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METHOD OF MAKING A COMPRESSOR SEAL

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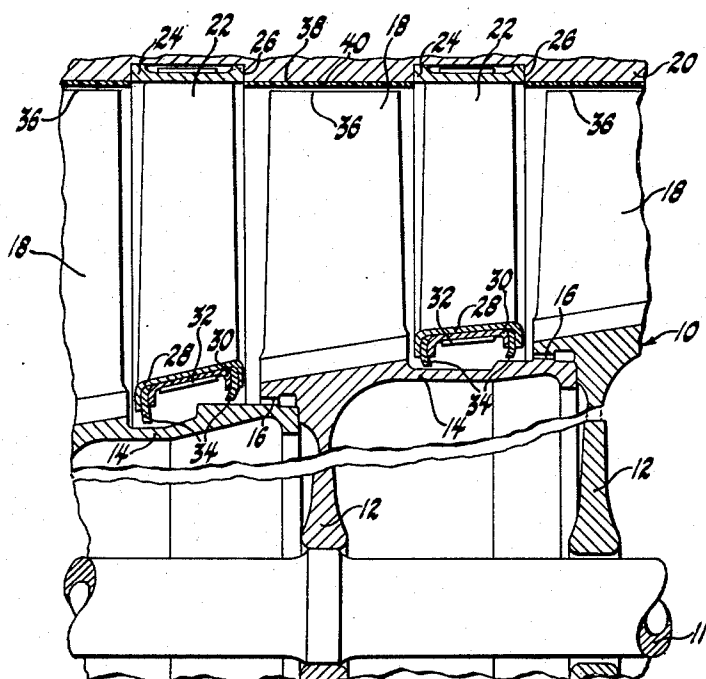


Fig. 1

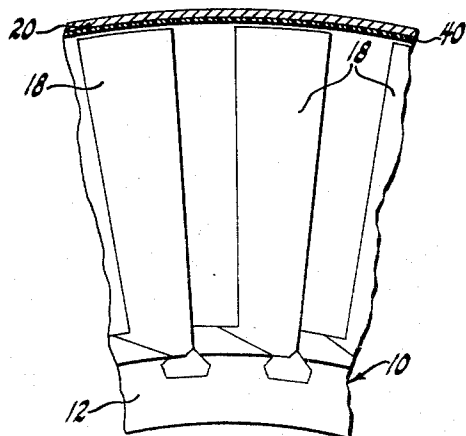


Fig. 2

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METHOD OF MAKING A COMPRESSOR SEAL

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This invention relates to improvements in method of making compressors and more particularly to improvements in the efficiency of axial-flow compressors.

Typical axial-flow compressors, such as those used in modern turbine engines, include a rotor which carries rows of outwardly extending rotor blades or vanes and a compressor housing which carries corresponding rows of stator vanes. Low speed compressors usually employ a rotor built from a number of rings flanged to fit one against the other and held together by means of a tie-bolt. High speed compressors on the other hand normally are of the disk type, comprising a number of metallic disks having their rims flanged to fit one against the other, and are either assembled on a shaft or held together by means of a tie-bolt.

The body of the rotor may be formed of a suitable high strength forgeable material such as an alloy of titanium, aluminum, and/or steel while the rotor vanes, generally dovetailed into the rotor, may be of stainless steel or the like.

The compressor housing or casing, which may be cast from alloys of aluminum, magnesium, or the like, generally is a two-piece assembly split on a plane through the compressor axis. Secured to the inner circumference of the housing are longitudinally spaced rows of stator vanes of stainless steel or the like which project inwardly between the corresponding rows of rotor vanes.

Multistage compressors having extremely high compression ratios may have the lower stage portions of the housing and rotor formed alloys of the aforementioned light metals with the higher stages of compression formed from alloys of steel or the like.

Up to the present time, one of the primary difficulties with axial-flow compressors has been the excessive energy loss due to the leakage of air past the rotor blade tips. The amount of air leakage depends to a large degree upon the clearance between the tips of the rotor blades and the compressor housing. This clearance in turn depends on the rigidity and dimensional stability of the compressor. In addition to the warpage and elastic deformation encountered in operation, the differential expansion of the compressor parts over the wide range of temperatures encountered in use makes it highly impractical to manufacture a compressor having a minimum clearance for optimum efficiency. Not only would more costly finishing and inspection operations be required in manufacture, but in many cases the dimensional instability of the closely fitting parts would result in damage to the compressor by scoring or gouging of the housing or breakage of the rotor vanes.

Accordingly, the principal object of this invention is to provide effective means for minimizing the clearance between the rotor blade tips and the compressor housing. A further object is to provide an abradable heat-resistant coating for the interior of the compressor housing to reduce the clearance between the blade tips and the housing. A still further object is to provide a compressor having an improved operating efficiency by coating the

interior of the compressor housing with a heat-resistant material adapted to be abraded or machined, if necessary, by the rotating blade tips in establishing a minimum operating clearance. Other objects and advantages will more fully appear from the description which follows.

We have discovered that the clearance between the blade tips and the compressor housing in an axial-flow compressor can be effectively reduced to a minimum by coating portions of the interior of the compressor housing with a heat-resistant material which is adapted to be cut away by the tips of the moving blades if necessary to provide a minimum clearance for optimum efficiency.

The invention will be best understood in connection with the accompanying drawing, in which:

Fig. 1 is a fragmentary sectional view of a multistage axial-flow air compressor for a turbine engine incorporating the invention; and

Fig. 2 is a fragmentary view, partially in section, of one stage of an air compressor similar to the compressor shown in Fig. 1.

Referring now to the drawing in detail, a known disk type compressor, indicated generally at 10, is shown in a compressor housing 20, only so much of the compressor being shown as is necessary to illustrate the invention. The rotor 10 is fabricated of a plurality of wheels or disks 12 having rims which are axially flanged at 14 to fit one against the other. The disks are held together by a tie-bolt 11 in a known manner. The thin flanges 14 are splined together as at 16 so that torsional forces may be transmitted between them. If desired, non-integral spacer rings may be utilized to separate the disks 12 rather than the integral flanges illustrated.

The disks 12 are dovetailed across the rims to carry rows of rotor blades 18. Extending inwardly from the casing 20 between the rows of rotor blades 18 are the rows of stator vanes 22. The stator vane rows are supported by rings 24 which are suitably secured in annular grooves 26 in the housing member. Flange rings 28 and 30 are secured to the inner ends of the stator vanes 22 by upsetting tangs 32 carrying the sealing rings 34 and extending from the blades through the rings.

The present invention is directed to means for reducing the clearance between the tips 36 of the rotor blades 18 and the inner circumferential surface 38 of the compressor housing. In accordance with this invention the portions of the housing adjacent the paths described by the tips 36 of the moving blades 18 are provided with a heat-resistant, abradable coating 40 which is adapted to be machined by the blade tips, if necessary, to establish an optimum minimum clearance between the blade tips and the rotor housing. As indicated in the fragmentary end view of Fig. 2, the heat-resistant coating 40 extends around the entire circumferential portion of the housing adjacent the moving rotor blade tips.

We have found that a very beneficial coating composition comprises a mixture of a silicone resin and a filler material such as finely divided graphite and/or asbestos. Such a coating not only adheres firmly and is flexible enough to prevent cracking at low temperatures, but also is easily machined by the blade tips when necessary to provide an optimum minimum clearance. In practice, such a mixture is applied to the interior of the compressor housing in the form of a paint or paste, then cured in situ and subsequently machined, before assembly, to provide a smooth coating having the desired thickness.

While the amounts of the ingredients can be varied for particular applications, we find that in many cases excellent results are obtained by employing various mixtures comprising powdered graphite and one or more silicone type resinous materials, such as the commercially available silicone resin paint known as "#505 Aluminum Polytherm," a product of the Interchemical Company.

The presently preferred coating has a composition, as applied, generally within the following range where the amounts are expressed in percent by weight.

	Percent
Heat hardenable silicone resin -----	7 to 45
Powdered graphite -----	15 to 55
Volatile matter -----	up to 65

In certain cases, it is desirable to replace the graphite, either wholly, or in part, with finely divided asbestos. In addition to the above-mentioned ingredients the preferred composition may at times contain up to about 10% by weight of finely divided aluminum or other metal for improved heat resistivity.

The following are specific examples of coatings in accordance with the present invention:

Example 1

A heat-hardenable coating composition is prepared by adding powdered graphite to No. 505 Aluminum Polytherm silicone base paint in an amount equal to about 1 gram of graphite per cubic centimeter of paint.

Example 2

A coating composition is prepared by adding 0.25 gram of powdered graphite per cubic centimeter of a liquid mixture comprising 7% of powdered aluminum, 40% of a heat-hardenable silicone resin, and 53% of toluene.

Example 3

A coating composition is prepared by adding finely divided asbestos to a silicone type resin paint in an amount equal to 1 gram of asbestos per cubic centimeter of paint.

The consistency or viscosity of mixtures having compositions as set forth in the preceding examples may, of course, be adjusted to suit the particular application intended by increasing or decreasing the amount of solvent or other volatile ingredients.

In more general terms, the coating, as applied, comprises a composition obtained by adding from a small but effective amount up to about 2 grams of powdered graphite and/or asbestos per cubic centimeter of a mixture comprising approximately 15% to 45% of one or more silicone resins, up to 75% of volatile solvent and/or diluent, and, in many cases, from about 7% to 12% of finely divided metallic powder.

In certain cases, satisfactory coating compositions may be formulated using, in addition to, or in lieu of, one or more silicone type resins, thermosetting resins such as phenol formaldehyde, urea formaldehyde, melamine formaldehyde, certain fluocarbon type resins, or other heat hardenable materials such as sodium silicate. It is essential, however, that the binder composition provide a machinable coating which is able to withstand temperatures as high as about 900° F. and remain adherent and non-blistering after prolonged exposure to temperatures of about 450° F.

Various filler or extender materials may be incorporated in the binder. Illustrative of typical filler materials which may be incorporated, the amount added depending upon the consistency desired as well as the application intended, are graphite, asbestos, glass fiber, or various ceramic materials such as silica flour, powdered spent catalyst, etc., various powdered metals such as aluminum, antimony, tin and lead. It will be understood, of course, that the consistency of the mixture also may be adjusted by the use of any conventional solvents and/or diluents such as secondary butyl acetate, mineral spirits, xylene, toluene or other liquid hydrocarbon materials. To improve the flexibility of the coating at low temperatures, certain plasticizers, such as various phthalates, glycol esters, etc., also may be incorporated in the coating composition.

In practice, the coating may be applied to the com-

pressor housing by brushing, spraying or, using thicker mixtures, with a roller or spreader. In certain cases, it may be desirable to employ a material having a similar composition in sheet or tape form which is cut to the proper size and bonded to the interior of the compressor housing. To improve the adherence of the coating material, it is necessary in many cases to thoroughly clean the surface to be coated as by degreasing, sand blasting, etching, or the like. Prior to applying the coating, the case is sprayed with clear (unpigmented) Polytherm paint to a thickness of about .002 inch and baked at 400° F. for one (1) hour. The coating of Polytherm paint and graphite is then sprayed on to a total thickness of approximately .065 inch.

The composition may be applied in one coat or in a number of coats with or without drying or heat treatment between applications. In general, the thickness of the coating depends upon the size of the compressor and the clearance desired. In many applications a typical thickness is about $\frac{1}{16}$ " or $\frac{1}{8}$ ".

While temperatures high enough to cure the coating material are encountered in operation, attempts to cure the coating merely by exposure to the temperatures encountered in use are generally unsatisfactory. Hence, in practice, the coating preferably is baked or otherwise cured before use to devolatilize the coating and convert it into a machinable, dimensionally stable material. In a preferred method of curing, the coating is heated for one hour at 100° F., one hour at 200° F., one hour at 300° F., one hour at 400° F. and one hour at 500° F. or a total of 5 hours in all. Such a stepwise heat treatment permits the volatile matter in the coating to gradually be driven off and avoids the formation of a vapor tight film or skin of resinous material at the surface which would prevent proper curing of the remainder of the coating. Depending upon the application intended and coating used, other curing cycles also may be used employing temperatures which are limited primarily by the characteristics of the coating material and the heating means employed. Typically practicable cycles include heating the coating at a temperature within a range of about 100° F. to 800° F. for a time of $\frac{1}{2}$ hour or more. The heat treatment may be conducted in any suitable heat treating apparatus, the construction of which forms no part of the present invention.

It is generally necessary to machine or grind the cured coating, before assembly of the compressor, to obtain the desired uniform thickness. Such a machining or grinding can be done on any conventional lathe or grinding apparatus. The thickness to which the coating is machined or ground is dependent upon the size of the compressor and the clearance desired, typical thicknesses after machining being within the range of from 0.01" to 0.030".

In a specific example of the practice of this invention the desired interior portions of a compressor housing are coated by brushing on a small amount of a mixture comprising powdered graphite and silicone base paint in which the graphite is present in an amount equal to about 1 gram per cubic centimeter of paint. Additional coating material is then sprayed on to provide a total coating thickness of about .065". The coating is subsequently heat treated in a stepwise baking cycle starting at 100° F. and increasing the temperature 100° F. at the end of each hour until the coating has been treated for one hour at 500° F. The cured coating is then machined to a uniform thickness of about 0.015 inch. When the coated housing is assembled in a completed compressor, the typical clearance is within the range of 0.001 to 0.010 inch.

The use of a coating in accordance with the present invention not only improves the efficiency of the compressor to permit increases of output horsepower of 20% or more, but additionally serves as a protective coating to prevent corrosion of the compressor housing.

It is to be understood that, although the invention has

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been described with specific reference to particular embodiments thereof, it is not to be so limited since changes and alterations therein may be made which are within the full intended scope of this invention as defined by the appended claims.

What is claimed:

1. A method of reducing the blade tip clearance in a multistage axial-flow air compressor of the type that includes a rotor carrying a multiplicity of rotor blades within a housing member which supports a multiplicity of cooperating stator vanes, by applying to the inner portions of said compressor housing adjacent the tips of said rotor blades a coating comprising a heat-hardenable mixture of about 7% to 45% by weight of a silicone-type resin, a volatile solvent in an amount not in excess of about 65% by weight, and 15% to 55% by weight of a filler material selected from the class which consists of powdered graphite and asbestos, curing said coating in situ by heating it to a temperature within the range of about 100° F. to 800° F. for at least ½ hour and thereafter machining said coating to obtain the desired thickness, said resulting coating being adapted to be cut away by the blade tips during operation of the compressor whereby optimum minimum clearance between the blades and the coated housing is obtained.

2. A method for producing improved operating efficiency in a multistage axial-flow compressor which includes the steps of applying to the interior of the compressor housing a heat-hardenable coating comprising a mixture of a thermosetting resin, a filler material, and a volatile solvent, curing said coating in situ by heat treatment in which the temperature is maintained at 100° F. for one hour and thereafter increased 100° F. hourly until the coating has been baked at 500° F. for 1 hour and thereafter machining the cured coating to obtain a coating of the desired uniform thickness, said resulting coating being adapted to be cut away by the blade tips of the compressor during operation thereof whereby optimum minimum clearance between the blade tips and the coated housing is obtained.

3. A method of reducing the blade tip clearance in a

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multistage axial flow air compressor of the type that includes a rotor carrying a multiplicity of rotor blades within a housing member which supports a multiplicity of stator vanes comprising the steps of applying to the inner portions of said compressor housing adjacent the tips of said rotor blades a coating comprising a heat hardenable mixture of about 7% to 45% by weight of a silicone resin, up to about 65% by weight of a volatile solvent and from about 15% to 55% of at least one filler material selected from the group consisting of powdered graphite, aluminum, and asbestos, curing said coating by heating it to a temperature within the range of about 100° F. to 800° F. for at least ½ hour to obtain a continuous hard sealing surface, machining said surface to provide a smooth coating having the desired thickness adapted to be cut away by the blade tips during operation of the compressor whereby optimum minimum clearance between the blade and the coated housing is obtained.

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