United States Patent [19]

Norris et al.

[11] **3,873,230**

[45] **Mar. 25, 1975**

[54] **STATOR VANE ACTUATING MECHANISM**

[75] Inventors: **James Reynolds Norris,** Bolton; **Frederick Mathew Pendoley,** Canton, both of Conn.

[73] Assignee: **United Aircraft Corporation,** East Hartford, Conn.

[22] Filed: **Apr. 10, 1974**

[21] Appl. No.: **459,836**

[52] **U.S. Cl.** **415/162,** 415/149

[51] **Int. Cl.** **F01d 17/16**

[58] **Field of Search** 415/149, 162, 23, 160

[56] **References Cited**

UNITED STATES PATENTS

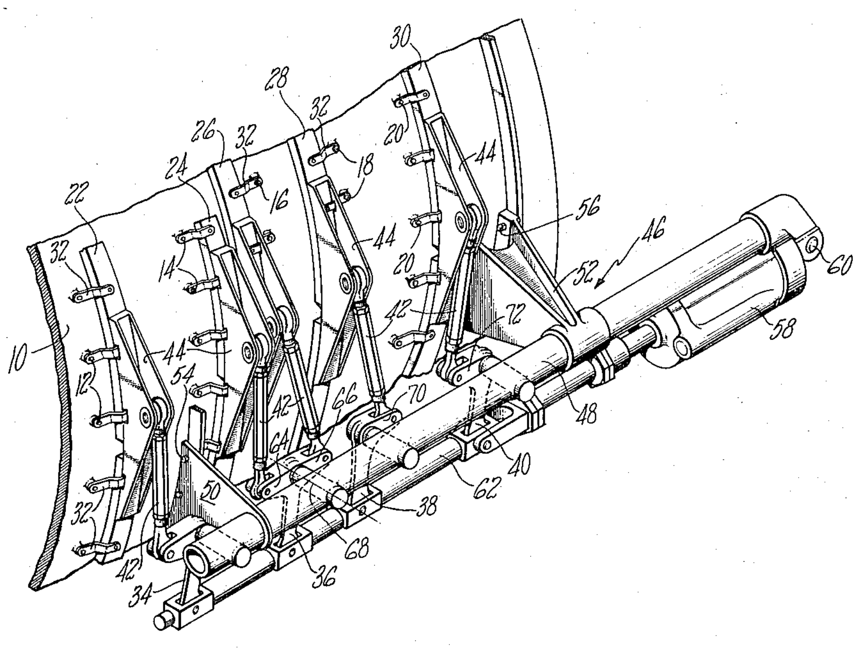
2,823,700	2/1958	Christensen	415/160
2,999,630	9/1961	Warren et al.	415/149
3,360,240	12/1967	Williamson et al.	415/160
3,487,992	1/1970	Pineda	415/149
3,614,253	10/1971	Gaertner	415/23
3,632,224	1/1972	Wright et al.	415/149

Primary Examiner—Henry F. Raduazo
Attorney, Agent, or Firm—Stephen E. Revis

[57] **ABSTRACT**

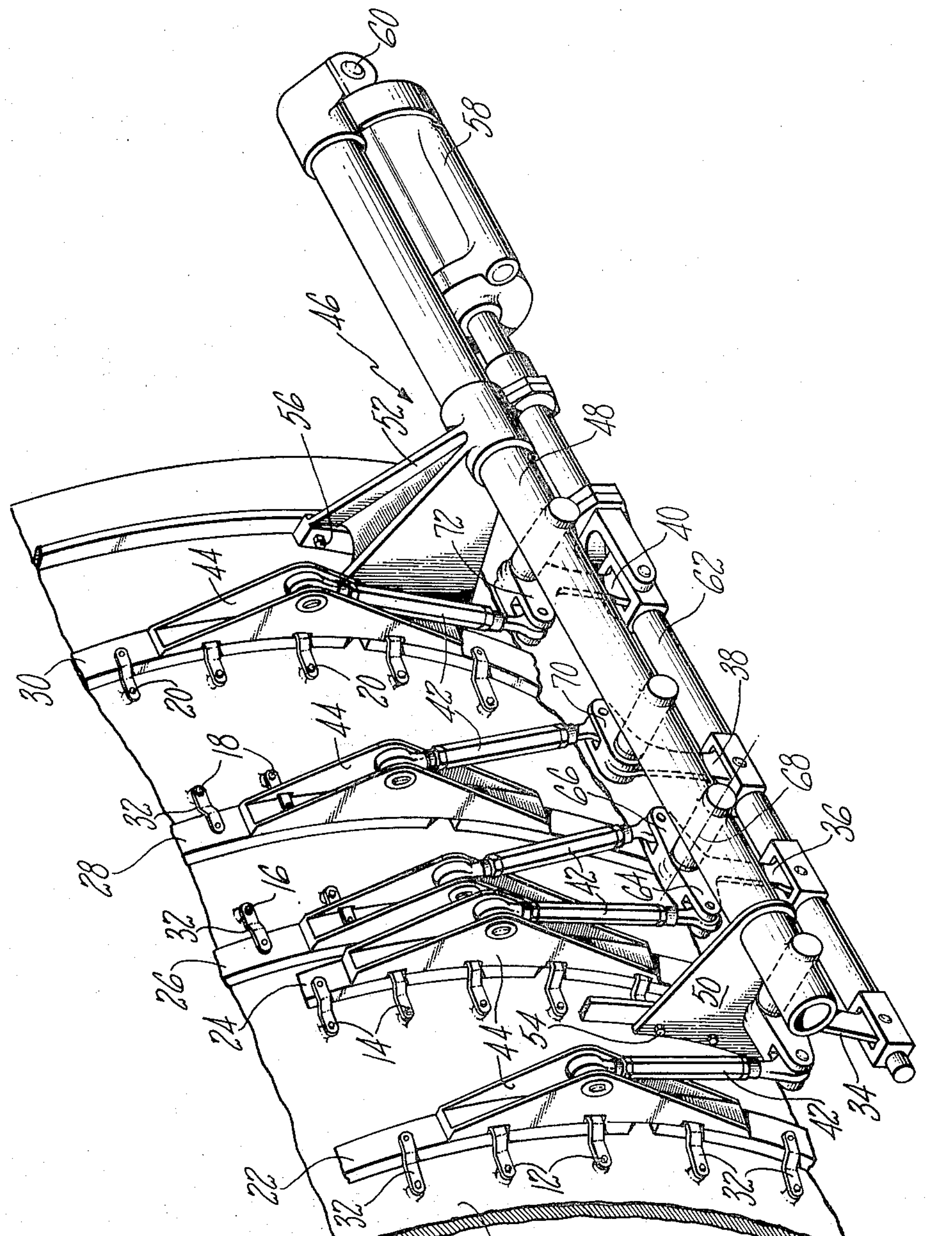
In a vane actuation system including several actuated stages, unison rings for pairs of stages are actuated in opposite directions. The bell-cranks for actuating the unison rings are all connected to a common carrier wherein the oppositely directed loads substantially balance out so that only the difference is transmitted into the engine casing. The bell-crank actuator is also mounted on the common carrier and therefore none of its loads are transmitted into the engine casing. The common carrier is substantially isolated from the casing by support members which permit the casing to grow and deflect without inducing large stresses in the common carrier.

5 Claims, 1 Drawing Figure



PATENTED MAR 25 1975

3,873,230



STATOR VANE ACTUATING MECHANISM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to actuation systems for adjustable vanes in gas turbine engines.

2. Description of the Prior Art

It is well known to provide axial flow compressors of gas turbine engines with adjustable stages of stator vanes to improve engine performance at various engine operating conditions. Mechanisms for actuating these adjustable vanes are mounted on the engine casing in a manner resulting in large actuation reaction forces being transmitted directly into the engine casing; this often requires strengthening of the casing or actuating mechanism supporting members to reduce system deflection and hysteresis, thereby adding weight to the engine which is undesirable. Also, since the mounting structure is usually rigidly secured to the engine casing at several locations the structure is subject to stresses imposed by case deflection and case thermal growth, necessitating heavier and stronger components. Unison rings are usually all actuated in the same direction and their reaction loads are therefore additive and are transmitted into the casing.

SUMMARY OF THE INVENTION

It is one object of the present invention to minimize the reaction forces transmitted into the engine casing through a stator vane actuation system.

A further object of the present invention is to reduce the stresses imposed upon an actuation system support structure due to engine case growth and engine case distortion.

Accordingly, in the present invention a vane actuation support structure is isolated, in so far as is possible, from the engine casing. Vane actuation means is connected to bell-crank means and both are entirely supported by this support structure. Pairs of unison rings are connected to and actuated by the bell-crank means in opposite directions whereby the reaction forces transmitted into the support structure are balanced and reduced to a minimum. By having the actuation means as well as the bell-crank means mounted entirely on the support structure the actuator reaction loads are not transmitted into the engine casing.

The prior art makes no effort to balance reaction forces off against each other before they are transmitted into the engine casing. It is often as if each bell-crank is directly secured to the engine casing. Also, it is usually the case that the unison rings rotate in the same direction and the actuation means is secured directly to the casing. Thus, virtually all the forces that are required to actuate each of the various unison rings are additive and have a direct load path into the engine casing. The present invention provides a common loop for these loads which permits various reaction loads to counteract each other that the engine casing sees a reduced load. In U.S. Pat. No. 2,999,630 to Warren et al., the two forward unison rings are actuated in opposite directions; however, this serves no useful purpose from the point of view of reducing engine casing loads since the first bell-crank is pivoted directly from the engine casing.

The foregoing and other objects, features and advantages of the present invention will become more apparent in the light of the following detailed description of a preferred embodiment thereof as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE is an external perspective view of a portion of the compressor section of a gas turbine engine showing one embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, the numeral **10** designates the annular casing for the compressor section of an axial flow gas turbine engine. Only a portion of the casing is shown; the forward end of the casing or the inlet end of the engine is to the left in the drawing. In this embodiment the engine includes five stages of adjustable compressor stator vanes, the number not being critical to the invention. The vanes themselves cannot be seen in the drawing but stems of several of the vanes of each stage can be seen extending radially outwardly through openings in the casing **10.** The vane stems of the forward most stage are designated by the numeral **12,** and the vane stems of the next succeeding stages are designated **14, 16, 18** and **20,** respectively. Each of the stages has a unison ring associated therewith. The unison ring of the forward most stage is designated by the numeral **22**; and the unison rings of the next succeeding stages are designated **24, 26, 28** and **30,** respectively. The unison rings are of the type which is well known in the prior art. The vanes of each stage are connected to their respective unison rings by means of actuating arms **32** in a manner well known to persons having ordinary skill in the art.

The unison ring **22** is connected to a bell-crank **34**; the unison rings **24, 26** are connected to a bell-crank **36**; the unison ring **28** is connected to a bell-crank **38** and the unison ring **30** is connected to a bell-crank **40.** The connecting means between the unison rings and the bell-cranks are links **42** secured to brackets **44** which are fixed to the unison rings. The bell-cranks are all pivotally mounted on a support structure generally represented by the numeral **46.**

The support structure **46** comprises a bell-crank carrier member **48** which is herein shown as being tubular in form and which extends in a direction substantially parallel to the engine axis. The support **46** also includes casing connecting means for securing the bell-crank carrier member to the casing. In this exemplary embodiment the casing connecting means includes forward and rearward support members or brackets **50,** 52, respectively, which are secured by suitable means such as bolts to flanges on the casing **10** such as for example at **54** and at **56.** The forward bracket **50** is flexible in the axial direction to accommodate axial casing growth and deflections so as to reduce stresses imposed on the carrier **48.** Thus the carrier **48** is isolated from casing growth and deflection. To further the purpose of isolating the carrier member from the casing it is preferable that no more than two spaced apart support members are used to attach the member to the casing.

An actuator **58** is also mounted on the bell-crank carrier **48** by suitable means such as the pin and clevis joint at **60.** The actuator **58** is connected to the bell-cranks **34, 36, 38** and **40** by a connecting rod **62** which may be one piece or several interconnected pieces as shown in this embodiment.

In a manner well known to one with ordinary skill in the art, when the connecting rod **62** is moved forwardly or rearwardly by the actuator **58** the bell-cranks **34, 36,** 38 and **40** pivot about their respective axes thereby rotating the unison rings **22, 24, 26, 28** and **30** which in turn rotate the vanes of their associated stage through actuating arms **32.**

In accordance with one aspect of the present invention the adjustable vane stages are divided into what shall hereinafter be referred to as "pairs of balanced stages." The two stages of vanes associated with the unison rings **24** and **26** are an example of one such pair. In the present invention the unison ring and actuating arms of one stage of a pair are positioned rearwardly of the vanes of their associated stage, while the unison ring and actuating arms of the other stage of such pair are positioned forwardly of the vanes of their associated stage. Thus, the unison ring **24** is positioned rearwardly of the vane stems **14** and the unison ring **26** is positioned forwardly of the vane stems **16.** Also in accordance with this invention, each pair of balanced stages has associated therewith a pair of bell-crank arms such as the arms **64** and **66** of the bell-crank **36.** One of the pair of arms extends forwardly of its pivot point, such as the arm **64,** and the other of the arms extends rearwardly of its pivot point, such as the arm **66.** In this particular instance both arms are part of a single bell-crank **36** and therefore pivot about a common axis **68.** Each of the pair of arms **64, 66** is connected to one of the unison rings **24, 26** by means of links **42.**

In operation, when the actuator **58** moves the connecting rod **62** the bell-crank **36** rotates about the axis **68** and, through links **42,** rotate the unison rings **24, 26** in opposite directions. Since the unison rings are positioned on opposite sides of their respective vane stages, vanes of both stages will rotate in the same direction. The important feature of this arrangement is that the reaction loads at the connection between the bell-crank **36** and the bell-crank carrier **48** (i.e., along the axis **68**) are substantially canceled out in view of the substantially equal and opposite loads exerted on the arms **64, 66** during actuation of the unison rings **24, 26** in opposite directions. Only the difference between the reaction forces from the unison rings **24, 26** is felt by the bell-crank carrier **48** and is passed into the casing **10** through the brackets **50, 52.**

Another pair of balanced stages is also shown in FIG. **1.** These are the stages associated with the unison rings **28** and **30.** Note once again that the pair of unison rings associated with the pair of balanced stages are positioned on opposite sides of the vanes of their respective stages. The unison ring **28** is positioned forwardly of the vanes of its stage and the unison ring **30** is positioned rearwardly of the vanes of its stage. Note, however, that this pair of balanced stages is actuated through individual bell-cranks **38, 40** rather than a common bell-crank such as the bell-crank **36** which operates two unison rings. As with the previous pair of balanced stages, this pair of balanced stages also has associated therewith a pair of bell-crank arms **70, 72.** The bell-crank arm **70** extends rearwardly of its pivot point and the bell-crank **72** extends forwardly of its pivot point. Thus, once again, when the connecting rod moves the bell-cranks **38, 40** in the same direction the unison rings **28, 30** are rotated in opposite directions and all the vanes of the pair of balanced stages are rotated in the same direction. Since the bell-crank carrier **48** is common to the bell-cranks **38, 40** the substantially equal and opposite reaction forces at the pivots of the bell-cranks **38** and **40** will once again counteract each other. The brackets **50** and **52** and the casing **10** will feel only the difference, which is usually very small.

In view of the fact that the axes or pivot points of the arms **70, 72** are spaced apart and the loads act in opposite directions, the bell-crank carrier **48** will be subjected to a local bending moment. For that reason a pair of bell-crank arms acting about a common axis, such as the arms **64, 66** is preferred for actuating a pair of balanced stages. Generally, space considerations around the engine casing and the spacing between adjustable vane stages will determine whether or not a single or two separate bell-cranks are used to actuate a pair of balanced stages. If it is necessary to use the two separate bell-cranks then it is preferable to have their pivot points as close together as possible to minimize the bending moment generated by the reaction forces. It is thus preferable, although not mandatory, that the pairs of balanced stages be adjacent stages such as they are in the exemplary embodiment of FIG. **1.** Also, within a multi-stage compressor the force required to rotate the vanes in a given stage will likely be different from the force required to rotate the vanes in another stage, and similarly the angle of rotation desired may vary from stage to stage. Within these constraints, linkage geometry and the arrangement of pairs of balanced stages are selected such that the summation of reaction forces and moments acting on the bell-crank carrier member **48** is as near zero as possible thus minimizing the loads on brackets **50** and **52** and the engine casing **10.** It should be noted in this embodiment that there is an odd number of stages and therefore it may not be possible to balance all the reaction loads going into the support structure **46.** In this embodiment the forwardmost stage is the odd stage. Preferably there should never be more than one unpaired stage. Note that in this embodiment it may also be stated that the rearward most stage is the odd stage and that the forward and next to last stages are the pair of balanced stages.

A further important feature of the present invention which is in keeping with the purpose of minimizing the loads transmitted to the casing **10** is that the actuator is mounted entirely on the support structure **46** so that the reaction forces associated therewith are confined to the load path loops formed by the support structure **46,** the connecting rod **62,** the bell-cranks **34, 36, 38, 40** and the actuating cylinder **58.** The reaction forces thereby balance each other and are not transmitted into the casing **10.**

Although the invention has been shown and described with respect to a preferred embodiment thereof, it should be understood by those skilled in the art that various changes and omissions in the form and detail thereof may be made therein without departing from the spirit and the scope of the invention.

Having thus described a typical embodiment of our invention, that which we claim as new and desire to secure by Letters Patent of the United States is:

1. In an axial flow gas turbine engine a stator vane actuation system comprising:

an annular casing;

a plurality of stages of rotatably mounted stator vanes disposed within said casing, including at least one pair of balanced stages;

a plurality of first actuating arms connected to the vanes of a first stage of each of said pairs and extending rearwardly therefrom;

a plurality of second actuating arms connected to the vanes of a second stage of each of said pairs and extending forwardly therefrom;

a first unison ring for each of said pairs surrounding said casing and disposed rearwardly of the vanes of said first stage of each of said pairs, said first actuating arms being connected thereto;

a second unison ring for each of said pairs surrounding said casing and disposed forwardly of the vanes of said second stage of each of said pairs, said second actuating arms being connected thereto;

a bell-crank support assembly including substantially axially extending bell-crank carrier means, said support assembly also including casing connecting means secured to said carrier means and to said casing, and adapted to substantially isolate said carrier means from deflection and axial growth of said casing;

bell-crank means including a pair of bell-crank arms for each of said pairs of stages, said arms being pivotally connected to said carrier means, one of said pair of bell-crank arms extending forwardly of its pivot point and the other of said pair of bell-crank arms extending rearwardly of its pivot point, one of said pair of bell-crank arms being connected to said first unison ring and the other of said pair of bell-crank arms being connected to said second unison ring; and

actuation means mounted entirely on said bell-crank support assembly and connected to said bell-crank means and adapted to simultaneously rotate said pairs of bell-crank arms in the same direction thereby rotating said first and second unison rings of each of said pairs of stages in opposite directions to balance the reaction forces transmitted into said carrier means through each of said pairs of bell-crank arms and to effectuate rotation in the same direction of the vanes of each of said pairs of stages.

2. The stator vane actuation system according to claim **1** wherein the stages of each of said pairs of stages are adjacent stages.

3. The stator vane actuation system according to claim **1** wherein at least one pair of bell-crank arms is pivotally connected to said carrier means about a common axis.

4. The stator vane actuation system according to claim **1** wherein not more than one of said stages of rotatably mounted stator vanes is an unpaired stage.

5. The stator vane actuation system according to claim **4** wherein said casing connecting means includes forward support means and rearward support means one of said support means being substantially rigid and the other permitting relative movement between said casing and said carrier means thereby substantially isolating said carrier means from said casing, said forward and rearward support means being the only load paths from said carrier means into said casing.

* * * * *