SHROUDING FOR COMPRESSOR STATOR VANES

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This invention relates to shrouding for the stator vanes of turbo-machines such as axial flow compressors and, more particularly, to improved shrouding capable of mechanically supporting the stator vanes without materially reducing the operating efficiency of the machine.

An axial flow compressor is conventionally provided with a plurality of axially spaced rows of stator vanes carried by and extending inwardly from the compressor casing. The inner tips of a row of stator vanes are often supported by a band-like member secured to and extending axially across the tips of the vanes, the band-like member being known as a shroud. Shrouds are most common on the first stages of a multi-stage compressor where undesired vibrations resulting from stall and other conditions are encountered most often and with the greatest severity. In addition to preventing excessive vibrations, the shrouds on the first stages of stator vanes provide the mechanical support required to resist vane damage by foreign objects accidentally drawn into the compressor during operation. The later stages of stator vanes in an axial flow compressor are not usually subjected to such excessive vibrations, and there is much less danger of foreign object damage to the later rows of vanes. Therefore, shrouds are often dispensed with on the later rows of stator vanes, the vanes being supported solely from their outer ends. With the inner tips of the vanes unsupported, the compressor rotor is conventionally provided with a smooth cylindrical or conical surface which rotates in proximity to the tips of the vanes to form a small clearance, known as the radial tip clearance, between it and the stator vane tips.

As air is forced through the stator vanes of an axial flow compressor, the static pressure is increased. For this reason, there is a tendency for air to leak around the shroud of a shrouded vane row from the trailing edges of the vanes where the static pressure is higher to the leading edges where it re-enters the compressor main flow stream, the leakage resulting in inefficient compressor operation. To reduce the leakage, the shroud is conventionally provided with sealing means operating at extremely small clearances. It has been found in practice, however, that unshrouded rows of stator vanes operating at conventional radial tip clearances are generally more efficient than shrouded vanes having seals running at much smaller clearances. While the reasons for this phenomenon are not entirely clear, the deleterious effect of shrouding on compressor efficiency appears to be that its presence precipitates local stalling by bleeding low energy air into the compressor main flow stream. The leakage around the shroud increases the boundary layer thickness in the vicinity of the stator vanes and adversely affects the incident angles of the air entering the stator vanes, thereby reducing compressor efficiency. It is thus seen that conventional shrouding, which is used to provide necessary mechanical support of the inner tips of the stator vanes, often results in inefficient compressor operation.

It is therefore a primary object of this invention to provide improved means for mechanically supporting the inner tips of stator vanes.

Another object of this invention is to provide means for both mechanically supporting the inner tips of the stator vanes and reducing leakage to a minimum.

A further object of this invention is to provide improved stator vane supporting means which provide the mechanical support of conventional shrouds without materially reducing the operating efficiency of the machine.

A still further object of this invention is to provide simple and inexpensive means for supporting the inner tips of the stator vanes.

Briefly stated, in accordance with an illustrated embodiment of the invention, the inner tips of a row of compressor stator vanes are mechanically supported by a band or shroud secured to the vane tips. The shroud extends axially from the leading edges of the vanes only a portion of the axial distance to the trailing edges of the vanes, the distance being determined by the amount of mechanical support required for the row of vanes. The shroud may be provided with conventional sealing means for reducing leakage, the amount of leakage around the shroud being less, however, than that normally encountered with conventional shrouds having similar sealing means since the shroud is not subjected to the full static pressure rise across the stage. The compressor rotor has a smooth conical surface which rotates in proximity to the tips of the vanes for substantially the remainder of the axial distance between the leading and trailing edges of the vanes. A small radial tip clearance similar to that accompanying conventional unshrouded vanes is formed between the cylindrical surface and the unsupported portions of the vane tips.

The features of the invention which are believed to be novel are set forth with particularity in the appended claims. The invention itself, however, together with further objects and advantages, may best be understood by reference to the following description taken in connection with the accompanying drawing, in which:

FIGURE 1 is a partial view in cross section of an axial flow compressor illustrating a conventional prior art shroud for mechanically supporting the inner tips of a row of stator vanes;

FIGURE 2 is a view similar to FIGURE 1 illustrating the use of shrouds constructed in accordance with this invention for supporting the tips of three rows of stator vanes; and

FIGURE 3 is a partial perspective view of one of the stator vane rows illustrated in FIGURE 2 along with the associated shroud and sealing structure.

It is believed that the present invention can best be described by first illustrating a conventional form of prior art shroud, after which the distinguishing features of the invention will be more readily apparent. Therefore, a conventional prior art shroud arrangement for an axial flow compressor is illustrated in FIGURE 1. The cylindrical compressor casing 10 has an annular groove 11 in its inner periphery, the groove 11 receiving the bases 12 of a plurality of stator vanes 13. The stator vanes 13 extend inwardly from the casing 10 across the compressor main flow stream 14 into the axial space between a first row of rotor blades 15 and a second row of rotor blades 16, the blades 15 being peripherally supported on a first
disc 17 and the blades 16 being peripherally supported on a second disc 18. The first disc 17 and the second disc 18 are axially spaced by an annular ring 19 secured to the disc 17 and 18 by a plurality of circumferentially spaced bolts 20 and 21, respectively.

Still referring to FIGURE 1, the inner tips 25 of the stator vanes 13 are secured to a ring-shaped band or shroud 26, the shroud 26 extending the entire axial distance between the leading edges 27 and the trailing edges 28 of the stator vanes 13. The shroud 26 is secured to the tips 25 of the vanes 13 by any suitable means, such as by welding. As discussed previously, the static pressure increases as the air is forced along the flow stream 14 and through the stator vanes 13. It will be appreciated, therefore, that the static pressure in the area A adjacent the leading edges 27. To prevent leakage around the shroud 26 from the high pressure area B to the low pressure area A, the shroud 26 is provided with inwardly extending flanges 27 and 28, the flange 27 cooperating with surface 29 on the spacer ring 19 to form a seal. The flange 27 supports a ring-shaped member 30 preferably comprised of a honeycomb material which cooperates with annullar seal teeth 31 and 32 carried on the spacer ring 19 to form a second seal.

Turning now to FIGURES 2 and 3, shrouds constructed in accordance with this invention are shown supporting the inner tips of three rows of stator vanes without the inner tips 25 of the stator vanes 13 shown in FIGURE 1. The compressor arrangement illustrated in FIGURES 2 and 3 is basically similar to that illustrated in FIGURE 1, the arrangement comprising a compressor casing 40 having three annular grooves 41, 42, and 43 located in its inner periphery from which three rows 44, 45, and 46 of stator vanes are supported in a conventional manner. The rows of stator vanes are located in the axial spaces between four rows 47, 48, 49, and 50 of rotor blades peripherally supported on rotor discs 51, 52, 53 and 54, respectively, which are spaced axially by rings 55, 56, and 57. It will be understood by those skilled in the art that the compressor structure described hereto is entirely conventional and may be varied in known manners without departing from the spirit of the invention. For example, the rotor may alternatively be comprised of an integral drum structure instead of the illustrated disc and spacer ring construction. Other modifications in the structure will also be obvious to those skilled in the art.

A ring-shaped baffle or shroud 60 is secured in a known manner, welds 61 being illustrated in FIGURE 3, to the inner tips 62 of the stator vanes 44. The shroud 60 extends axially from the leading edges 63 of the vanes 44 only a portion of the distance to the trailing edges 64, the precise distance being that required to support adequately the vanes 44. As shown, the shroud 60 extends approximately one-half of the axial distance between the leading and trailing edges. Assuming that the pressure rise across the row of vanes 44 is the same as that across the row of vanes 13 shown in FIGURE 1, it is clear that the pressure drop from area B to area A is substantially less than the pressure drop from B to A. As a result, less air will tend to leak around the shroud 60 than around the shroud 25. To reduce to the greatest possible extent that leakage which tends to occur, the shroud 60 is provided with a flange 65 which supports a sealing ring 66 of honeycomb or similar material. The sealing ring 66 cooperates with annular seal teeth 67 and 68 carried by the spacer ring 55. The spacer ring 55 has a conical surface 69 thereon which extends into proximity to the vanes tips 62 for substantially the remainder of the distance between the leading edges 63 and the trailing edges 64 of the vanes 44 to form a conical band of constant area 70 therewith. It has been found in practice that the total leakage around vane tips 62 is substantially less than that around vane tips 25, the efficiency thereby being greater.

A similar shroud 75 is secured in a known manner to the inner tips 76 of the stator vanes 45. Since the vanes 45 require less mechanical support than the vanes 44, the shroud 75 extends axially a shorter distance than the shroud 60. As illustrated, the shroud 75 extends approximately one-third of the distance between the leading edges 77 and the trailing edges 78 of the stator vanes 45. The shroud 75 carries a flange 79 which supports an annular sealing ring 80. With the pressure rise from area C to area D even less than that from area A to B, adequate sealing may be accomplished by means of a single seal tooth 81 cooperating with sealing ring 80. The spacer ring 55 has a conical surface 82 thereon which forms with the vane tips 72 for the remainder of the axial distance between the vanes edges 77 and 78 a conventional radial tip clearance 83.

Since stator vanes 46 require even less mechanical support than vanes 45, shroud 85 extends axially a very short distance from the leading edges 86 of the vanes 46. In view of the extremely small pressure rise from area E to area F, good efficiency can be attained even without the use of sealing means. A conical surface 88 on the spacer ring 57 extends for substantially the remainder of the axial distance from leading edges 86 to the trailing edges 87 to form with the vane tips 89 a conventional radial tip clearance 90.

It is thus seen that the improved shroud arrangement of this invention provides the mechanical support necessary for the stator vanes without materially reducing the operating efficiency of the compressor.

It will be understood that the invention is not limited to the specific details of the construction and arrangement of the embodiments illustrated and disclosed herein. It is therefore intended to cover in the appended claims all such changes and modifications which may occur to those skilled in the art without departing from the true spirit and scope of the invention.

What is claimed as new and desired to secure by Letters Patent of the United States is:

1. In a stator of a compressor comprising a rotor including at least two axially spaced rows of radial rotor blades, an axially extending ring-shaped structure connected to and separating said rows of rotor blades and defining a hollow rotor structure, a row of stator vanes interposed between said rows of rotor blades, each of said stator vanes having axially spaced leading and trailing edges and a radially inwardly projecting lip axially spaced from said axially extending ring-shaped structure, a continuous solid supporting band connecting said tip ends of said stator vanes, said continuous solid supporting band extending axially only a portion of the distance between said leading and trailing edges of said vanes, said ring-shaped structure having a conical surface complementary to said continuous solid supporting band and cooperating therewith whereby said continuous solid supporting band forms a support for said stator vanes and cooperates with said conical surface of said ring-shaped structure to form a seal between said axially spaced rows of radial rotor blades.

2. In a turbo-machinery, the combination as recited in claim 1 including sealing means carried by said continuous solid supporting band coating with said ring-shaped structure to further reduce leakage around the tips of said stator vanes.

3. In an axial flow compressor, the combination comprising a rotor including at least two axially spaced rows of radial rotor blades, an axially extending ring-shaped structure connected to and separating said rows of rotor blades and defining a hollow rotor structure, a row of stator vanes interposed between said rows of rotor blades, each of said stator vanes having axially spaced leading and trailing edges and a radially inwardly projecting tip end radially spaced from said axially extending ring-shaped structure, a continuous solid supporting band connecting said tip ends of said stator vanes, said continuous solid supporting band extending axially only a portion of
the distance between said leading and trailing edges of said vanes, said ring-shaped structure having a conical surface complementary to said continuous solid supporting band and cooperating therewith whereby said continuous solid supporting band forms a support for said stator vanes and cooperates with said conical surface of said ring-shaped structure to form a seal between said axially spaced rows of radial rotor blades.

4. In an axial flow compressor, the combination as recited in claim 3 including sealing means carried by said supporting band cooperating with said ring-shaped structure to further reduce leakage around the tips of said stator vanes.

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