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[54] **METHOD OF CONTROLLING MULTI-CASING VARIABLE SPEED COMPRESSORS**

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[58] **Field of Search** 415/1

[56] **References Cited**

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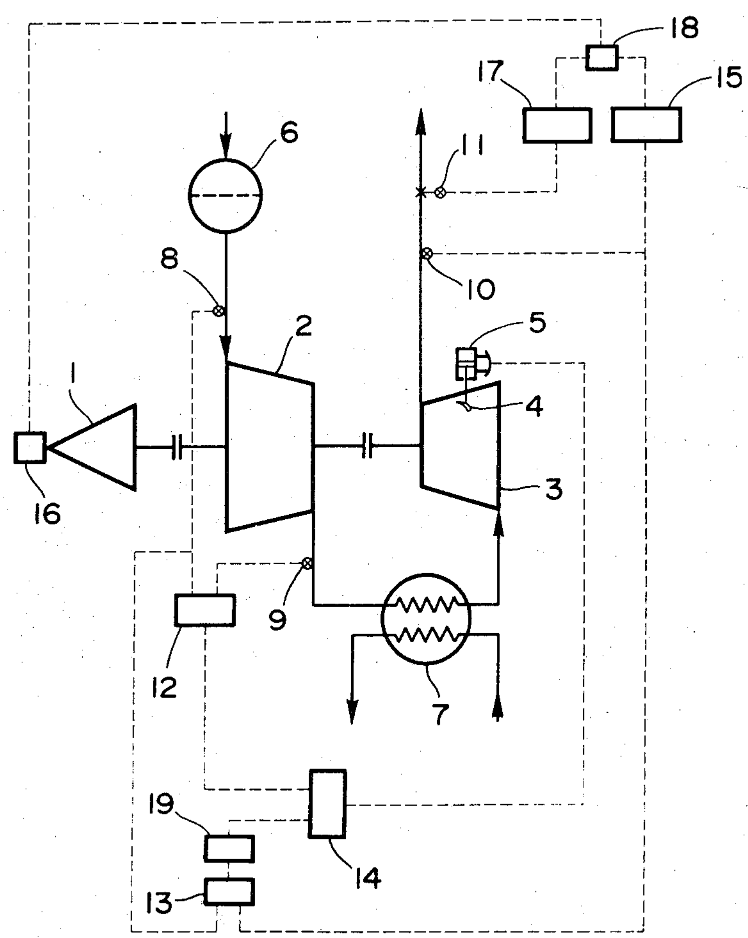
[57] **ABSTRACT**

A method of controlling multi-casing variable speed compressors comprising a low pressure compressor and a high pressure compressor at least one of which is of axial type and has stator blades which are adjustable in setting angle, said method includes steps of measuring the pressure rise in one compressor and the total pressure rise in both said high pressure and low pressure compressors, adjusting the setting angle of the stator blades in accordance with the ratio of the pressure rise in said one compressor to the total pressure rise so as to obtain a predetermined share of pressure rise in said one compressor, and controlling the speed of the compressors in accordance with the output pressure or air flow in the compressor.

6 Claims, 2 Drawing Figures



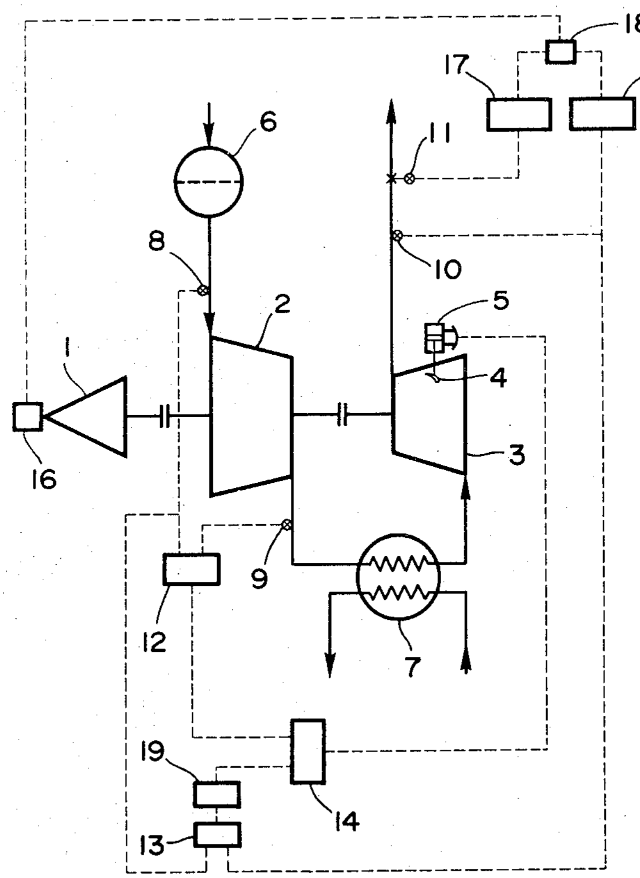


Fig. 1

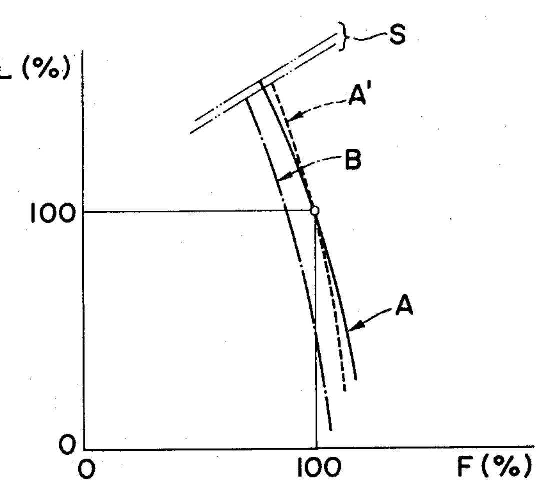


Fig. 2

METHOD OF CONTROLLING MULTI-CASING VARIABLE SPEED COMPRESSORS

The present invention relates to a method of controlling multi-casing variable speed compressors and more particularly to a method for controlling pressure ratio among compressors, that is, pressure distribution or load distribution between low pressure and high pressure compressors.

In a conventional compressor having an intermediate cooler, pressure distribution is not controlled. In an actual practice, a compressor is operated either without any control or under a constant pressure control in which output pressure is maintained substantially constant or under a constant flow control in which air flow is maintained substnatially constant. In either case, any substantially is not performed for obtaining predetermined distribution of pressure among a low pressure and a high pressure compressors. Therefore, when the performance of a high pressure compressor is deteriorated, the pressure increase or the share of load on the high pressure compressor is reduced and that on the low pressure compressor is correspondingly increased. From the view-point of aerodynamics, this means a reduction in angle of attack in the high pressure compressor and increase in the low pressure compressor, with the result that the low pressure compressor is possibly operated in a surging zone. This may ultimately cause a failure of the low pressure compressor. When the low pressure compressor is provided with an anti-surge control means which serves to prevent the surging phenomenon by sensing the flow and the pressure in the low pressure compressor, it may be possible to prevent the surging, however, when a control is made in such a manner that a constant air flow is maintained, there may be a substantial decrease in the outlet air pressure to such a degree that a plant operation may become impossible.

The deterioration in the performance of the high pressure compressor is caused by dust carried by the air and absorbed in drain water separated in the intermediate cooler and adhered on compressor blades, or by scales or the like produced by sulphuric acid corrosion or other chemical corrosion of components of the intermediate cooler. Therefore, this deterioration in performance of the high pressure compressor cannot be avoided as far as the intermediate cooler is used. Further, even if there is no adverse effect of the dusts or the like from the intermediate cooler, there inevitably occurs an unbalance in pressure distribution among the compressors when it is operated at off-design. Thus, the compressor must be operated within a very limited range.

The present invention has an object to eliminate the aforementioned disadvantages of the conventional methods.

To attain this, it is proposed to present a load distribution in a form of load shared by the low pressure compressor or the high pressure compressor to the total load. In other words, the pressure ratio shared by the low pressure compressor or the high pressure compressor is previously set to a optimum value as a function of the total pressure ratio. The actual pressure ratio shared with the low pressure compressor or the high pressure compressor is compared with the set ratio in a controller and equalized by controlling the setting angle of the stator blade.

Another object of the present invention is to provide a method for controlling multi-casing compressors in which an unbalance in pressure distribution between a high pressure and a low pressure compressor due to a deterioration in performance of the high pressure compressor is self-compensated by controlling the pressure distribution so that there is no decrease in capacity.

A further object of the present invention is to provide a method for controlling multi-casing compressors which is effective to prevent any failure of low pressure compressor blades which may be caused by an unbalance in pressure distribution between a high pressure and low pressure compressors and which can provide sufficient safety margins to surging points of the high and low pressure compressors when the compressors are operated under a part load pressure being different from a design pressure.

According to the method of the present invention, it is possible to ensure a safety of operation under a constant air flow and to maintain a whole pressure level and an air flow level through a control of the rotational speed.

The method in accordance with the present invention is characterized by the fact that the outlet pressure of the high pressure compressor or the ultimate pressure and the air flow are controlled by regulating the speeds of the high pressure and the low pressure compressors and the unbalance in pressure ratio is self-compensated by adjusting the angle of stator blades in the high pressure compressor. Thus, the low pressure compressor can be of a fixed stator axial or centrifugal type which does not have any control means. Of course, it is also possible to make the stator blades of the low pressure compressor adjustable in lieu of those in the high pressure compressor. In this case, the load distribution is compensated in the low pressure compressor, and the decrease in total capacity can be recovered by an increase in speed.

The above and other objects and features of the present invention will become apparent from the following descriptions of a preferred embodiment which will be proceeded taking reference to the accompanying drawings, in which;

FIG. 1 is a diagrammatical illustration of one embodiment of the present invention; and,

FIG. 2 is a diagram showing the characteristic curves of a compressor which is controlled in accordance with the present invention.

Referring to the drawings, particularly to FIG. 1, the reference numeral (6) designates an inlet filter through which fluid is sucked into a low pressure compressor (2) which is driven by a variable speed prime mover (1) such as a steam turbine, a gas turbine or the like. The fluid compressed in the low pressure compressor (2) is then cooled by an intermediate cooler (7). The atmospheric air usually includes water moisture and when the air is cooled this moisture is made to condensate. The condensate has to be deleted from the pipe line as much as possible. At this instance, a condensate is usually separated from the fluid and the relative humidity of the fluid becomes 100 percent. Even when the fluid is not cooled to the relative humidity of 100 percent, the portion of the fluid which is in contact with walls of cooling pipes is locally supercooled until a condensate is separated therefrom. Although the arrangement is such that the drain is expected to be discharged through suitable means such as a drain trap, a portion of the drain is taken into a high pressure compressor (3) in the form of a mist which may adhere to blade surfaces to cause erosion thereof. The fluid introduced into the high pressure compressor is expanded at the first blade row therein so that the temperature thereof is decreased. As the fluid is of such a high humidity as 100 percent or so, a condensate is separated therefrom and adheres to blades in the next row. When the drain is deposited on the blade surfaces, dusts are absorbed thereby resulting in a decrease in performance of the compressor. When the air include sulphur dioxide, a sulphate solution is produced by reaction with water in the intermediate cooler and causes corrosion of the cooler parts to produce scales of such as copper sulphate and iron sulphate which are also adhered to the blade surfaces. A similar phenomenon may be produced even in an atmosphere including nitric acid or the like. It may be possible to prevent these scales from being produced by selecting suitable materials, however, in any event, a small quantity of scales will be produced.

From the above descriptions, it will be apparent that contamination of compressor blade will cause a deterioration in performance of the high pressure compressor resulting in a decrease in capacity and the range in which the compressor can be operated without surging. In order to prevent such disadvantage, it is only necessary in the characteristic curve of FIG. 2 wherein the axis of ordinate represents the load ratio L(%) and the axis of abscissa the flow ratio F(%), to shift the characteristic curve B of the high pressure compressor after the contamination to the position of a self-compensated characteristic curve A′, by varying the setting angle of the stator blades of the high pressure compressor. In a strict sense, the characteristics A′ does not exactly coincide with the characteristics A which is obtained by a new compressor blades, however, it is practically acceptable because both characteristics substantially coincide with each other in the actual operating range.

Now, referring to the control in accordance with the present invention, in case of a constant flow control, a pressure signal from a pressure signal generator (10) is introduced into a pressure controller (15) which produces an output for controlling a rotational speed controller (16). When a change-over switch (18) is selected to control the flow, a signal from the flow detector (11) which is attached to a venturi or an orifice is fed to a flow controller (17) and compared with a set signal, thus controlling the speed controller (16) until any difference between both signals is completely eliminated. Thus, a constant air flow can be maintained. The pressure ratio between the high pressure and the low pressure compressors is controlled in the following manner. Pressure signals from an inlet pressure signal generator (8) and an output pressure signal generator (9) in the low pressure compressor are introduced into a pressure ratio operator (12) which produces a pressure ratio signal for the low pressure compressor. Further, pressure signals from the inlet pressure signal generator (8) of the low pressure compressor and from an outlet pressure signal generator (10) of the high pressure compressor are introduced into a pressure ratio operator (13) which produces a total pressure ratio signal corresponding to that between the inlet pressure of the low pressure compressor and the outlet pressure of the high pressure compressor. The total pressure ratio signal is introduced into a function generator (19) which determines the ratio of the pressure in the low pressure compressor in accordance with a predetermined curve throughout the operating range of the compressor. The output of the function generator (19) is then introduced into a pressure ratio controller (14) and compared with an actual pressure ratio signal in the low pressure compressor to adjust the stator blades (4) in the high pressure compressor by means of an actuator (5) in accordance with the amount of difference between the two signals.

In accordance with the present invention, a pneumatic pressure system, an electro-hydraulic system or other suitable system may be used for performing the control. When the inlet pressure of the low pressure compressor is substantially constant, a similar result can be obtained by using the output pressure signal generators (9) and (10) in lieu of the pressure ratio operators (12) and (13), respectively. Further, a similar result can be obtained by adjusting the stator blades in the low pressure compressor, although the detail of the operation is not described herein.

From the above descriptions, it will be understood that in accordance with the present invention the pressure ratio can be controlled by adjusting the setting angle of the stator blades of the compressor, so that the following advantages can be obtained.

1. The compressor is free from decrease in capacity.

2. Both the low pressure and high pressure compressor have substantially the same amount of safety margins of surging, so that the compressor can be operated substantially free from surging.

3. Even under a part load condition in which pressure and air flow are different from a design value, it is possible to perform a pressure ratio control so that an increased range of operation can be obtained under various rotational speeds and at the same time the compressor can have a wider high efficiency range.

We claim:

1. A method of controlling multi-casing variable speed compressors at least one of which is of axial compressor type and has stator blades which are adjustable in setting angle, said method comprising steps of determining the unbalance in pressure distribution, adjusting the setting angle of the stator blades so as to compensate unbalance in pressure distribution between the compressors, and controlling the speed of the compressors for adjusting the total pressure rise or air flow.

2. A method in accordance with claim 1 in which said compressors include a high pressure compressor and a low pressure compressor, said high pressure compressor having adjustable stator blades.

3. A method in accordance with claim 1 in which said compressors include a high pressure compressor state and a low pressure compressor stage, said low pressure compressor having adjustable stator blades.

4. A method in accordance with claim 1 which said step of determining the unbalance in pressure distribution comprises steps of detecting pressure rise in one compressor and the total pressure rise in the compressors, said setting angle of the adjustable stator blades being adjusted in accordance with the ratio of said pressure rise in said one compressor to said total pressure rise.

5. A method in accordance with claim 1 in which the speed of the compressors is controlled in accordance with the output pressure thereof.

6. A method in accordance with claim 1 in which the speed of the compressors is controlled in accordance with air flow.

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