CARBON-CARBON PISTON ARCHITECTURES

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Filed: Apr. 14, 1999

An improved structure for carbon-carbon composite piston architectures is disclosed. The improvement consists of replacing the knitted fiber, three-dimensional piston preform architecture described in U.S. Pat. No. 4,909,133 (Taylor et al.) with a two-dimensional lay-up or molding of carbon fiber fabric or tape. Initially, the carbon fabric or tape layers are prepregged with carbonaceous organic resins and/or pitches and are laid up or molded about a mandrel, to form a carbon-fiber reinforced organic-matrix composite part shaped like a “U” channel, a “T”-bar, or a combination of the two. The molded carbon-fiber reinforced organic-matrix composite part is then pyrolyzed in an inert atmosphere, to convert the organic matrix materials to carbon. At this point, cylindrical piston blanks are cored from the “U”-channel, “T”-bar, or combination part. These blanks are then densified by impregnation with resins or pitches which are subsequently carbonized. Densification is also accomplished by direct infiltration with carbon by vapor deposition processes. Once the desired density has been achieved, the piston billets are machined to final piston dimensions; coated with oxidation sealants; and/or coated with a catalyst. When compared to conventional steel or aluminum alloy pistons, the use of carbon-carbon composite pistons reduces the overall weight of the engine; allows for operation at higher temperatures without a loss of strength; allows for quieter operation; reduces the heat loss; and reduces the level of hydrocarbon emissions.

14 Claims, 5 Drawing Sheets
CARBON-CARBON PISTON ARCHITECTURES

CROSS REFERENCE TO RELATED APPLICATION

This application is a divisional application of commonly owned, patent application Ser. No. 08/805,195, filed Feb. 27, 1997, now U.S. Pat. No. 5,900,193.

CLAIM OF BENEFIT OF PROVISIONAL APPLICATION

Pursuant to 35 U.S.C. §119, the benefit of priority from provisional application 60/012,930, with a filing date of Mar. 6, 1996, is claimed for this non-provisional application.

ORIGIN OF THE INVENTION

This invention was jointly made by NASA employees and an employee of Carbon—Carbon Advanced Technology, Inc. under purchase order no. L-62270 and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefrom.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to lightweight piston design, and more specifically to improved structures for a carbon—carbon composite piston.

2. Description of the Related Art

Carbon—carbon composite materials, as used herein, refers to a predominantly carbon matrix material reinforced with predominantly carbon fibers. The properties of these materials may be tailored to produce any desired mechanical and physical properties by preferred orientation of the continuous or staple fibers in the composite materials; and/or by the selection of additives; and/or by thermal treatment of the fibers and matrix before, during, or after fabrication. Carbon—carbon composite materials may be cast, molded, or machined. The surface or near-surface material can also be treated and/or coated with oxidation protection or sealing material, or with a catalytic materials such as nickel.

Carbon—carbon composite materials have been developed for aerospace applications for which high-temperature strength, light weight, and dimensional stability are desirable. Current aerospace application of carbon—carbon composite materials includes use as heat-shield material on advanced aerospace vehicles. Non-aerospace applications have been suggested due to the mechanical and physical advantages of carbon—carbon composite materials. Current non-aerospace applications include use in brakes and clutches for high-performance automobiles and in brakes for aircraft.

Internal combustion reciprocating engines and compressors used for aerospace, military, and transportation applications must be lightweight and capable of operating at elevated temperatures and pressures. Current state-of-the-art piston manufacture employs aluminum alloys and steel because pistons composed of these materials can withstand the relatively high temperatures and pressures associated with operation of an internal combustion engine or compressor. However, engine and compressor pistons manufactured of steel and/or aluminum alloys are significantly heavier than pistons made of carbon—carbon composite materials. In addition, aluminum alloy and steel pistons lose strength at elevated temperatures, i.e. operating temperatures above 600 degrees Fahrenheit (F), while carbon—carbon composite pistons retain their strength under operating conditions which exceed 1200 degrees F.

The inherently high coefficient of thermal expansion of aluminum alloys also necessitates larger clearances between an aluminum alloy piston and an engine cylinder wall, to allow for expansion of the aluminum alloy piston during high temperature engine operation. In order to seal the gap between an aluminum alloy piston and engine cylinder wall, the piston must be fitted with a plurality of piston rings which seal the gap until the aluminum alloy piston has expanded sufficiently. However, at operating temperatures above 300 degrees F, the mechanical strength of aluminum alloy pistons decreases dramatically. This strength loss precludes locating the uppermost compression piston ring too close to the top, or crown, of the piston. Thus, a crevice between the piston crown and the uppermost compression ring is created. This crevice allows raw, unconsumed fuel to escape directly into the atmosphere, which contributes to atmospheric pollution and reduces fuel efficiency.

Another disadvantage associated with aluminum alloy pistons is the noise created as the undersized aluminum alloy pistons "rock" within the cylinder chamber.

SUMMARY OF THE INVENTION

It is an object of this invention to reduce the weight of an internal combustion reciprocating engine and/or compressor with the use of carbon—carbon composite pistons.

It is another object of the present invention to provide an engine and/or compressor piston with adequate mechanical strength during high engine operating temperatures.

Another object of the invention is to provide an engine and/or compressor piston with a low coefficient of thermal expansion, resulting in lower distortion and higher dimensional stability.

It is yet another object of the invention to provide an engine and/or compressor piston which can be ringless.

It is a further object of the invention to provide an engine and/or compressor piston which improves engine operating efficiency.

It is a further object of the invention to provide an engine and/or compressor piston which operates more quietly.

It is a further object of the invention to provide an engine piston which reduces the emission of hydrocarbons during operation by reducing the crevice volume.

According to the present invention, the foregoing and additional objects are attained by providing an improvement of a carbon—carbon composite piston, wherein the improvement consists of replacing the knitted fiber, three-dimensional piston preform architecture described in U.S. Pat. No. 4,909,133 (Taylor et al.) with a two-dimensional lay-up or molding of carbon fiber fabric or tape. Initially, the carbon fabric or tape layers are prepregged with carbonaceous organic resins and/or pitches and are laid up or molded about a mandrel, to form a carbon-fiber reinforced organic-matrix composite part shaped like a "U" channel, a "T"-bar, or a combination of the two. The molded carbon-fiber reinforced organic-matrix composite part is then pyrolized in an inert atmosphere, to convert the organic matrix materials to carbon. At this point, cylindrical piston blanks are cored from the "U"-channel, "T"-bar, or combination part. These blanks are then densified by reimpregnation with resins or pitches which are subsequently carbonized. Densification is also accomplished by direct infiltration.
with carbon by vapor deposition processes. Once the desired density has been achieved, the piston billets are machined to final piston dimensions; coated with oxidation sealants; and/or coated with a catalyst.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of a prior art knitted carbon fiber structure engine piston;
FIG. 2 is an illustration of a “U”-shaped channel billet for making a carbon—carbon composite piston according to the present invention;
FIG. 3 is an illustration of a “T”-shaped channel billet for making a carbon—carbon composite piston according to the present invention;
FIG. 4 is an illustration of a combination “U”- and “T”-shaped channel billet for making a larger carbon—carbon composite piston according to the present invention; and
FIG. 5 is an illustration of a dovetail notch detail for installing a bridge according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention is an improvement in the manufacture and structure of a lightweight carbon—carbon composite engine piston for use in internal combustion engines and/or compressors. U.S. Pat. No. 4,909,133 by Taylor et al. discloses the use of knitted or warp interlock preforms which are embedded in the composite matrix so as to comprise structural components of the completed piston. The lightweight piston architecture claimed by Taylor et al. is shown in Fig. 1 which depicts a carbon—carbon composite engine piston that includes a knitted or woven carbon fiber structure 12 which is selectively reinforced with directionally-oriented carbon fibers at the crown 13 and adjacent to the wrist pin boss 14.

The improvement claimed hereinafter comprehends fabricating carbon—carbon composite pistons from a billet composed of woven carbon-fiber fabrics or unidirectional carbon-fiber yarns, referred to hereinafter as “tapes.” Refer to Figs. 2 through 4, which depict carbon—carbon composite piston architectures cut from a “U”-shaped channel, a “T”-bar shaped channel, or a shape comprising a combination of these two forms, called a “Double T,” respectively. The claimed improved process begins by stacking plies, or “laminae,” 21, 31, 41 of woven, two-dimensional carbon-fiber fabric or unidirectional tape, which have been prepregged with carbonaceous resins. The laminae 21, 31, 41 are directionally-oriented to tailor both the structural and thermal properties of the cut piston blanks 22, 32, 42.

To fabricate a “U”-shaped channel billet 20, the laminae 21 were stacked over a male mandrel (not shown). To fabricate a “T”-bar shaped channel billet 30, the laminae 31 were stacked over two mold segments (not shown), to create two “L”-shaped plies 33, 34 which, when oriented back-to-back, formed the “T”-bar shaped channel billet 30. To fabricate a “Double T” channel billet 40, the laminae 41 were stacked over a male mandrel and two mold segments (not shown), in a manner such that the “U”-shaped channel plies 43 were sandwiched between each of the “L”-shaped plies 44, 45.

During the stacking process, the laminae 21, 31, 41 were debulked as necessary, to eliminate wrinkles in the laminae 21, 31, 41. Debunking was typically accomplished using a vacuum bag.
The invention can be practiced in other manners than are described herein without departing from the spirit and the scope of the appended claims.

What is claimed is:

1. An improved carbon—carbon composite piston for an internal combustion engine wherein the improvement comprises a piston manufactured from a carbon—carbon composite billet made from a carbon—carbon composite fiber lay-up structure of stacked, prepregged carbon fabric which has been placed over a plurality of male mandrels.

2. An improved carbon—carbon composite piston for an internal combustion engine as in claim 1, wherein the stacked, prepregged carbon fabric comprises woven carbon fiber laminae.

3. An improved carbon—carbon composite piston for an internal combustion engine as in claim 1, wherein the stacked, prepregged carbon fabric comprises unidirectional carbon fiber laminae.

4. An improved carbon—carbon composite piston for an internal combustion engine as in claim 1, wherein the plurality of male mandrels form a U-shaped laminated composite billet.

5. An improved carbon—carbon composite piston for an internal combustion engine as in claim 1, wherein the plurality of male mandrels form a T-shaped laminated composite billet.

6. An improved carbon—carbon composite piston for an internal combustion engine as in claim 1, wherein the plurality of male mandrels form a combination U- and T-shaped laminated composite billet.

7. An improved carbon—carbon composite piston for an internal combustion engine as in claim 1, wherein the method of manufacture further comprises coring a piston blank from a laminated carbon—carbon composite billet.

8. An improved carbon—carbon composite piston for an internal combustion engine as in claim 7, further comprising ring grooves which have been machined into the piston.

9. An improved carbon—carbon composite piston for an internal combustion engine as in claim 7, wherein the crown and skirt surfaces of the carbon—carbon composite piston are coated with a sealant.

10. An improved carbon—carbon composite piston for an internal combustion engine as in claim 9, wherein the sealant is a ceramic coating.

11. An improved carbon—carbon composite piston for an internal combustion engine as in claim 9, wherein the sealant is a metallic coating.

12. An improved carbon—carbon composite piston for an internal combustion engine as in claim 7, wherein the crown surface of the carbon—carbon composite piston is catalytically coated.

13. An improved carbon—carbon composite piston for an internal combustion engine as in claim 12, wherein the catalytic coating is nickel.

14. An improved carbon—carbon composite piston for an internal combustion engine as in claim 7, wherein the method of manufacture further comprises machining said piston blank to final dimensions to form a piston.

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