angle between OR and OMX,

$$\beta=i-\frac{\pi}{2}$$

and on the other hand

$$\beta=\tfrac{1}{2}\left(\alpha-\frac{\pi}{2}\right)$$

which leads to

$$i=\frac{\pi}{2}+\tfrac{1}{2}\left(\alpha-\frac{\pi}{2}\right)$$

and consequently

$$i=\frac{\pi}{4}+\frac{\alpha}{2}$$

In conformity with our invention, a tilting of the blade is performed in an area located on the upstream side or else, as illustrated in FIG. 4, on the downstream side of the driving shaft M. During said tilting movement, the blade which is substantially perpendicular to V_R at the point **6***a* turns so as to show a zero incidence slightly beyond the point **7***a* and it then resumes gradually an incidence producing a driving torque. The leading edge becomes the trailing edge, and vice versa. The actual

speed of the blade end following the cam is set substantially in the direction of the component Vf. Said speed is obtained therefore without any absorption of power from the driving shaft, while in contradistinction the higher speed of the fluid stream produces on the blade a tilting torque, the leading edge lying on the upstream side which leads to an opening of the angle between the blade and the arm carrying it and produces a further driving torque. In said area, the wake of the blade which was perpendicular at *6a* to the direction of the stream has a tendency to decrease since the incidence decreases and no disturbance is liable to act on the other blades lying all on the upstream side.

In the practical embodiment illustrated in FIG. 8, the power-tapping shaft M carries four arms B to the ends of which are pivotally secured at R the blades A. The pivoting of each blade is executed around an axis **10** formed by a pin fitted in the sleeve R at the end of the arm B. Said pins are stationary with reference to the blades extending vertically underneath the arms B while cranks **11** are keyed to their upper ends. Said cranks carry at their free ends a vertical stub shaft **12** on which is fitted a roller **13**; the latter is fitted in the U-shaped channel forming the cam C which is stationary with reference to the frame which is not illustrated or else the angular setting of said cam may be adjusted.

The embodiment described hereinabove by way of example may be subjected to numerous modifications without widening by any means the scope of the invention as defined in the accompanying claims.

What we claim is:

1. An engine driven by a fluid stream, comprising an output shaft rotatable about a first axis, a blade carried by the output shaft and rotatable relative to the output shaft about a second axis parallel to and spaced a substantial distance from said first axis, said second axis during each revolution of said blade about said first axis passing twice through a first plane parallel to the fluid stream and including said first axis and twice through a second plane perpendicular to said first plane and including said first axis, and means for positioning the blade during its revolution about said first axis so that the blade is substantially parallel to the stream when said second axis passes through said first plane downstream of said first axis and when said second axis next passes through said second plane and is substantially perpendicular to the stream when said second axis next again passes through said second plane and so that the blade feathers when moving upstream, said positioning means comprising an arm fixed to the blade, a cam follower carried by said arm, and stationary cam means about and in contact with which said cam follower moves, said arm being disposed substantially in the plane of the blade, said cam means intersecting the path of said second axis when said second axis crosses said second plane moving upstream, said cam means being spaced from the path of said second axis a distance substantially equal to the length of said arm when said second axis passes through said second plane moving downstream.

2. An engine as claimed in claim **1**, said cam means being disposed inside the path of said second axis in the last mentioned position of said second axis.

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