United States Patent [19]

Shirato et al.

[11] **3,737,246**

[45] **June 5, 1973**

[54] **CONTROL METHOD OF COMPRESSORS TO BE OPERATED AT CONSTANT SPEED**

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[22] Filed: **July 30, 1971**

[21] Appl. No.: **167,672**

[52] **U.S. Cl.** **415/1,** 415/26, 415/179

[51] **Int. Cl.**.....**F01d 1/00**

[58] **Field of Search**.....415/1, 26, 179

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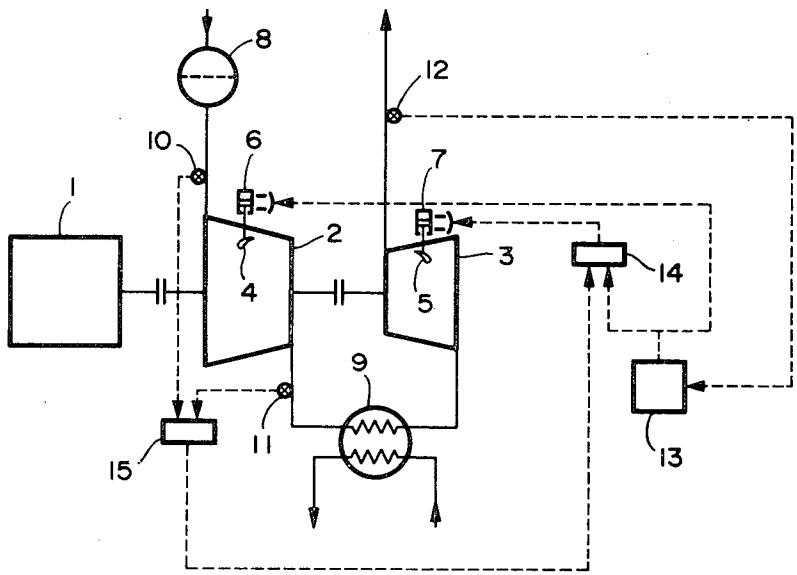
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[57] **ABSTRACT**

In a compressor system comprising a low pressure compressor, an intermediate cooler and a high pressure compressor, wherein the compressors are operated at a constant speed, and the pressure distribution ratio is controlled to bring it to an optimum value, by employing a variable blade type compressor for said high pressure compressor and varying the setting angle of the stationary blades of said high pressure compressor according to the delivery pressure of its own, and thereby securing a safety operation and a wide operational range when said compressors are used in off-design.

2 Claims, 2 Drawing Figures



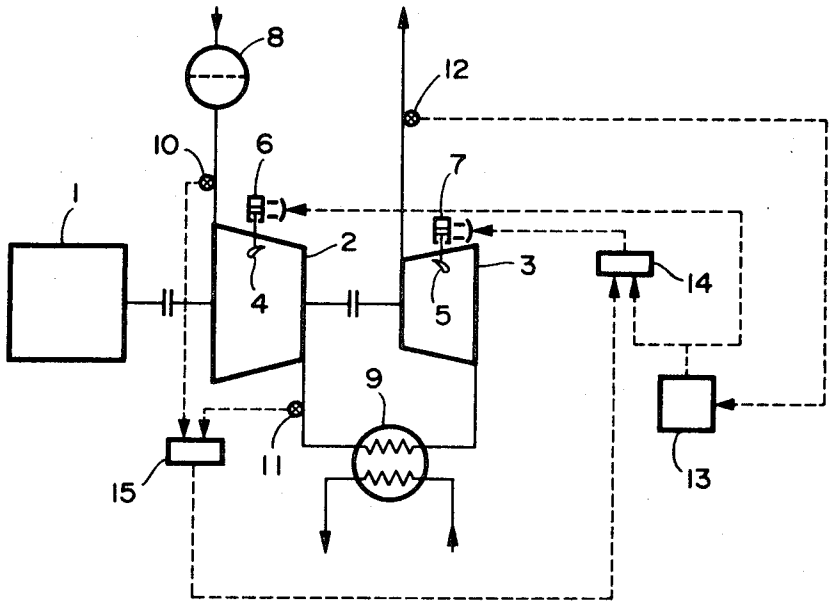


Fig. 1

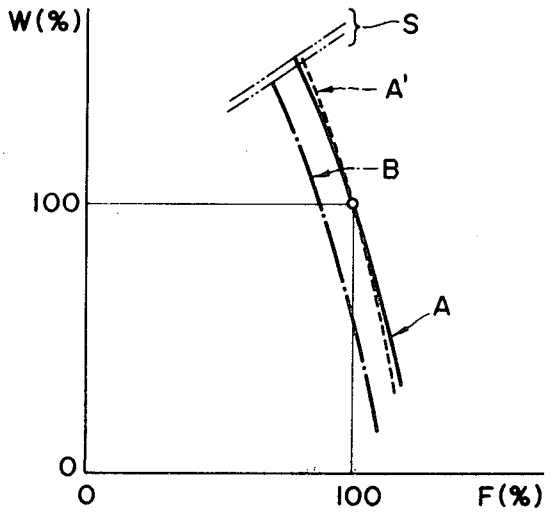


Fig. 2

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CONTROL METHOD OF COMPRESSORS TO BE OPERATED AT CONSTANT SPEED

This invention relates to a method of controlling the pressure ratio distribution and therefore the load distribution of a compressor system comprising a low pressure compressor, an intermediate cooler and a high pressure compressor, so as to bring said ratio to an optimum set value.

In conventional compressor systems having an intermediate cooler, the controlling of the delivery pressure has been effected, not by controlling the aforesaid pressure ratio but by controlling only the delivery pressure of a high pressure compressor, to obtain arbitrary delivery pressure. In some cases there are no controlling devices and the delivery pressure is controlled indirectly by the resistance of the plant. Therefore, when the performance of the high pressure compressor has been deteriorated, the high pressure compressor does not perform the intended work. On the other hand, the delivery pressure of the high compressor must be maintained constant. Consequently, it has been necessary that a pressure shortage of the high pressure compressor must be borne by a low pressure compressor. Describing this from the standpoint of aerodynamics, the high pressure compressor moves in a direction in which the angle of attack decreases and conversely the low pressure compressor moves in a direction in which the angle of attack increase, with the result that the capacity decreases and finally the low pressure compressor goes into a surging region, causing a breakage of blades. From the standpoint of preventing the low pressure compressor from becoming surged, it is useful to set a surge preventing line based on the suction flow and delivery pressure characteristic of only the low pressure compressor, but in this case, the delivery pressure of high pressure compressor may be insufficient to operate the plant resulting in interruption of the plant operation. The deterioration of performance of the high pressure compressor is caused by the drain generated in the cooler adhering to the surfaces of the blades to which the dust present in fluid and/or scales formed in the cooler are attached. The scales are formed by corrosion of the intermediate cooler material with sulfuric acid or other chemical corrosion, and the formation of such drain or scales is inevitable due to the inherent nature of the intermediate cooler.

The object of the present invention is to provide a controlling method by which the unbalance of the pressure ratio distribution resulting from a performance deterioration of the high pressure compressor is self-compensated by controlling the pressure ratio distribution so as not to induce a capacity decrease, and thereby the breakage of the blades of the low pressure compressor can be prevented which would otherwise be caused by the unbalance of pressure ratio distribution, and further a part load operation range can be maintained as wide as designated to meet the demand of the plant. Thus, it is easily understood that the present invention is also useful when the compressors are operated in a region of off-design.

The control method according to the present invention is characterized in that the delivery pressure of the high pressure compressor, i.e., the pressure of the entire system, is controlled by varying the stationary blade angles of both compressors by the same amount, and the unbalance of the pressure ratio distribution is

selfcompensated by varying the stationary blade angle of only the high pressure compressor.

The present invention will be described in greater detail hereinafter with reference to the accompanying drawing. In the drawing,

FIG. 1 is a block diagram showing an embodiment of the controlling method according to the present invention, and

FIG. 2 is a graphic representation illustrating the characteristic changes of the compressor making use of the method of the invention.

Referring to FIG. 1, fluid sucked through a filter 8 is compressed by a low pressure compressor 2 of the compressor system which is driven by a constant speed prime mover 1, and cooled by an intermediate cooler 9. The intermediate cooler 9 usually generates a drain and the relative humidity of the fluid becomes 100 percent. Even when the fluid is cooled only to a relative humidity below 100 percent, the portion of the fluid in direct contact with the wall of a cooling tube is excessively cooled locally to make the relative humidity reach 100 percent and thus generates a drain. The drain thus generated is discharged to the outside of the system through a drain trap or the like. However, part of the drain is sucked into a high pressure compressor 3 in the form of mist and adheres to the surfaces of the blades, or causes an erosion. On the other hand, fluid sucked into the high pressure compressor 3 is expanded in the inlet guide vanes and lowered in temperature. Therefore, the fluid at a humidity of 100 percent or close to 100 percent is over-saturated to generate a drain and the drain thus generated adheres to the surfaces of the blades in the next row. The presence of the drain on the blade surfaces causes a deterioration of performance since fine dust present in the fluid is attracted thereby. Adhering to the blade surface is not only the dust contained in fluid but also scales such, for example, as copper sulfate and iron sulfate resulting from corrosion of the intermediate cooler materials with sulfuric acid which is formed by the reaction between the sulfur dioxide contained in atmosphere and the water generated in the cooler 9. A similar phenomenon occurs in the atmosphere containing nitric acid or other errosive compound-forming gas, but can be avoided to some extent by suitably selecting the materials of the cooler. However, the formation of some amount of scales is inevitable. The contamination of the blades in the manner described above causes the performance of the high pressure compressor to be deteriorated and the capacity to be decreased, and surging is liable to occur and the operational range to be narrowed.

In order to prevent such undesirable phenomena, it is only necessary in the characteristic curve of FIG. 2 wherein the axis of ordinate represents the load ratio W (%) 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 static blades of the high pressure compressor. Strictly speaking, the characteristic curve A' cannot be exactly superimposed on the characteristic curve A of the low and high pressure compressors, but no practical problem will occur only if these curves are through the operating point of before contamination. Reference symbol S in FIG. 2 designates a surge curve.

Now, the way of control of the compressor system will be described. Reference numerals **10** and **11** designate transmitters respectively which detect the pressure of suction and discharge sides of the low pressure compressor **2,** and its respective signal is transmitted to a pressure ratio generator **15.** The pressure ratio generator **15** in turn generates a pressure ratio signal as its output. This pressure ratio signal is lead to a compensation operator **14** in which differential of an output signal of a constant delivery pressure controller **13** and that of pressure ratio generator **15** is generated. The compensation operator **14** transmits the resultant output signal to a high pressure compressor operating cylinder **7** to operate, whereby the setting angle of the stationary blades **5** of said high pressure compressor **3** is adjusted to bring the pressure ratio distribution to a set value. As is often the case, if the pressure of suction side of the low pressure compressor **2** is constant, the pressure ratio operator **15** can be eliminated and the pressure signal from the transmitter **11** can be lead directly to the compensation operator **14.** It will be obviously understood that the same result can be obtained by detecting the pressure ratio between the inlet and outlet of the high pressure compressor and feeding to the compensation operator **14,** though not shown in the drawing. For controlling the delivery pressure of the entire system, the delivery pressure of the high pressure compressor **5** is detected by a transmitter **12** and after comparing the detected pressure with the set value of the controller **13,** the output signal of said controller proportional to the pressure differential is transmitted to operating cylinders **6** and **7** of both compressors. When the output signal of the pressure ratio generator **15** is the same as the set value, the cylinders **6** and **7** are operated by the same amount until the pressure differential becomes zero. The controlling method of the invention may be practiced by using a pneumatic pressure system, electro-hydraulic system or other systems.

According to the present invention, as described above, the pressure ratio distribution can be adjusted by controlling the setting angle of the stationary blades of the high pressure compressor, so that the capacity of the system is not decreased, and it is possible to prevent the low pressure compressor from becoming surged and hence to prevent the breakage of the blades, and a stable operation can be obtained for over a long period. Furthermore, it is possible to maintain the part load operation range as wide as the designed one.

What is claimed is:

1. A compressor system comprising in combination a low pressure compressor, a high pressure compressor, said compressors being operable at constant speed and a cooler intermediate therebetween, characterized in that at least the high pressure compressor includes variable angle stationary blades, pressure transmitters (**10, 11**) disposed on suction and discharge sides, respectively, to detect pressure of said low pressure compressor and transmitting to a pressure ratio generator (**15**), the output signal of which is communicated to compensation operator (**14**) which also receives an output signal of a constant delivery pressure controller (**13**), differentiates the output signals of said ratio generator and said constant delivery pressure controller and transmits a resultant output signal to a high pressure operating cylinder (**7**) to adjust the setting angle of stationary blades of said high pressure compressor to provide a set value pressure ratio distribution.

2. A method of controlling a compressor system including an intermediate cooler, in which compressors are operated with a constant speed, by using high and low pressure compressors, both being a variable blade type, and with the delivery pressure of the high pressure compressor being controlled by varying the setting angles of the stationary blades of both said high and low pressure compressors by the same amount, and characterized in that the varying of the setting angle of said stationary blades of the high pressure compressor is achieved by an operating cylinder responding to an output signal of a compensation operator, said output signal being the differential between an output signal of a constant delivery pressure controller and a pressure ratio signal of a pressure ratio generator, the input of said pressure ratio generator being derived from pressure-sensing transmitters, thereby the unbalance of the pressure ratio distribution is self-compensated.

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