May 27, 1969 SHAO WEN YUAN 3,446,288

HIGH SPEED ROTOR

Filed June 28, 1967 Sheet 1 of 3

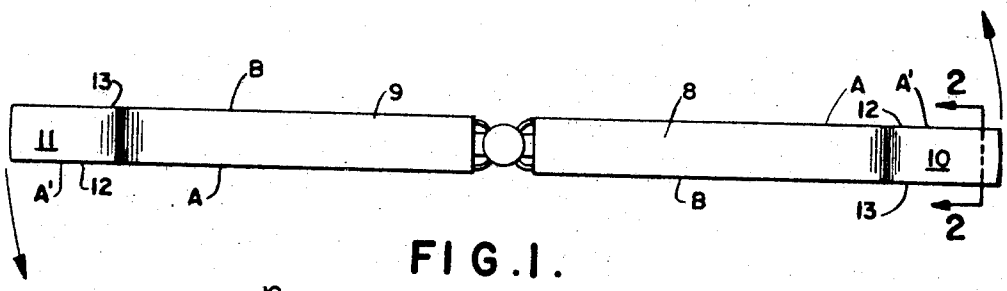


FIG. 1.

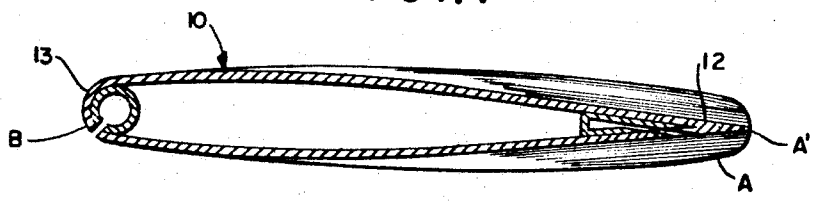


FIG. 2.

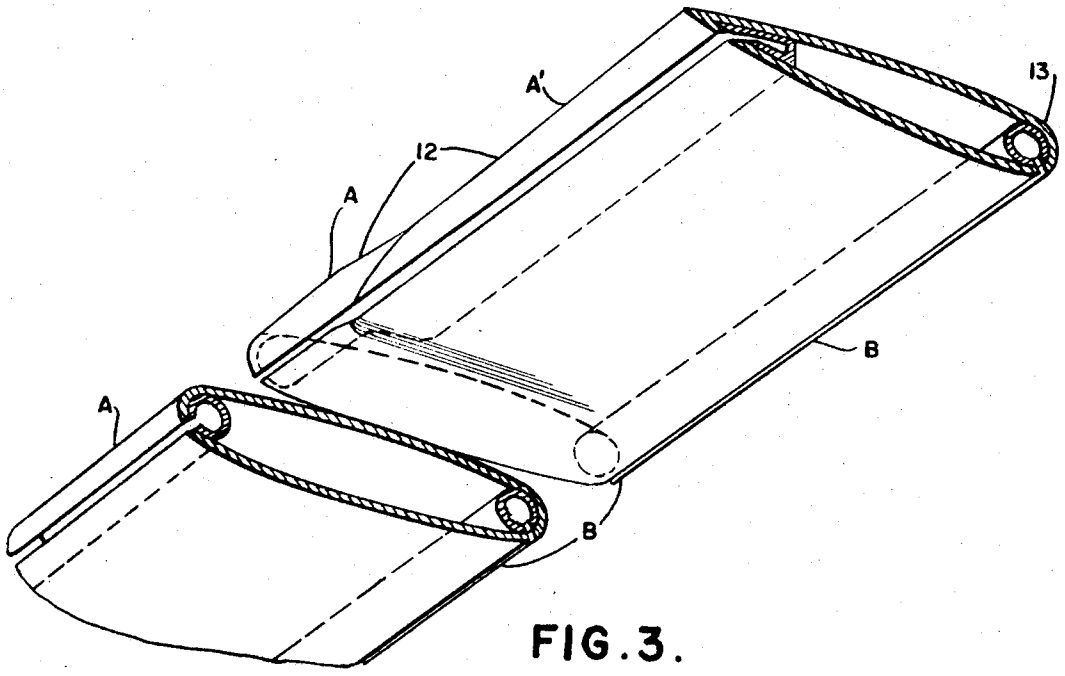


FIG. 3.

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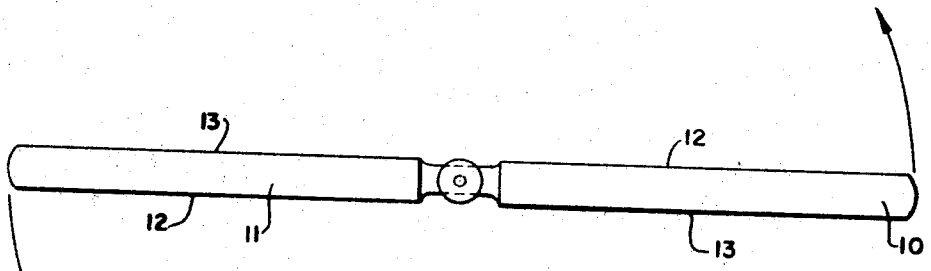


FIG. 4.

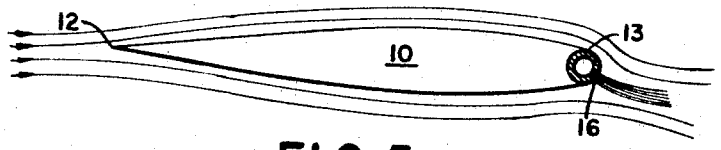


FIG. 5.

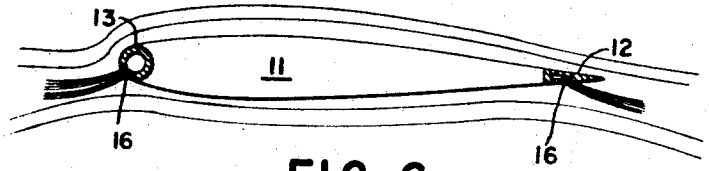


FIG. 6.

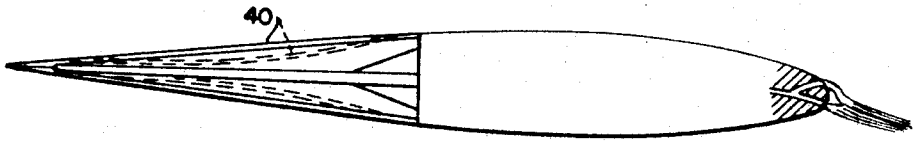


FIG. 7.

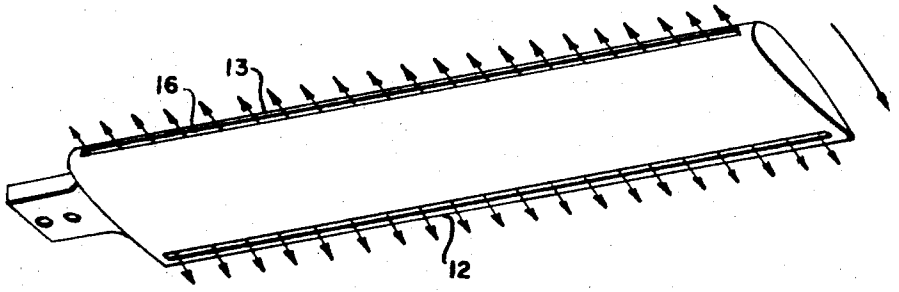


FIG. 8.

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HIGH SPEED ROTOR

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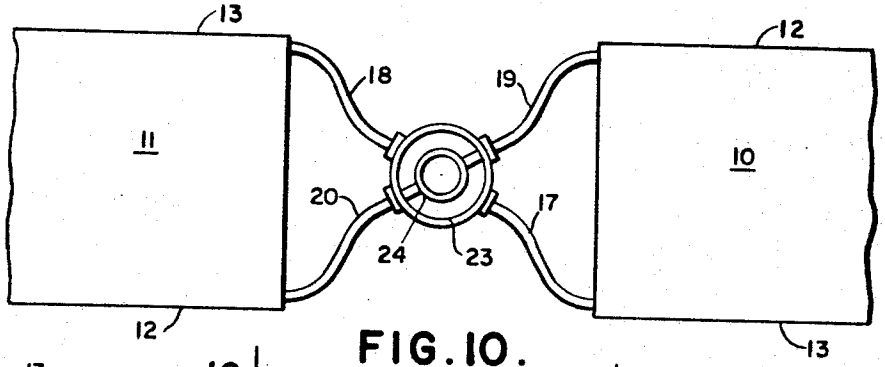


FIG. 10.

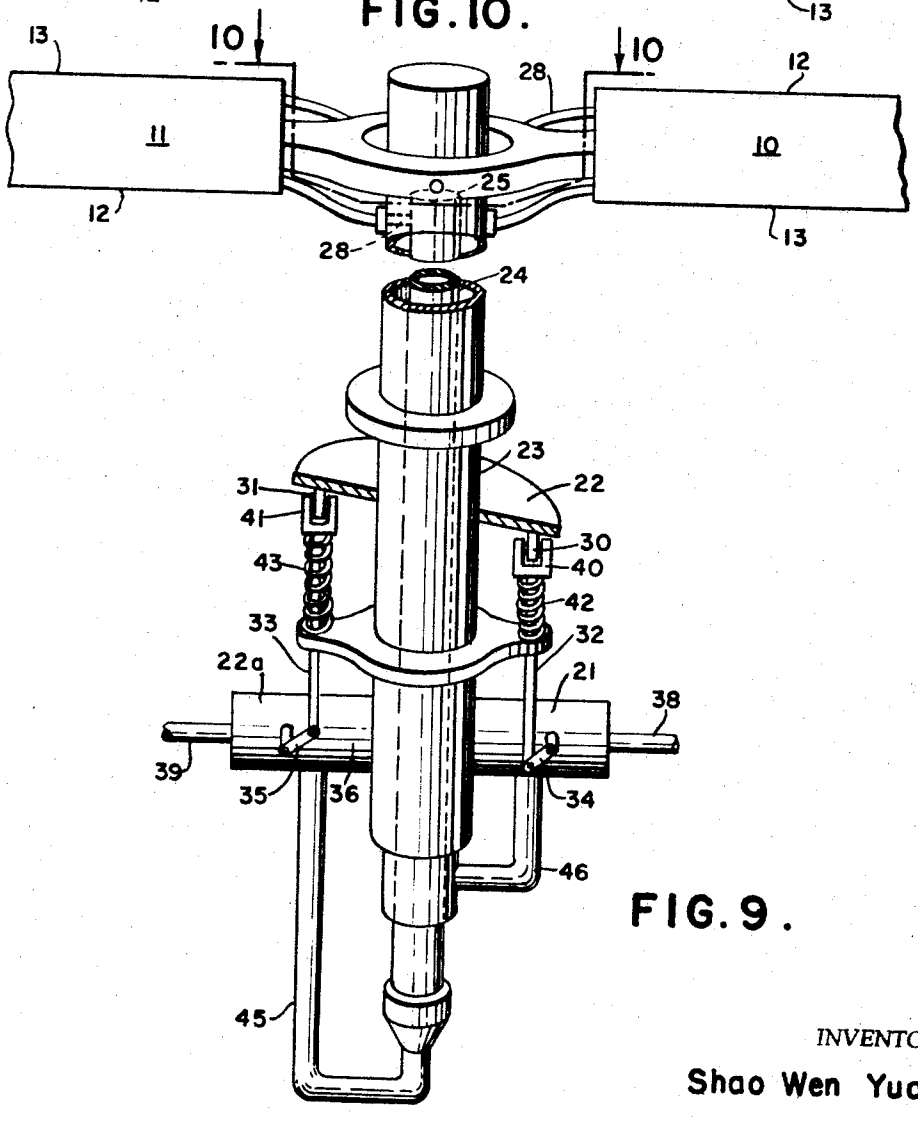


FIG. 9.

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3,446,288

HIGH SPEED ROTOR

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Int. Cl. B64c 27/18
U.S. Cl. 170—135.4 3 Claims

ABSTRACT OF THE DISCLOSURE

An airfoil formation for the blades of helicopter rotors, the blades each having inner and outer portions extending from the axis of rotation thereof and the outer portion having a relatively sharp normally leading edge with respect to a round normally trailing edge extending to the tip of the blade, the respective edges having jet means therein to provide a calculated dividing streamline at the trailing edge of the blades to control circulation to thereby increase the coefficient of lift thereof. Also, jet means may be formed in the sharp normally leading edge of the blades of the outer portion to increase the coefficient of lift of each of the blades in like manner during the retreating cycle of the blades.

The present invention relates to aircraft, such as helicopters, autogyros, gyrodynes, convertible crafts and the like and, for the sake of brevity of description, the invention is particularly illustrated with respect to jet rotor helicopters.

Heretofore, most rotary lifting crafts are of the shaft driven type with hinged blades which require complex driving connections in the form of gearing, clutches and the like to the rotor shaft to provide for craft lift and propulsion, and complex control mechanism for both cyclic and collective lift control. Numerous attempts have been made to eliminate the shaft and gear drive arrangement and hinges connections required with such craft by research and development of jet-flap systems, for example as shown in prior art Patents 2,650,666; 2,759,548 and 2,925,129. During the course of research and development of the circulation jet control principle of propulsion, it has been discovered to be of importance to provide novel rotor blade or airfoil formations to increase the coefficient of lift in conjunction with jet arrangements to provide for optimum propulsion and operating efficiency of the rotor.

Accordingly, with the foregoing prior art and research in view, an important object of this invention is to provide a novel and improved rotary blade for rotor aircraft, whereby novel blade formations and jet arrangements are provided for breaking the compressibility barrier of the advancing rotor blade during high forward speeds, flight conditions, etc., may exceed rotor blade tip speed.

A more specific object is to provide a rotor blade having a novel cross-sectional shape with a sharp leading edge and a round trailing edge and including suitably mounted, at least one, jet-producing means on/or adjacent the trailing edge of the blade for blowing jets of fluid into the slip stream, said jets having means for controllably adjusting the jet means to materially increase the lift and thrust of the rotor blade to extremely high degrees of efficiency.

Another object of the invention is to provide a novel system for rotary-wing craft, whereby the respective blades have novel improved means for cyclically altering performance characteristics during rotation to impart additional lift to each blade throughout the retreating portion of its cycle without the necessity of changing the angle of attack or the camber of the blade.

A further object of the invention is to provide rotary-wing type craft rotor blades of the above character having control means operable by the pilot for changing the magnitude of the lift imparted by the orientation of the blowing jets and for attaining directional control of the rotary-wing type craft while in flight.

Still a further object of the invention is to provide blowing jets along the span of the blade with different magnitude and orientation with respect to the blades, to thereby give different lift coefficients along the blade section, which in turn gives a favorable spanwise lift distribution.

Still a further object of the invention is to provide a contribution to propulsion of the rotor blades by the horizontal component of the reactive forces of blowing jets, whereby this system eliminates the mechanical driven shaft system, and whereby great saving in weight and a great increase in the efficiency of the rotor are accomplished.

Another object is to provide jet means to induce the flow of streams of fluid, such as air or gas streams, upon the upper side of the blade around the trailing edge and smoothly off along the jet stream, whereby certain circulation, as the cause of the lift, is created and whereby, in addition, the vertical component of the reaction of the jet gives further lifting force, while the component of the momentum of blown air in the direction of the main air stream contributes a thrust to propel the blade's rotation.

Another object is to provide novel means to control rotary wing craft, so that certain conditions of flight may be efficiently controlled by jet means novelly arranged at the blade edges to provide for substantial equalization of lift for the advancing and retreating blades, the hovering, vertical ascending and vertical descending conditions, and for forward and sidewise flight and control due to gust and turbulence conditions.

Still another object is to provide means for shifting the fluid supply from the rotor blade's trailing edge to the blade's leading edge during rotation of the rotor, whereby the leading edge jet momentum provides high lift coefficients to the retreating blades in the reverse flow region and very high forward speed of the rotor craft results.

A further object is to provide a novel fluid flow distribution system adapted to be cyclically controlled by the pilot of the craft.

Still a further object is to eliminate the mechanical linkage of conventional rotor blades, which linkage is required to vary the rotor blade incidence both collectively and cyclically by rotation of the blade about its pivoted spanwise axis to prevent sidewise overturning movement; by compensating for changes made in the blade lift with predetermined location of jet means along the blade edges and by directing the fluid mass flow to the jet means to the proper blade or to the proper zone in the blade at the proper time for substantially optimum control.

Still another important object of the invention is to provide a novel, flexible skin for the forward portion of the blade so that the contour of the blade can be adjusted, either concavely or convexly, for maximum benefits during at least a portion of its rotation.

With the foregoing and other objects in view, which will become apparent as the invention is fully understood, the same resides in the novelty of construction, combination and arrangement of elements hereinafter described in detail and distinctly summarized in the appended claims.

The description should be read in conjunction with the accompanying drawings wherein:

FIGURE 1 is a top plan view of a high-speed rotor blade assembly without the aircraft body portion and including direction symbols to indicate the respective

leading and trailing edges of the blades as they advance and retreat during rotation;

FIGURE 2 is a cross-section view taken on line **2—2** of FIGURE 1 of the blade or airfoil shape to illustrate the pointed apex of the leading edge of the blade along a portion of the leading edge and the relatively rounded trailing edge of the blade, including jet means in the form of slotted ducts shown diametrically discharging air or gaseous media into the slip stream of the advancing blade;

FIGURE 3 is a perspective view partly in cross section of one of the blades with the air or gas ducts and their respective jet outlet portions;

FIGURE 4 is a diagrammatic top plan representation view of a second form of a high-speed rotor blade;

FIGURE 5 is a schematic cross-section view of one of the respective rotor blades showing one blade with one jet means in the trailing edge with the flow lines thereabout in relation to the jet path from the trailing edge;

FIGURE 6 is a schematic partial section of one of the blades showing jet ducts in each edge thereof, including flow lines about the blades in relation to the respective jet paths from the leading and trailing edges, respectively;

FIGURE 7 is a diagrammatic representation in cross-section of a third embodiment of high-speed rotor blade having a flexible portion of suitable skin material positioned at the leading edge portion of the blade and including an internal gas pressure area adapted to permit variations in the leading edge exterior surfaces for pilot controlled adjustment of the blade contour, if desired;

FIGURE 8 is a perspective view of the blade shown in FIGURE 6 illustrating the jet mass slots formed in the air duct members mounted inside of the airfoil;

FIGURE 9 is a semi-diagrammatic illustration of a fluid or an air distribution system for supplying such fluid or air into the blade ducts to thereby selectively discharge fluid or air during their respective advancing and retreating cycles, and

FIGURE 10 is a partial top plan view of the illustration in the direction of line **10—10** of FIGURE 9.

Referring to the drawings, and with particular reference to FIGURES 1, 2 and 3, the rotor employed may comprise blades **8** and **9** of an elliptical form or shape having a round leading edge A and a round trailing edge B. The round leading edge extends along the span of the respective blade for the greater portions thereof and is formed with a relatively sharp leading edge A' for a predetermined extent to the tip of the respective blades. With the relatively sharp section of leading edge of each blade, the rotor may rotate at very high speeds without suffering usual high drag. For example, the round leading edge may be 85% of the edge span and the sharp edge be for the remainder thereof to the end or tip of the respective blades. The optimum percentages of round leading edge and sharp leading edge portions may be varied to suit various determined conditions in proportion with regard to the speeds to be provided during forward motion of the craft.

With a rigid high speed rotor having such blade formations, the lift may be increased and equalized for each cycle of rotation by use of air or gas flow from slots formed in air ducts mounted in either one or both of the respective blade leading or retreating edges. These ducts are illustrated in FIGURES 1 and 2 and are formed to provide for conformably mounting in the respective round and relatively sharp blade edge portions. As shown in FIGURE 9, there is provided means for cyclically altering the jet mass flow during rotor rotation in the reverse flow region of each of the blades, so that greatly increased lift is imparted to the respective blades throughout the reverse flow region on the retreating side as well as on the advancing side of the blades.

A specific control means for the jet mass flow is described hereinafter in connection with a second embodiment of the blade formation, wherein only the leading edge is formed with a relatively sharp leading edge A for the outer span of the blade and the trailing edge remains rounded for this portion of span, as in embodiment one.

In the blade formation the leading edge is partially relatively sharp with respect to the rounded trailing edge to provide for high forward speed of the rotor craft beyond craft speeds attainable heretofore with rotor blades such as provided in prior Patents 2,650,660, 2,759,548 and 2,925,129. Such speeds of rotor blade may be in the supersonic range and will provide for forward speeds of the craft far beyond helicopters in the prior art.

With reference to the first embodiment and FIGURES 1, 2 and 3, the detail of the respective edges is illustrated schematically and includes jet flow illustrations from the jet ducts and slots therein at the respective leading and trailing edges. Since the actual performance, as far as illustration is concerned, is substantially identical, this description will now go forward with reference to FIGURES 4 through 8 of the second embodiment and the jet mass cycle control means of FIGURES 9 and 10, which, for example, may be identical for each of the two embodiments illustrated.

Now with reference to embodiment two, there is shown a top view of two rotor blades **10** and **11**. Each of these blades is of a specific novel formation at the leading edge **12** and at the trailing edge **13** thereof. For example, the leading edge **12** is pointed in the form of a sharp or pointed shape, while the trailing edge is rounded in the form of a blunt rounded shape, see FIGURES 4 and 5.

As further shown in FIGURE 4 of the drawing, a very high forward velocity of the rotor supported craft, such as a helicopter, the forward speed or velocity V of the helicopter is added to the speed ($\Omega\gamma$) of the advancing blade, for example, blade **10**, but is subtracted from the rotational speed or velocity $V-(\Omega\gamma)$ of the retreating blade **11**.

Assuming that the leading and trailing edges of the respective rotor blades are conventional rotor blades, that is, with round or blunt leading edges and sharp or pointed trailing edges, the blades would produce a prohibitively large drag on the blade on the advancing side of the rotor due to the compressibility effect and negative lift in the reverse flow region in the blade retreating side of the rotor. Thus, both the maximum forward speed and lifting capacity of present day helicopters are limited, as the resultant speed at any blade section on the advancing side is $\Omega\gamma+V$, where $\Omega\gamma$ is the rotational speed of the rotor blade and V the forward speed of the helicopter, while resultant speed at any blade section of a conventional airfoil shape of the retreating side is $\Omega\gamma-V$.

The excessive drag of conventional rotor blades is materially reduced with the present invention's novel rotor blade formations. The blades of this invention are formed with sharp, thin, leading edges and round trailing edges, see FIGURES 4 and 5. With such formation, especially at supersonic speeds of blade motion, such leading and trailing edge formations provide for material reduction in drag. This is because supersonic wave drag of an airfoil is proportional to the square of the nose angle of the airfoil. Accordingly, with reference to FIGURE 4, it can be seen that a large portion of the flow reverses its direction relative to the rotor blade **10**, for example, on the retreating side. This is due to opposite flow directions of the high forward velocity of the helicopter and the rotational velocity of the rotor blade. As a result, the flow with relatively low velocity in the reverse flow region on the retreating side approaches the rotor blade **11**, for example, from the round trailing edge **13** and smoothly off the sharp leading edge **12**, as is usually experienced with the performance of conventional airfoils on the advancing side.

In the practice of this invention, high-speed rotor means with novel rotor blades having a cross section as shown

in FIGURES 4 thru 8, namely, a sharp thin leading edge and a round trailing edge are utilized to attain the objects above set forth. This specific form of blade airfoil is further enhanced for efficiency in operation by at least one jet means **16** connected to any suitable source of air supply, not shown, carried or originating in the fuselage of the helicopter to air supply ducts **17**, **18**, **19** and **20**, see FIGURES 9 and 10.

By providing one or more blowing jets of fluid in conjunction with the above-described blades, a very desirable high lift is attainable through proper circulation control of the blowing jets of fluid with respect to the surfaces of the rotor blades.

Accordingly, it is a part of this invention to provide means, not shown in detail, for adjustably displacing the jet means with respect to their respective blades to achieve an optimum result.

With reference to FIGURE 9, there are shown supply conduits **18** and **19** from a suitable air supply source, not shown, to suitable follower and valve assembles **21** and **22***a*. Assemblies **21** and **22***a* are controlled by a swash plate **22** on a hollow rotor post **23**, which is rotatable with the rotor of the helicopter. Longitudinally and concentrically spaced in the hollow post **23** is an air feed tube **24** which terminates in a separator-bulkhead or manifold **25** inside the post **23**. From this conduit **24** are connected flexible conduits **17** and **20**. For example, flexible conduit **17** connects with jet means **16** in the trailing edge of blade **10** and flexible conduit **20** connects with the sharp edge **12** of retreating blade **11**, while flexible conduits **18** and **19** from separator-bulkhead of the hollow post **23** above the end portions of tube **24** connect respectively with the sharp leading edge **12** of blade **10** to jet means therein and to the round edge **13** of the retreating blade **11**. Thus, as the rotor revolves, the swash plate **22** activates the follower and valve assemblies for automatic circulation of jet air currents with respect to the rotor blades during the advancing and the retreating cycles thereof. For example, the swash plate **22** is in contact with roller means **30** and **31** carried by roller shafts **32** and **33** connected by link members **34** and **35**, respectively, to each of one of a pair of butterfly valves, not shown, in a valve chamber **36** connected to fluid supply conduits **38** and **39**. Also, as shown, each roller is shock mounted in a bracket **40** and **41** by spring means **42** and **43**, respectively.

The respective jet conduits in the blades or airfoils of the present embodiments are supplied with air or gas from a suitable main source in the craft by supply hoses **45** and **46**, which connect to the valve chamber **36** adjacent each valve therein.

The swash plate **22** may be controlled by the pilot to regulate the valve means and the quantity of air or gas flow to the ducts in the edges of the airfoils. This adjustment may be accomplished in the same manner as illustrated in FIGURE 1 of prior Patent 2,925,129.

With a novel rotor blade formation, according to this invention, the fluid stream such as air, gas or the like, directed from the jet means at very high velocity can flow from the pointed, sharp thin edge of a blade to the round trailing edge and smoothly off from the underside of the trailing edge where the jet stream serves as a dividing streamline. Hence, a high increase in lift coefficient of the blade can be inherently attained without the requirements of the usual means for changing blade pitch angle.

In a similar manner, the fluid stream, such as air, gas or the like, moving at relatively low velocity in the reverse flow region of the retreating side of the rotor, can flow from the trailing edge to the sharp leading edge, where the jet stream under this condition also serves as a dividing streamline. Here again an increase in lift coefficient is accomplished without the necessity of changing the blade pitch angle.

The static conditions inherent in novel airfoil or rotor blade formations during rotation may be dynamically variable by the provision of a flexible front portion at/or adjacent the leading edge of the blade, see FIGURE 7 of the drawings. In this embodiment, a flexible skin portion **40** is provide with an interior area connected to a suitable source of pressure, whereby the flexible skin portion may be made concave or convex by pressure variations to thereby attain maximum benefits during portions of the rotation cycle of the rotor. For example, the internal fluid pressure may be varied cyclically and collectively by suitable means or devices, not shown.

Thus, there is provided, by the present invention, a novel rotor blade with a novel airfoil shape adapted to increase the coefficient of lift and to equalize the lift during the advancing and retreating portions of the cycle of each rotor rotation and wherein no rotor driving shafts or gears or mechanical means for changing angle of attack or the camber of the respective blades of the rotor are needed.

Also, the main purpose of this invention is to reduce the high drag at supersonic speed of the advancing blade (rotational speed plus forward speed), however, the rotational speed of the rotor blade remains the same as those of conventional helicopters.

While only several specific embodiments are hereinbefore illustrated and described, it is to be expressly understood that this invention is not intended to be limited to the exact formations, construction or arrangement of parts as illustrated and described because various modifications may be developed in putting the invention to practice within the scope of the appended claims. For example, this invention may have equal lift utility in shaft driven rotors.

What is claimed is:

1. A rotor blade for rotary wing aircraft comprising a leading edge and a trailing edge, each edge being longitudinally of the blade, said blade having an inner portion extending from the axis of rotation thereof and an outer portion extending to the tip thereof, said inner portion being transversely elliptical with rounded leading and trailing edges and said outer portion extending from said inner portion to the tip of the blade having a relatively sharp leading edge with respect to a rounded trailing edge to the tip thereof, and slot means in at least one of said edges to provide a jet stream along a calculated dividing streamline to increase the lift coefficient of the blade by circulation control additional to main flow around the blade.

2. A rotor blade for rotary wing aircraft as described in claim 1, wherein the said inner and outer portions of the blade are each formed with slot means to permit flow therefrom of a jet stream to provide for increase in the coefficient of lift during the retreating cycle of the blade.

3. A rotor blade having a leading edge with a sharp point and a rearwardly extending flexible skin portion and trailing edge with a round portion, means for changing the surface of the flexible skin portion into a convex or concave surface and fluid jet circulation control means in the said trailing edge portion of the blade.

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U.S. Cl. X.R.

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