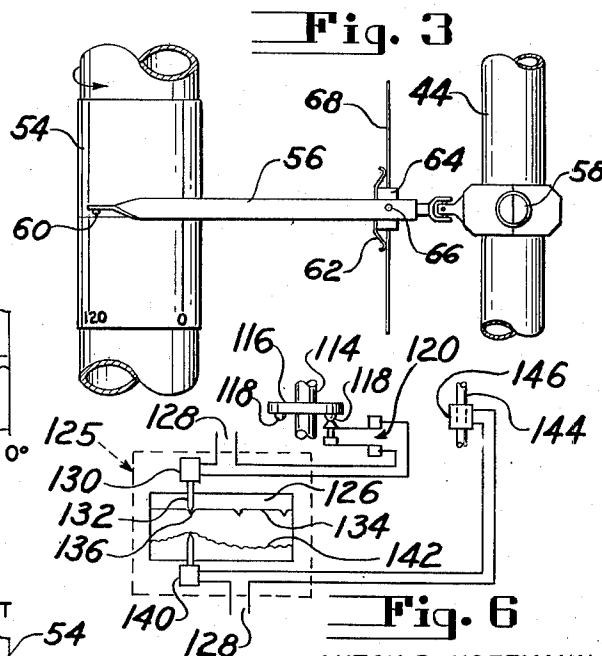
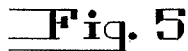
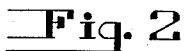


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PITCHING MOMENT RECORDER

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5 Claims. (Cl. 73-147)

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This invention relates to means for measuring the moments of a rotor blade or blades for helicopters, or the like, and for adjusting the blade or blades in accordance with such measurement.

In helicopters, during flight, certain vibrations may be present due to unbalance of the rotor blades with respect to each other. Such vibrations will cause an unbalanced resultant moment acting on the control system felt in the control stick as a one per revolution shake and may render the controls inaccurate or difficult to operate or fatiguing to the operator.

Hitherto, devices have been built to measure such vibrations so that corrections could be made in the rotor blades therefor. Such devices have included synchroscopes and electrical recorders and have been bulky and difficult of manipulation, and not suited for use away from factories or completely equipped airport services.

It is an object of this invention to provide a simplified, but very accurate, means for balancing rotor blades for helicopters, or the like.

Another object is to provide a device as set forth in the above object that may be readily installed and used by a person not necessarily skilled in the measuring arts.

Other objects reside in the details of construction, arrangement of parts, and will be either obvious or pointed out in the following specification and claims, in view of the drawing of a presently preferred embodiment, in which:

Fig. 1 is a diagrammatic plan view of a three-bladed rotor type of helicopter;

Fig. 2 is an elevational view with parts broken away and non-essential parts omitted for clarity;

Fig. 3 is a diagrammatic view of the chart and stylus arrangements;

Figs. 4 and 5 are sample charts; and

Fig. 6 is a diagrammatic illustration of a modified form of the indicating mechanism of Figs. 1 through 3.

Referring first to Figs. 1 and 2, a helicopter has a body 10 in which an engine 12 is mounted. The engine 12 turns a drive shaft 14 through suitable reduction gearing 16 to turn several rotor blades 18 carried above the body 10. The rotor blades are mounted upon the drive shaft 14 by universal hinges, not shown, but which may be substantially the same as those shown in application Ser. No. 592,862 of Igor I. Sikorsky, filed May 9, 1945, now Patent No. 2,517,509 of August 1951. The rotor blades are equipped with tabs 20 which may be bent by suitable tools between limits indicated at 22, Fig. 2, to change the pitching moment of a blade due to aerodynamic forces.

Each of the rotor blades 18 is provided with a control arm 24 which is connected by a push-pull rod 26 to a whiffletree 28. The whiffletree 28 is connected at its inner end to a movable plate 30 which can be moved up and down to change the pitch of all of the blades 18 by total pitch control

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means, not shown. The outer end of the whiffletree 28 is connected by push-pull rod 32 to a plate 34 which is driven around with the shaft 14. The plate 34 is connected by suitable bearings with a non-rotatable tilt plate 36 which can be tilted in any direction in azimuth by a plurality of push-pull rods 40, only one of which is shown. When the rod 40 is moved up or down, the plates 34 and 36 are tilted correspondingly and the pitch of the blades 18 will be controlled cyclically in accordance with such tilting. When the rod 40 is in a mid or neutral position, the blades maintain the same pitch during an entire revolution.

The rod 40 is positioned by a crank 42 pivoted upon the framework of the body 10, and is moved up and down by a rod 44 connected at its lower end to a bell crank 46 pivoted by its mid pivot to a fixed portion of the craft. The bell crank 46 is rocked by a rod 48 which in turn is moved by a control stick 50 in the occupant's portion of the body 10. As the control stick 50 is pushed forwardly, the rod 40 will be moved upwardly through the linkage above described, and as the control stick 50 is moved backwardly, the rod is pulled down. With the stick 50 held in the neutral position shown, the rod 40 will likewise remain substantially in the position shown in which the blades 18 have a constant angle of incidence through their entire revolution. Lateral control is effected by similar linkage, not shown.

When the rotor blades 18 are turned by the engine 12, or due to aerodynamic action in the autorotation state, the control rod 40 will be subjected to cyclical vibrations if the pitch of the rotor blades 18 differ with respect to each other, or if the aerodynamic pitching moments of these blades are different. In order to measure the different aerodynamic pitching moments of the several blades, an indicating mechanism is provided as generally indicated at 52 in Fig. 2. This mechanism 52 comprises a chart 54 that is driven by and may be secured to the drive shaft 14 and a stylus arm 56 mounted upon the push-pull rod 44 by a pivot bracket 58. The stylus arm 56 is equipped with a marking device, or stylus, 60 at its outermost end for marking the chart 54. The arm 56 is pivoted at a point between its ends by a multiplying mechanism comprising a slip friction device including a spring 62 cooperable with a clip 64 carried by a pivot 66, which spring and clip restrain the pivot to a position along a wire 68 that is secured at its upper and lower ends to fixed parts of the body of the helicopter. The slip friction device may be moved along the wire 68 so that the marking point 60 of the stylus arm 56 may register with a fixed mark around the chart 54, or to a position in which new marks may be made upon the chart 54, and allows for movement of the controls.

As best shown in Fig. 2, each blade when in the position shown will have its push-pull rod 32 in substantial registry with the push-pull rod 40 at one position in its cycle, so that any net difference of the pitching movements of the three blades at this time will be transferred through the rod 40 to the rod 44 to cause the stylus arm 56 to be moved. The resulting chart when utilized as set forth hereinafter, permits appraisal of the pitching moments of all the blades and, therefore, it is necessary to use but one indicating mechanism 52.

In Figs. 4 and 5, the charts 54 are shown as they would appear if unrolled and after marks have been made thereon by the marking point 60 of the stylus arm 56. As the shaft 14 moves through a complete revolution from 0° to 360° on the chart, a push-pull rod 32 of a blade lines up with control rod 40 at the 0°, 120°, 240° and 360° positions on the chart. In Fig. 4, a straight line marked "stick-locked" could be made by holding the control stick by a suitable fastener and operating the rotor blades 18 and placing the marking point 60 against the chart 54. Under such conditions, any vibration of the rotor blade cannot be transferred to the marking point 60 because of the locked stick. The line marked "stick free" is irregular and indicates variations in the pitching moments of the several blades between zero degrees and 360 degrees on the chart.

At the zero position on the chart 54, the line marked "stick free" indicates that there is a positive pitching moment of the blade 18 which has its control linkage in registry with the rod 40. Inasmuch as there are three blades 18 spaced substantially 120 degrees apart, substantially 120 degrees later, the indication of the "stick free" line on the chart 54 at 120 degrees will indicate positive pitching moment for the second blade of the three. 120 degrees still later, the third blade 18 will have its control linkage in registry with the push-pull rod 40 and the chart indicates a negative pitching moment.

Upon examining a chart as described above, an operator will be apprised of the fact that the first and second blades have a positive pitching moment, with the second blade having a slightly greater moment than the first blade. Each blade may be marked with a distinguishing color and, if desired, the lines denoting the degree position upon the chart may be of the same color, and the operator, by moving a blade to a position in which its control linkage is in registry with push-pull rod 40, will then know that the corresponding line on the chart beneath the marking point 60 should correspond to this color. With such information, the operator will then be able to bend the tab of the first and second blades downwardly to a required degree to give a more negative pitching moment to such blades. The third blade shows a negative pitching moment so that its tab 20 will need be bent upwardly, but to a lesser extent than the other two tabs were bent downwardly because this moment is of a lower magnitude than the positive moments of the first two blades. Thereafter another run may be made and a new tracing made by the marking point 60 upon the chart 54.

Fig. 5 discloses what is considered to be a desirable trace of the resulting moments of all blades as recorded with proper trim tab adjustment thereof and the "stick free." The line bearing the legend "tab adjusted—no resulting moment" is substantially horizontal and the irregu-

larity thereof is caused only by engine vibration due to explosions, and gear tooth vibrations in the reduction gearing 16.

The indicating mechanism 52 of this invention is of such simple construction that it may be made part of the regular equipment for the helicopter so that periodically it may be used to correct the blade action. When not in use the slip friction device may be slid along the wire 68 so that the stylus is out of the way of other operating parts of the machine, or the entire mechanism can be easily removed and replaced, if desired. It is also obvious that the chart 54 might be operated by different parts of the mechanism associated with the rotor drive and that the stylus could be actuated from other of the rods connected between the control stick 50 and the tilt plate 36, and that the choice of position for this mechanism may be left with the mechanic who is to use the device.

It will be understood that in testing the rotor of a helicopter as above described the helicopter would be held stationary on the ground either by loading it with sufficient weight or by using tie-down cables.

In Fig. 6, a modification of the indicating mechanism for performing the functions outlined above is shown and comprises a drive shaft 114, which may be the rotor drive shaft 14 of Fig. 2, mounting a plate 116 which turns cam projections 118, one of which is shown in engagement with a breaker switch generally indicated at 120. The breaker switch 120 engages three times in each revolution of the rotor for a three-bladed rotor at the time that the rotor control mechanism is in registry with a control rod 144 corresponding to rod 44 of Fig. 2. At the time of engagement of the switch 120 the force in the control rod 144 due to the action of a rotor blade will be reflected in a strain gauge 146, or the like, which registers the strain in the rod 144. Obviously, other pressure responsive electrical means could also be used to generate a signal. Wires from the breaker switch 120 and the strain gauge 146 lead to a suitable recorder 125 which may carry a chart 126 driven by the shaft 114 or otherwise. Current for the circuits to the breaker switch 120 and the strain gauges 146 are supplied from suitable sources, not shown, through wires 123. The breaker switch 120 may energize a spring biased solenoid 130, or the like, to move a stylus 132 to make a mark 134 on the chart 126. Peaks 136 on the mark 134 will occur 120 degrees apart upon energization of the solenoid 130 by the breaker switch 120 under the influence of the cams 118.

To obtain a trace upon the chart 126, of the force caused by blade action, the strain gauge 146 may operate a solenoid 140, or the like, to make a mark 142 upon the chart 126. The mark 142 will accurately indicate upon the chart the force upon the control rod 144. With such structure, by providing an external driving means for chart 126 the chart and mechanism containing the chart may be removed from the body of the helicopter so that a ready field test may be obtained merely by plugging into the circuits of the breaker switch 120 and the strain gauge 146. Obviously, electrical equivalents could be used for the various parts of the combination to obtain the same result as obtained by the means explained.

While we have shown and described two modifications of our invention and the method for using the same, it will be understood that modi-

fied means and methods will occur to those skilled in the art within the spirit and scope of the following claims:

We claim:

1. Apparatus for testing helicopter rotors, in combination, a drive shaft, a plurality of variable pitch blades driven by said shaft, a rotating pitch control mechanism driven by said shaft and connected to said blades, a non-rotating pitch control mechanism connected to said rotating mechanism for controlling the pitch of said blades, a movable chart, a stylus for making a trace on said chart, means responsive to vibrations and the dynamic pitching moment of each blade as it passes a given point during each revolution, said last mentioned means being connected to said non-rotating control mechanism, means operatively connecting said responsive means and said stylus so that said stylus marks and records on said chart the combined pitching moments for all of said blades, and means including an element driven by said shaft for indicating on said chart the points on the trace of said stylus at which each of said blades passes said given point.

2. Apparatus for testing helicopter rotors, in combination, a drive shaft, a plurality of variable pitch blades driven by said shaft, a rotating pitch control mechanism driven by said shaft and connected to said blades, a non-rotating control mechanism connected to said rotating mechanism for controlling the pitch of said blades, a movable chart, a stylus for making a trace on said chart, means responsive to the combined dynamic pitching moments of said blades as they pass a given point during each revolution, said means being connected to said non-rotating control mechanism, means operatively connecting said responsive means and said stylus so that said stylus marks and records on said chart the combined pitching moments of said blades, and means including an element driven by said shaft for indicating on said chart the point on the trace of said stylus at which each of said blades passes said given point.

3. Apparatus for testing helicopter rotors, in combination, a shaft, a plurality of blades mounted on said shaft for pitch varying movement, means for varying the pitch of said blades including a swash plate mechanism having relatively stationary and rotatable parts, control members connecting the pitch varying elements of each of said blades with said rotatable part, means including a pilot operative member connected to said relatively stationary part, and recording means for registering forces set up in said pilot operative member and in the connections between the latter and said stationary part by the dynamic pitching moments of the several blades as the control member associated with each blade moves past said pilot operative member including, a movable chart, a stylus for marking said chart, means carried by said pilot operative member and responsive to the combined dynamic pitching moments of said blades, means operatively connected to said last mentioned means and to said stylus for moving the latter to mark said chart in proportion to the magnitude of said pitching moments, and means including an element driven by said shaft for indicating on said chart the points on the trace of said stylus at which said control members pass said pilot operative member.

4. Apparatus for testing helicopter rotors, in combination, a shaft, a plurality of blades mount-

ed on said shaft for pitch varying movement, means for varying the pitch of said blades including a swash plate mechanism having relatively stationary and rotatable parts, generally upright members connecting the pitch varying elements of each of said blades with said rotatable part, means including a generally upright pilot operative member connected to said relatively stationary part, and recording means for registering forces set up in said pilot operative member by the pitching moments of the several blades as the upright member associated with each blade moves past said pilot operative member including, a movable chart, a stylus for marking said chart, means carried by said pilot operative member and responsive to the forces exerted on said member due to the combined pitching moments of said blades, means operatively connected to said last mentioned means and to said stylus for moving the latter to mark said chart in proportion to the magnitude of said pitching moments, and means including an element driven by said shaft for indicating on said chart the points on the trace of said stylus at which said upright members pass said pilot operative member.

5. Apparatus for testing helicopter rotors, in combination, a shaft, a plurality of blades mounted on said shaft for pitch varying movement, means for varying the pitch of said blades including control mechanism having relatively stationary and rotatable parts, control members connecting the pitch varying elements of each of said blades with said rotatable part, means including a pilot operative member connected to said relatively stationary part, and recording means for registering forces set up in said pilot operative member by the pitching moments of the several blades as the control member associated with each blade moves past said pilot operative member including, a movable chart, a stylus for marking said chart, means carried by said pilot operative member and responsive to the forces exerted on said member due to the combined pitching moments of said blades, means operatively connected to said last mentioned means and to said stylus for moving the latter to mark said chart in proportion to the magnitude of said pitching moments, and means including an element driven by said shaft for indicating on said chart the points on the trace of said stylus at which said control members pass and pilot operative member.

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