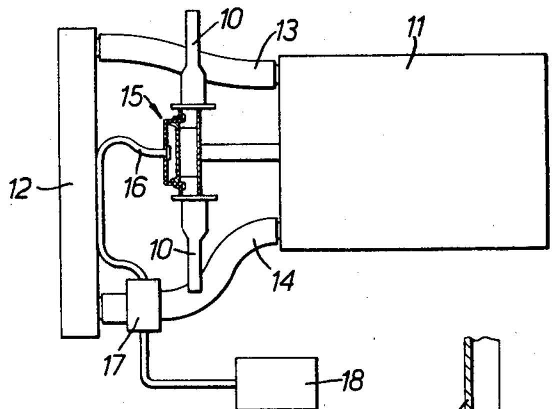

FIG. 1.

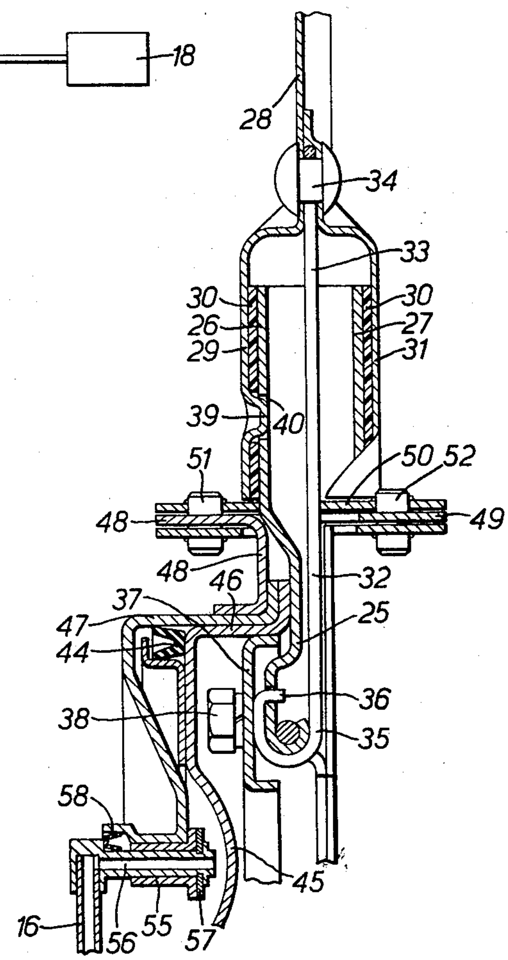

FIG. 2.

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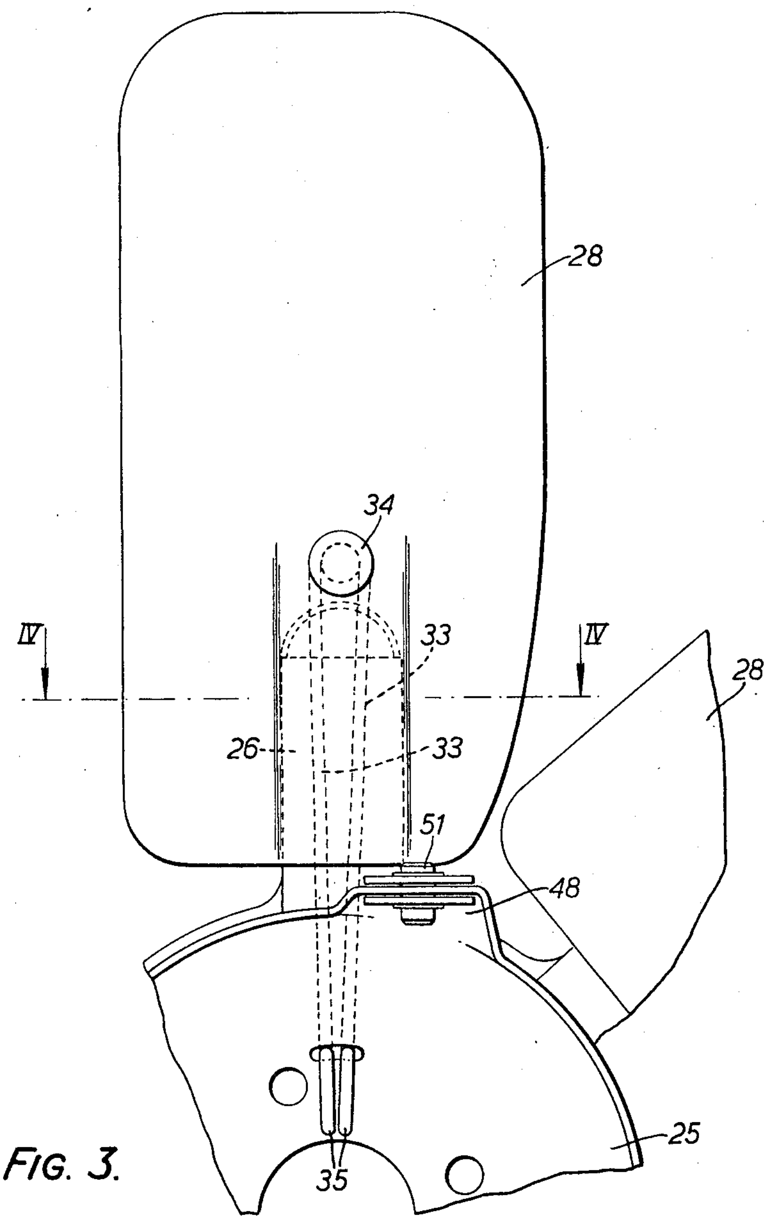

FIG. 3.

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June 18, 1968 | A. E. H. ELMER | 3,388,694

ADJUSTABLE-PITCH ENGINE COOLING FAN AND SERVOCONTROL MECHANISM THEREFOR

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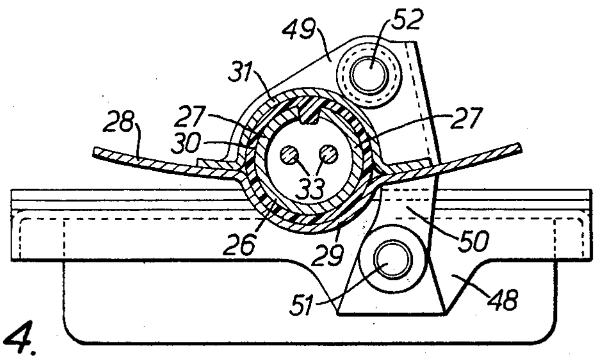

FIG. 4.

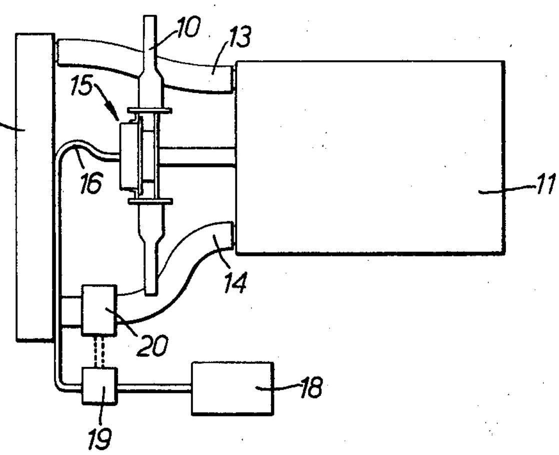

FIG. 5.

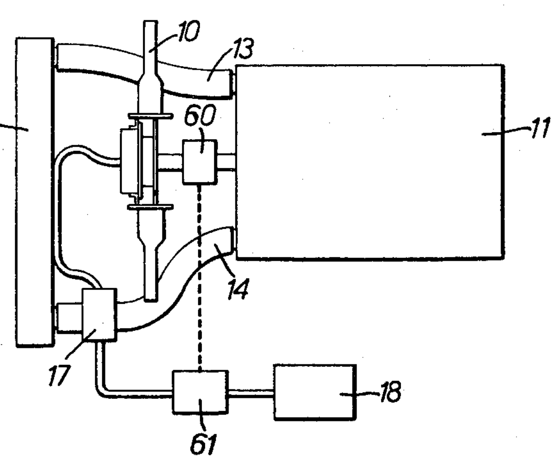

FIG. 6.

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United States Patent Office

3,388,694

Patented June 18, 1968

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3,388,694

ADJUSTABLE-PITCH ENGINE COOLING FAN AND SERVOCONTROL MECHANISM THEREFOR

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Claims priority, application Great Britain, May 28, 1965, 22,861/65
4 Claims. (Cl. 123—41.12)

ABSTRACT OF THE DISCLOSURE

An adjustable pitch cooling fan for a water cooled engine, the fan hub including a pneumatic piston secured to a drive shaft and a ram cylinder sliding over the piston and arranged to cause twisting of the fan blades against torsion springs, compressed air to actuate the ram being supplied through a central rotary cylinder in the end wall of the ram cylinder and controlled by a thermal valve in the water circuit.

This invention relates to servocontrol mechanism for rotary bladed machines having means for altering the pitch of the blades to control the rate at which fluid passes through the machine. The invention is particularly applicable to rotary fluid pumps or fans for a coolant medium, variations in the blade pitch being used to control the flow of the coolant medium and hence the overall cooling effect. The invention is particularly applicable to cooling systems of internal combustion engines for road vehicles, aircraft, locomotives, marine purposes, or stationary engines, and may also be applied to air conditioning systems. However, as will become apparent, the invention is of particular advantage in connection with cooling fans for impelling the cooling air stream through a radiator of a water-cooled engine or over the heat exchange surfaces of an air-cooled engine.

In many applications, and particularly in the case of internal combustion engines for vehicles, the cooling requirements are subject to wide variations dependent upon the operating conditions. For example, when starting from cold little or no cooling is required until the engine has reached a predetermined temperature. Also during running the degree of cooling required varies greatly in accordance with the load and with external conditions such as air temperature and wind velocity relative to the vehicle. A cooling fan absorbs a considerable proportion of the total output power of an engine and considerable economies can be effected if the power absorption of the fan is reduced when cooling is not required or only required on a reduced level.

A number of prior proposals have been made for controlling cooling fans: for example variable speed transmissions have been included between the fan and the associated engine, so that the fan will be driven at lower speeds when the cooling requirements are reduced. Many of these prior proposals have been complex and expensive to manufacture and the control impulse used for controlling the fan has been only indirectly related to the cooling requirements of the engine. Accordingly it is an object of the invention to provide an improved control for a rotary fluid pump or fan for a coolant medium which will be simple and economical to manufacture and effective in reducing the power consumption when cooling requirements are low.

From one aspect the invention consists in a control apparatus for an adjustable pitch cooling fan including thermally responsive pneumatically operated servomechanism for adjusting the pitch of the fan blades.

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From another aspect the invention consists in a rotary fluid pump or fan for a coolant medium, having adjustable pitch blades, and means for adjusting the pitch of the blades including a thermal responsive element connected to a servo or electrical control system arranged to actuate the pitch adjusting mechanism.

The apparatus will preferably include means for supplying or admitting a servofluid at a suitable pressure to the servocontrol system, the servofluid being of the same composition as the coolant medium. For example where the invention is applied to an air fan it is preferred to use a pneumatic servo since any small leakage of air from the servosystem will be unharmful.

In the case of a cooling fan impelling air through a radiator the air temperature may not be the best indication of the cooling requirements. A more direct positive indication may be obtained in such circumstances from the water passing through the cylinder jacket. Thus from another aspect the invention consists in a rotary fluid pump or fan for a cooling system including a heat exchanger, over one section of which flows a coolant medium conveyed by the pump or fan, while another heat exchange medium flows through a second section of the heat exchanger, the pump or fan having adjustable pitch blades, and including thermal responsive means, sensitive to the temperature of the second heat exchange medium, for controlling the pitch of the blades.

In the case of a conventional water-cooled engine the thermal responsive means would preferably be positioned adjacent to the lower radiator connection so as to be sensitive to the temperature of the water entering the engine cooling jacket.

Where the servosystem is of a pneumatic type either compressed air or vacuum operation may be used depending upon the type of engine and the associated auxiliary equipment. In some cases the vacuum servo may be employed using suction derived from the engine intake manifold. Preferably, however, the servosystem will be connected to a compressed air or vacuum supply derived from a compressor or exhauster driven by the engine itself, or from a supercharger or exhaust turbo-supercharger.

In most applications the full cooling performance is only required sporadically and it is convenient to design the rotary pump or fan in such a way that the blades are normally urged by resilient means and by the inherent centrifugal twisting moment towards a zero or fine pitch condition, the servosystem being arranged when actuated to move the blades into a coarse pitch position. Thus according to a preferred feature of the invention the servomechanism opposes both the centrifugal twisting moment and a spring system urging the blades towards a fine pitch condition. The springs are conveniently torsion springs and may be used also as anchorages holding the fan blades radially inwards.

In the case of an air cooled engine the thermally responsive means may be situated in the air stream created by the fan but preferably the temperature responsive means is located remote from the fan itself and it may be situated on a part of the engine such as an engine cylinder block.

The invention may be performed in various ways and one specific embodiment and certain modifications thereof will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a diagrammatic side elevation of a cooling system for a water-cooled vehicle motor incorporating a variable pitch cooling fan according to the invention,

FIGURE 2 is a half sectional side elevation of the fan and pitch adjusting mechanism on an increased scale,

FIGURE 3 is a fragmentary end view of the parts illustrated in FIGURE 2,

FIGURE 4 is a radial sectional view on one of the fan blades on the line IV—IV in FIGURE 3, and

FIGURES 5 and 6 are diagrammatic illustrations of alternative thermal control systems.

In the example illustrated in FIGURE 1 the invention is applied to an adjustable pitch axial flow cooling fan **10** for a water-cooled internal combustion engine **11**, particularly in the case of a heavy duty commercial vehicle installation. The cooling system for the engine includes the usual radiator **12** with upper and lower water hose connections **13**, **14** to and from the cylinder water jacket. The blades of the cooling fan are spring urged towards a fine or zero pitch attitude and the inherent centrifugal twisting moments on the blades also urge the blades to the fine pitch condition. A pneumatic ram generally indicated at **15** mounted in the hub of the fan is arranged when operated to urge the blades towards a coarse pitch condition. This ram is connected through a flexible pressure connection **16** to a thermally operated valve **17** which controls the admission of compressed air to the ram from a compressed air system **18** forming part of the engine installation. For example this compressed air may be derived from a compressed air braking circuit. The thermally operated valve **17** is of the direct-operating wax capsule type and is positioned in the lower radiator hose connection **14** to the engine jacket so as to be responsive to the temperature of water entering the cooling jacket. In place of such a thermally operated valve a solenoid operated valve **19** may be used, as illustrated in FIGURE 5, the valve solenoid being controlled by a thermally operated electric switch **20** positioned in the lower hose connection **14**.

The fan itself may be of symmetric or asymmetric design (i.e., having an even or odd number of blades) and comprises a hub or spider **25** formed as a sheet metal pressing with six short radial arms **26**. Each arm is of semicircular cross-section and has wing portions **27** which are wrapped around to form a hollow tubular spigot. The spigot is surrounded by a nylon bush **30**. Each fan blade **28** has a corresponding radial semicircular depression **29** to form a sliding fit on the outer front surface of the respective bush **30** and to each blade is welded a backing piece **31** formed with a semicircular depression to fit closely around the rear external surface of the bush. Each blade is thus capable of pivotal movements relative to the arm about its respective radial axis. Each blade is radially located by a torsion spring anchorage **32**, the torsion spring having a loop **33** extending outwardly within the hollow tubular part of the arm of the hub and being riveted at its outer end **34** to the blade. The inner ends **35** of the two legs of the spring are hooked through apertures in a central part of the hub **25** and have rearwardly turned hook-like extremities **36** which fit into locating apertures in the hub. In assembly these inner hooked portions **36** of the torsion springs are located in position by an annular locking plate **37** on the front face of the fan hub which is bolted through the hub onto the driving shaft of the fan (not shown) by means of bolts **38**, and clamps the inner ends of the springs in position. As a safety measure and to ensure that the blades cannot become detached from the hub if the springs should fail the inner part of each blade is formed with a projection **39** which extends through a slot in the bush **30** into a circumferential slot **40** in the respective arm **26** of the hub so as to locate the blade radially while permitting the necessary range of pivotal movement.

The pneumatic ram **15** for controlling the pitch of the blades is mounted on the front end of the fan hub. The ram includes an axially stationary piston **45** formed as a sheet metal domed pressing and having a peripheral flange **46** fitting over the outer rim of the annular locking plate **37**. Over and around the piston **45** fits an axially movable cylinder **47** which is connected to each of the blades to impart twisting movement thereto about the

blade axis. A seal **44** prevents escape of air between the cylinder and piston, both of which rotate with the hub. Secured to the rear lip of the cylinder are a series of outwardly projecting ears **48** spaced circumferentially from the respective blade axes, as seen in FIGURES 3 and 4, and at the adjacent inner corner of each blade a projecting flange **49** is formed integral with the backing piece **31**. The ear **48** and the flange **49** are connected by a channel-shaped folded operating link **50** having pivotal connecting pins **51**, **52** at opposite ends. Thus axial movements of the cylinder **47** impart corresponding rotational movements to each blade about its axis. The operating links **50** also act to hold the cylinder **47** in its assembled position on the piston **45**, the torsion springs **32** always acting to urge the blades towards their zero pitch positions so that the operating links **50** bear rearwardly on the ears **48** attached to the ram cylinder.

Compressed air to operate the ram is admitted through a central aperture in the front face of the ram cylinder **47**. For this purpose a bearing sleeve **55** is rigidly secured in an aperture in the front wall of the cylinder and through this sleeve extends an inner hollow non-rotary stem **56** having a flange **57** at its inner or rear end which engages against the adjacent face of the sleeve **55** to form a seal. A further seal **58** is positioned between the stem **56** and the lip of the cylinder at the front end of the stem.

The outer or front end of the stem is connected to the flexible pressure conduit **16** through which compressed air is admitted from the thermal valve. Thus it will be seen that when compressed air is admitted through the stem **56** the air pressure on the rear face of the cylinder **47** urges the head of the stem **56** against the sleeve **55** so as to increase the effectiveness of the seal and this same air pressure acts forwardly on the cylinder in a direction to urge the blades to a coarse pitch attitude whenever the water temperature at the inlet of the cylinder jacket rises above a predetermined value.

The embodiment described is intended primarily to adjust the blades either to a coarse pitch attitude or to a fine pitch attitude without any intervening positions of adjusment. However, by appropriate design of the operating ram and the torsion spring acting on the individual blades, or by adopting a variable pressure control thermally actuated valve, the control system may be arranged to apply a continuously variable pitch adjustment to the blades. Moreover since the pneumatic ram opposes both the centrifugal loading and the torsion springs it is possible by appropriate design of the effective area of the ram and additionally or alternatively by choice of the pressure of the compressed air supply to arrange that the movement of the ram is at least partially dependent upon the rotational speed of the fan, since at higher rotational speeds the centrifugal twisting moment is greatly increased and this force opposes that applied by the ram. Thus in effect a variable speed responsive limit will be set to the ram operating in dependence upon the rotational speed of the fan.

In a further possible alternative illustrated in FIGURE 6, a speed responsive device **60** is connected to the fan drive shaft and controls a pneumatic valve **61** arranged to reduce the air pressure supplied to the ram at higher rotational speeds. This valve **61** is additional to the thermal control valve **17** previously described.

In place of the operating links **50** and the noses a modified form of bayonet joint connection may be adopted. In this construction an annular axially movable plate is provided, to lie on the rear side of inwardly extending operating arms on the individual blades, each arm having a nylon block on its inner end to engage the plate. The internal circumferential edge of this plate is formed with a number of spaced inwardly projecting tongues, and at its outer edge it has a fork to embrace one of the fan blade supporting arms so as to prevent the plate rotating relative to the fan hub. The rear lip of the ram cylinder has a radial flange formed with slots to register with the tongues on the plate, and the side wings of each slot are bent forwards to form pockets between the slots. To assemble the ram cylinder onto the hub the cylinder is merely pressed rearwardly so that the tongues pass through the slots, then rotated through a small angle and released so that the tongues seat in the pockets. When compressed air is admitted to the ram the forward thrust is then transmitted through the annular plate to the nylon blocks, thus causing the blades to twist, as in the construction described above.

It will be understood that a vacuum operated servo system can equally be applied. In one such example the piston will be anchored to the fan hub, and the cylinder will then move rearwards as suction is applied. The rotary seal between the cylinder and the flexible conduit would be reversed, and the cylinder would bear at its rear edge on operating arms attached to the opposite sides of the blades, so that rearward movement of the cylinder causes the blades to move to a coarse pitch condition.

It will be understood that the invention can readily be applied to a blade pitch control system which is responsive to changes in the temperature of the air passing through the radiator and over the fan blades. For example a simple bi-metal pneumatic valve may be mounted directly on the stem **56** to control the admission of compressed air to the cylinder so as to increase the pitch of the blades as the air temperature rises, and vice versa.

I claim:

1. An adjustable pitch fan comprising a hub assembly, a plurality of blades mounted on said hub assembly for pivotal movement about their respective longitudinal blade axes to vary the pitch of said blades, means for attaching said hub assembly directly to a drive shaft, and single-acting pneumatic ram means mounted for rotation with said hub assembly, said ram means comprising a piston fixed axially in relation to said hub assembly, a cylinder movable on said piston, said cylinder having an end wall on the side of said piston remote from said attachment means to the drive shaft, and a rotary pneumatic coupling positioned centrally in said end wall, and having a connection to an external non-rotary flexible pressure line, and blade adjusting mechanism connected to said cylinder, for simultaneously adjusting the pitch of said blades.

2. A fan according to claim **1**, including resilient means urging the blades towards a fine pitch condition, the single-acting pneumatic ram acting to move the blahes towards a coarse pitch condition.

3. A fan according to claim **1**, including speed sensitive means sensitive to the speed of rotation of said hub assembly and acting to oppose the force exerted by said pneumatic ram.

4. A fan according to claim **1**, mounted on a drive shaft of a water-cooled internal combustion engine, and acting to impel cooling air through a radiator of said engine, and including in combination a thermal responsive element connected in a water cooling duct of said engine, a pneumatic valve controlled by said element, means for connecting said valve to a pneumatic pressure source, and a flexible pressure connection between said valve and said rotary pneumatic coupling.

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