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PLASTIC COATING FOR COMPRESSORS

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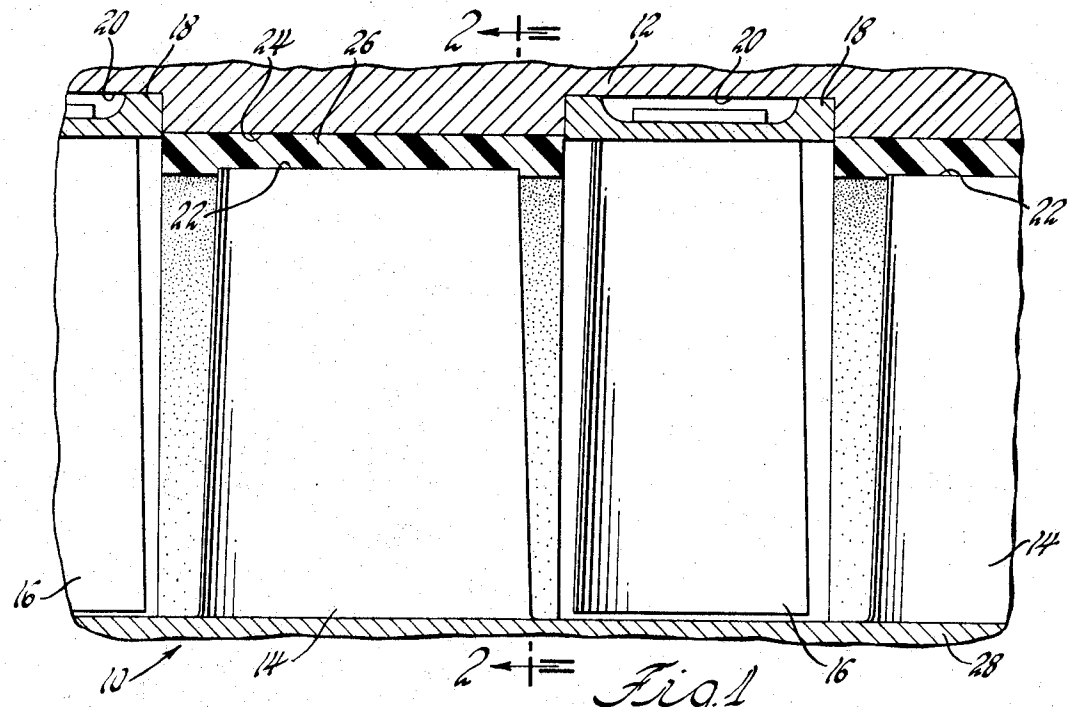


Fig. 1

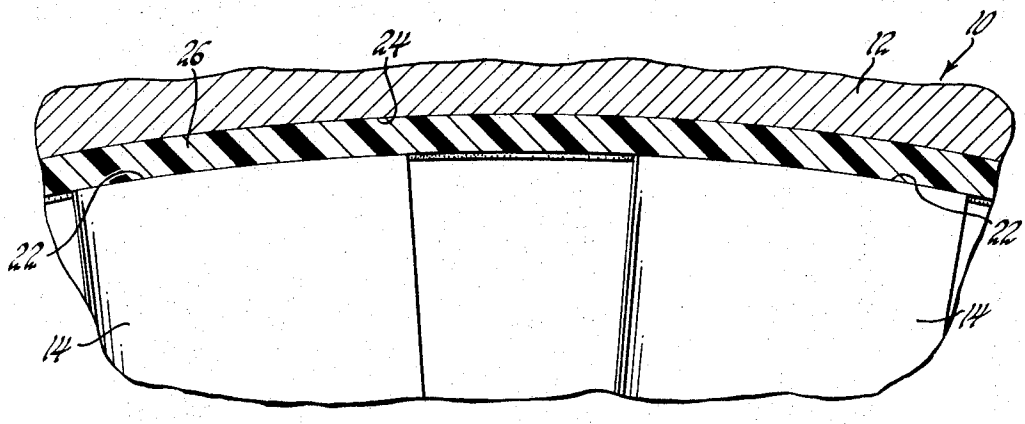


Fig. 2

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PLASTIC COATING FOR COMPRESSORS

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This invention relates to improvements in compressors and more particularly to improvements in the efficiency of axial flow compressors by application of a suitable abradable thermosetting resin to the inner wall surface of the compressor housing.

Typically 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 an annular-shaped compressor housing which carries corresponding rows of stator vanes. The rotor is aligned coaxially with the housing and rotates therein. 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, usually dovetailed into the rotor, may be of stainless steel or the like.

The compressor casing or housing which may be cast from stainless steel, aluminum, magnesium, or the like, and various alloys thereof, 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.

A suitable design of an axial flow compressor must also make some provision to prevent leakage of air past the tips of the rotor blades, between the blades and the housing. This spillage may substantially reduce the efficiency of the machine. The amount of air leakage depends to a large degree upon the clearance between the tips and the housing. The design clearance depends upon 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, a principal object of this invention is to provide a readily abradable zero clearance seal between a rotor blade and the compressor housing effectively eliminating excessive air flow over the tips of the blades. Such an abradable coating would permit each row of rotor blades to cut their own path through the coating to maintain a minimum tolerance without damaging compressor parts.

A further object of this invention is to provide such a coating formed of thermosetting epoxy resin materials which are readily applied and cured upon the inner surface of the compressor housing.

Another object of this invention is to provide a cured thermosetting resin coating having thermal expansion characteristics similar to those of the metal housing so that the compressor may be operated for a period of about

one thousand hours at temperatures ranging between —65° F. and 350° F. without failure of the coating.

In accordance with this invention, these and other objects are accomplished by providing a metallic compressor housing member with an inner circumferential thermosetting resin layer, which resin layer is formed of a composition cured from a mixture comprising by weight, 22–26 parts of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 25° C. in the range of 11,000 to 14,000 cps. and an epoxide equivalent weight of about 187–193; 160–194 parts of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 65.6° C. of about 300 to 500 cps. and an epoxide equivalent weight of about 235–255; 60–72 parts hexahydrophthalic anhydride; 225–275 parts of 325 mesh alumina; and 1.25–1.55 parts diethylaminoethanol.

The invention will better be understood after a complete description thereof reference being made to the accompanying drawings in which:

FIGURE 1 is a fragmentary view partially in section of a multi-stage axial flow air compressor incorporating the invention; and

FIGURE 2 is a fragmentary view partially in section of one stage of an air compressor taken on line 2—2 of FIGURE 1.

Referring now to the drawings in detail, the turbocompressor indicated generally at **10** is shown in a housing **12**, only so much of the compressor being shown as is necessary to illustrate the invention. The rotor shaft **28** (FIGURE 1) is fabricated to carry a plurality of rows of rotor blades **14**, the blades being supported on the rotor shaft **28** in any manner well known in the art. Extending inwardly from the housing **12** between the rows of rotor blades **14** are the rows of stator vanes **16**. The stator vane rows are supported by rings **18** which are suitably secured in annular grooves **20** in the housing **12**.

The present invention is directed to an abradable epoxy resin-based coating suitable for reducing the clearance between the tips **22** of the rotor blades **14** and the inner circumferential surface **24** of the compressor housing. The coating layer provided by this invention is indicated at **26**.

In accordance with this invention, a strongly adhering abradable epoxy-based coating is applied to the inner surface of the housing and cured thereon. As shown in FIGURES 1 and 2, the thickness of the coating preferably is such that in the initial run-in period of the compressor the rotor blades may cut a path through the coating which is suitable for each row of blades or stage of the compressor. The presence of the coating permits the metallic member of the housing to be manufactured to less close tolerances with respect to the rotor blades.

While a variety of types of abradable compressor housing coatings are known in the art, a suitable coating has not heretofore been devised having the combination of properties required for long coating life and efficient compressor operation. Known plastic seals become highly stressed due to the difference in thermal expansion between the metal and plastic material. This stress causes the coating to break away from the housing requiring replacement before the compressor would ordinarily be overhauled. Attempts in the prior art to reduce the greater thermal expansion of the plastic material have tended to reduce the flexibility of the material which also may cause premature failure of the coating. Moreover, many of the

resins in the present art do not form strong bonds with the metal housing.

The coating material of my invention is one which I have discovered to be particularly suitable for coating the inner surface of turbo-compressor housings. In the uncured state, the material may readily be applied to the housing and cured thereon. The cured resin strongly adheres to the metallic surface of the housing. Its thermal expansion properties closely approximate those of the metal member of the housing. To the extent that the coefficient of thermal expansion are different the coating is sufficiently flexible so that the compressor may be operated at temperatures between —65° F. and 350° F. for periods up to 1,000 hours without failure of the abradable coating material.

The basic ingredient in the coating material is an epoxy resin of the epichlorohydrin-bisphenol-A type having an epoxide equivalent weight of about 235–255 and a viscosity at 65.6° C. (150° F.) of 300–500 cps. Epoxy resins having these properties are frequently semisolids at room temperature. I have found that this epoxy resin will furnish the bonding strength, thermal shock resistance, and low shrinkage characteristics required, in addition to overall flexibility.

A lesser amount of a second epichlorohydrin-bisphenol-A type resin is added to provide the proper viscosity for flowing the material into the compressor casing without degrading the thermal properties. This resin preferably has a viscosity at 25° C. in the range of about 11,000 to 14,000 cps. and an epoxide equivalent weight of about 187–193. A hardener material is added to the formulation to provide desired coating properties when the material is in the hardened state. The hardener material utilized in my composition is specifically hexahydrophthalic anhydride. Alumina of fine particle size is added to lower the coefficient of thermal expansion of the coating material to approximately that of the compressor case. Preferably 325 mesh alumina is used. The catalyst which I have found to provide suitable curing properties for my coating composition is diethylaminoethanol. In accordance with my invention only the above-identified materials are to be used.

The uncured coating material may be formulated as follows. It is comprised by weight of: 22–26 parts, preferably 24 parts, of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 25° C. in the range of 11,000 to 14,000 cps. and an epoxide equivalent weight of about 187–193; 160–194 parts, preferably 176 parts, of an epichlorohydrin-bisphenol-A type resin having a viscosity at 65.6° C. of 300–500 cps. and an epoxide equivalent weight of 235–255 and which may be semisolid at room temperature; 60–72 parts, preferably 66 parts, hexahydrophthalic anhydride; 225–275 parts, preferably 250 parts, of 325 mesh alumina and 1.25–1.55 parts, preferably 1.40 parts, of diethylaminoethanol.

This formulation may be applied to the inside surface of the housing in a number of ways. I have found it preferable to apply it by a centrifugal casting technique to obtain a smooth coating of uniform thickness. The compressor casing may, for example, be mounted to the head of a lathe with the longitudinal axis of the casing in a horizontal position. Weirs are mounted on both ends of the compressor casing, the coating thickness, or the final inside diameter of the compressor casing being controlled or determined by the inside diameter of the weirs.

All the ingredients of the formulation with the exception of the catalyst are preheated to about 200° F. and thoroughly blended. The catalyst may then be blended into the filled resin mixture shortly before expected usage. The thoroughly blended composition is preferably maintained at about 200° F. during application to the compressor housing. An injector device containing a plurality of nozzles is placed into the casing inside diameter so that a nozzle is located between each row of vanes. The casing is then rotated rapidly and the liquid plastic material is forced through the injector nozzles into the casing. The formulation is added into the rotating casing until the plastic overflows the control weirs. The injector is subsequently removed from the casing and heat applied to cure the resin. Rotation of the casing at about 2900 to 3200 r.p.m. is continued throughout the initial cure cycle. When the plastic has cured to a hard solid, rotation may be stopped and the casing removed from the machine. Initial curing is effected during rotation by maintaining the compressor casing at about 200–250° F. for four hours. Final curing is effected after rotation is stopped by maintaining the casing at about 250° F. for an additional fourteen hours.

The above-identified composition has been applied in the described manner to a compressor casing and run in a turbine compressor for a period of about one thousand operating hours without failure. This means that a typical compressor could be operated for six months to a year without down time caused by coating failure. When eventually it is necessary to replace the coating, a brief run-in period is allotted during which time the rotor blades abrade paths in the new lining. The close rotor blade to casing wall tolerance permitted results in increased efficiency of the compressor. Preferably the thickness of the coating is such that the blades must abrade such a shallow path through the coating. The coating may be expected to withstand stresses caused by expansion and contraction of the casing wall over the temperature range from —65° F. to 350° F.

While this invention has been described in terms of a particular embodiment, it is apparent that other forms might readily be adopted by one skilled in the art and the invention should be considered limited only by the following claims.

I claim:

1. An axial flow compressor comprised of an annular housing, a rotor inside said housing and aligned coaxially therewith, and at least one circumferential row of blades attached to said rotor and extending outwardly therefrom, said housing being comprised of an annular metal member and a synthetic thermosetting abradable resin coating on the inner surface of said housing, said coating being of sufficient thickness that said rotor blades abrade a path therein during the rotation of said rotor, said coating being formed of the composition cured from a mixture comprising by weight 22 to 26 parts of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 25° C. in the range of 11,000 to 14,000 cps. and an epoxide equivalent weight of about 187–193; 160 to 194 parts of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 65.6° C. of about 300–500 cps. and an epoxide equivalent weight of about 235–255; 60–72 parts hexahydrophthalic anhydride; 225 to 275 parts of 325 mesh alumina; and 1.25 to 1.55 parts diethylaminoethanol.

2. An axial flow compressor as in claim 1 wherein said coating is formed of the composition cured from a mixture comprising by weight about 24 parts of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 25° C. in the range of 11,000 to 14,000 cps. and an epoxide equivalent weight of about 187–193; about 177 parts of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 65.6° C. of 300–500 cps. and an epoxide equivalent weight of 235–255; about 66 parts hexahydrophthalic anhydride; about 250 parts of 325 mesh alumina; and about 1.40 diethylaminoethanol.

3. An abradable epoxy resin sealing composition suitable for use between a stator member and a rotor member of a rotary machine at temperatures between about —65° F. and 350° F., said composition being the reaction product of the mixture comprising, by weight, 22 to 26 parts of an epichlorohydrin-bisphenol-A type epoxy resin having a viscosity at 25° C. in the range of 11,000 to 14,000 cps. and an epoxide equivalent weight of about 187–193; 160 to 194 parts of an epichlorohydrin-bis-

phenol-A type epoxy resin having a viscosity at 65.6° C. of about 300–500 cps. and an epoxide equivalent weight of about 235–255; 60 to 72 parts hexahydrophthalic anhydride; 225 to 275 parts of 325 mesh alumina; and 1.25 to 1.55 parts diethylaminoethanol.

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