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PISTON SLEEVE

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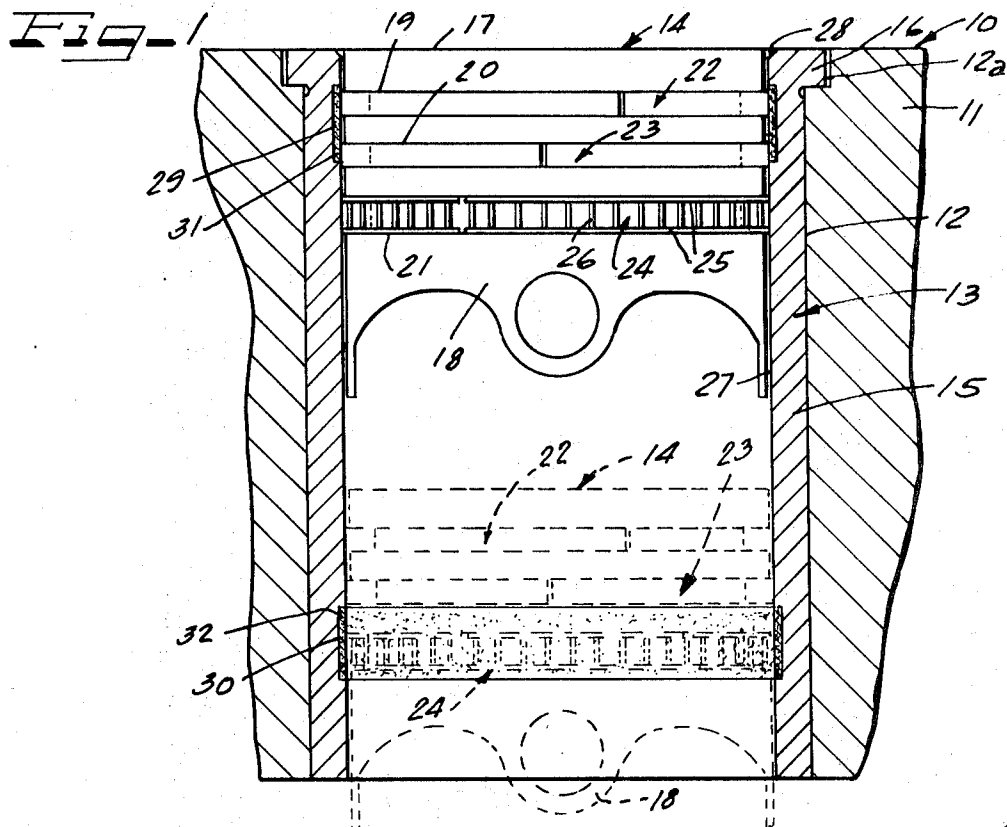
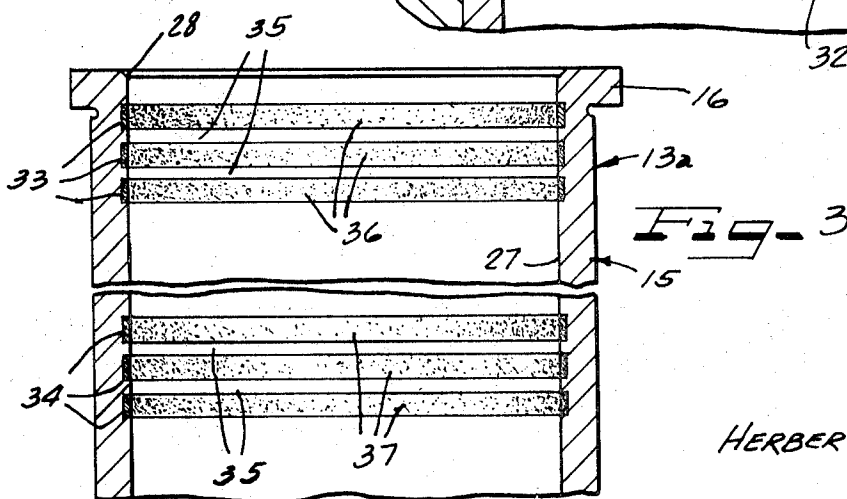
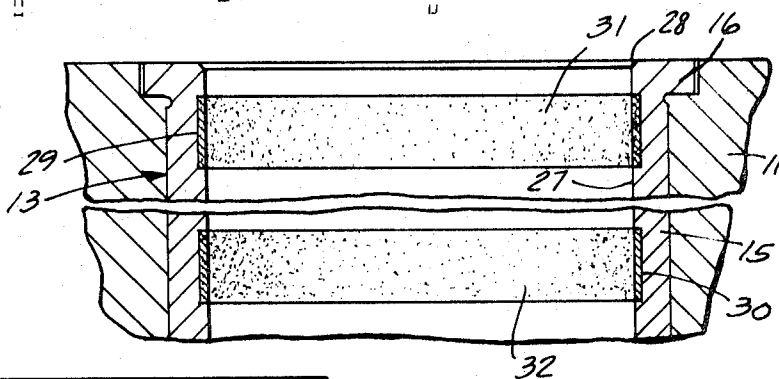


Fig. 2



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PISTON SLEEVE

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Continuation-in-part of application Ser. No. 696,647,
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U.S. Cl. 92—169

9 Claims

ABSTRACT OF THE DISCLOSURE

A piston cylinder, particularly an internal combustion engine cylinder liner sleeve, having a band of hard-facing metal such as molybdenum, refractory metal carbide alloys, preferably tungsten carbide, or the like, embedded in the inner surface of the sleeve to provide a corrosion and wear resisting bearing face around the piston rings at the top end of the piston stroke and, if desired, also at the bottom end of the piston stroke. The hard-facing metal band preferably surrounds the top ring of the piston at the top end of the piston stroke. If a hard-facing metal band is provided at the bottom of the piston stroke, it is located to surround the bottom oil ring of the piston at the bottom of the piston stroke. The band is applied by a plasma arc flame spray and has a total porosity level and pore size range able to retain lubricant without retaining grit of a size which would damage the sleeve or piston rings.

This application is a continuation-in-part of U.S. patent application No. 696,647, filed Jan. 9, 1968, and now abandoned.

BACKGROUND OF THE INVENTION

Field of the invention

This invention pertains to the art of tubes or cylinders defining the bore wall in which a piston operates, as for example in internal combustion engines, compressors, pumps and the like. Specifically, the invention relates to internal combustion engine cylinder liner sleeves, and while the invention will be hereinafter specifically described as embodied in such sleeves, it will be understood that the use of the tubes or cylinders of this invention is not limited to internal combustion engines.

Description of the prior art

Internal combustion engine cylinder liner sleeves are generally gray iron castings with carbon contents around 3 to 3½ percent, silicon contents around 1.8 to 2.20 percent, manganese contents around .60 to 1.00 percent, with maximum sulphur contents of about 0.15 and maximum phosphorus contents of about 0.15. Typical gray iron compositions for engine cylinder liner sleeves are S.A.E. numbers G 3,500 and G 4,500 of the following analyses:

S.A.E. No.	Total carbon	Silicon	Manganese	Sulphur max.	Phosphorus max.
G 3,500.....	3.10-3.40	1.90-2.20	.60-.90	.15	.15
G 4,500.....	3.00-3.30	1.80-2.10	.70-1.00	.15	.10

These liner sleeves encounter the most wear at the ends of the stroke of the piston especially at the level where the piston is at its top dead center. At the ends of the piston stroke, the direction of travel of the piston is reversed, causing the piston to rock and impart the most severe side load on the cylinder wall. To resist this wear it has been proposed to plate the bore defining wall of the sleeve with hard wear resisting metals such as chromium and to use metal alloys having greater wear resisting capacity than the conventionally used gray iron castings.

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However such liner sleeves are very expensive and very difficult to hone.

The prior art has also attempted to overcome the problem of sleeve wear, which it has observed as occurring to the greatest extent adjacent the point of turn-around of the top piston ring, by proposing the use of metal-filled grooves throughout the length of the cylinder liner. Patents teaching the use of such grooves, such as the U.S. patents to Sanders, Nos. 2,108,392 and 2,292,662, propose filling the grooves with metal inserts which are either welded in place or which are filled by welding-spraying or by electrical deposition. Such attempted solutions, and those which attempted to solve the problem by the provision of a lined sleeve, have failed to consider both the difficulties of honing and the importance of porosity. The majority of metals suggested by the prior art, and the methods of applying such metals, are of a nature which fail to produce the desired porosity levels and bond characteristics.

SUMMARY OF THE INVENTION

The present invention now provides an inexpensive piston cylinder which has embedded in the cylinder wall defining the bore for the piston a hard facing metal at localized areas subjected to the most severe wear in the operation of the piston. This hard facing metal is applied by flame or plasma jet spray technique into grooves in the inner wall of the cylinder which are located at the areas subjected to most wear. Since the most severe wear occurs adjacent the head of the piston at the top of the piston stroke the hard facing metal is positioned to surround the piston rings at this area. Since the area of the cylinder surrounding the piston rings at the bottom of the stroke of the piston is also subject to severe wear, the hard facing metal may also be localized to surround the piston rings at this area.

In internal combustion engines the pistons are equipped with compression-type piston rings and oil control rings. It has been found that the most severe wear of the piston cylinder in such applications occurs around the top compression ring of the piston at the top of the piston stroke while the next most severe wear occurs around the bottom oil control ring at the bottom of the piston stroke. In this embodiment therefore the hard facing metal may be localized in one or more groups surrounding the top compression ring at the top of the piston stroke and the bottom oil control ring at the bottom of the piston stroke.

Because the hard facing metal is localized only where needed, the remainder of the cylinder wall can be formed of readily honed material such as the conventional gray iron casting.

In the preferred arrangement, the band or inlay of hard facing metal need only be about one-half inch in length or can be broken up into two or three bands spaced apart by small land areas of the cylinder metal. The top of the band is below the top of the piston head at the top of the piston stroke and is generally positioned to surround the top fire ring as it approaches the top of the stroke and then extends slightly beyond the fire ring at the very top of the stroke. The bottom inlay band or bands is positioned in the same relation to the bottom oil ring groove of the piston at the bottom of the piston stroke.

The inlay metal need not be of any appreciable depth since it is very hard and does not exhibit wear after severe and prolonged usage.

The metal used is a hard-facing metal alloy of either tungsten carbide or molybdenum, which I have found in tests to provide superior results. The alloys exhibit desired wear qualities and have both a porosity level and porosity open pore size sufficient to retain oil for lubrication without retaining grit particles of a size and quantity which would be detrimental to the wear charac-

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teristics of the engine. In order to obtain the desired alloy-liner bond and to obtain the desired porosity level and pore size, the alloys must be applied by a plasma arc flame spray.

It is then an object of this invention to provide piston cylinders with hard facing inlays at the areas of excessive wear.

A further object of this invention is to provide engine liner sleeves with bands of hard facing metal embedded in and bonded to the inner wall of the sleeve at the ends of the piston stroke.

A further object of this invention is to provide an engine liner sleeve having a band of hard facing metal such as stainless steel, tungsten carbide alloy, molybdenum and the like embedded therein to surround the top compression ring of the piston at the top of the piston stroke.

A still further object of this invention is to provide a cast iron cylinder liner sleeve with one or more bands of hard facing material embedded therein to surround the top compression ring of the piston at the top of the stroke and to surround the bottom oil control ring of the piston at the bottom of the stroke.

It is a still further and more specific object of this invention to provide a cast iron cylinder liner sleeve having one or more bands of hard-facing porous material embedded therein to surround one or more of the compression rings of the piston at the top of the stroke wherein the material is either a molybdeum alloy or a tungsten carbide alloy and is plasma arc flame spray applied.

It is a general object of this invention to provide a cylinder liner sleeve having embedded bands of hard-facing material therein which have a porosity level and pore size sufficient to retain lubricant without retaining harmful grit particles.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the invention will be readily apparent from the following description of certain preferred embodiments thereof, taken in conjunction with the accompanying drawings, although variations and modifications may be effected without departing from the spirit and scope of the novel concepts of the disclosure, and in which:

FIG. 1 is a somewhat diagrammatic elevational view, with parts in vertical cross section of a portion of an internal combustion engine having a liner sleeve of this invention and showing the positions of the piston in the sleeve at the ends of the piston stroke.

FIG. 2 is a broken fragmentary cross-sectional view of the liner sleeve of FIG. 1.

FIG. 3 is a view similar to FIG. 2 but illustrating a modified liner sleeve according to this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 the reference numeral 10 designates generally a portion of an internal combustion engine having a block 11 with a bore 12 lined by a liner sleeve 13 of this invention. A piston 14 is slidably mounted in the liner 13 and moves from a top position shown in solid lines to a bottom position shown in dotted lines.

The liner sleeve 13 is a cast iron tube 15 with an out-turned flange 16 at the top end thereof. The tube 15 is pressed into the bore 12 of the engine block 11 and the flange 16 is seated in a counterbore 12A of the top of the engine block.

The piston 14, as indicated, has a head 17, a dependent skirt 18 and three ring grooves 19, 20 and 21 around the head. The top ring groove receives a split compression or fire piston ring 22. The middle groove 20 receives a split second compression or sealing piston ring 23. The bottom groove 21 receives an oil control ring assembly 24. The assembly 24 includes thin metal

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split top and bottom rail rings 25 supported on and expanded by a circumferential expanding spacer ring 26 as is conventional in the art.

The outer faces of the rings 22, 23 and 25 ride on and seal against the inner cylindrical wall 27 of the tubular portion 15 of the liner sleeve 13.

At the top of its stroke the piston head 17 is about flush with the top of the flanged end 16 of the liner sleeve. At the bottom of its stroke as shown in dotted lines the bottom of the skirt 18 is generally within the confines of the tubular portion 15 of the liner in bearing engagement therewith.

The cylindrical wall 27 of the liner is bevelled at 28 at the top end thereof and the piston head rides past the bevel at the end of its stroke to be exposed at the bevelled gap.

In accordance with this invention the inner wall 27 of the tubular portion 15 of the liner sleeve 13 is peripherally grooved at 29 near the top of the liner and at 30 inwardly from the bottom of the liner. The grooves are positioned to surround the top compression ring 22 at the top of the piston stroke and the bottom oil control ring assembly 24 at the bottom of the piston stroke and to extend slightly beyond the tops and bottoms of these rings in these positions. The grooves 29 and 30 may be relatively shallow and range from about .002 to .010 inch in depth. The axial extent of the grooves is about one-half inch.

The grooves 29 and 30 are filled with flame spray applied or plasma jet applied hard facing metals including stainless steel, molybdenum, and tungsten carbide alloys to form bands 31 and 32 bonded to the liner body 15. The bands 31 and 32 are honed flush with the cylinder wall 27. Since the cylinder wall except at the band areas is composed of the conventional liner materials such as gray cast iron and since the band areas 29 and 30 are only a relatively small portion of the total area of the cylinder wall 27 the honing operation is not unduly stressed by the hard facing metals.

There are three types of flame spray techniques presently utilized. These are basically: the oxy-fuel spray process; the detonation process; and the plasma arc process. The same metal or alloy applied by the differing processes will have different characteristics. Further, different metals applied by the same process exhibit different characteristics. In order to obtain a desired band, I have found that the preferred alloys must be applied by the plasma arc flame spray process. This process provides a band which has a desired porosity level with advantageous pore size characteristics while having a good bond with the cylinder liner metal.

The flame spray applied or plasma jet applied hard facing materials are supplied to the spray guns in wire or powdered form including conventional stainless steel formulations for flame spray application, molybdenum, and refractory metal carbide alloys including tungsten carbide, binders such as chromium, nickel and boron, and a matrix material such as nickel alumide. A suitable tungsten carbide alloy has the following formulation:

	Percent by weight
Tungsten carbide	25 to 55
Cobalt	4 to 8
Nickel	25 to 45
Chromium	3 to 7
Aluminum	1 to 7
Boron	.5 to 3
Substantially all iron	Balance

The tungsten carbide may be replaced fully or in part with other refractory metal carbides such as the carbides of titanium, tantalum, columbium, molybdenum, vanadium, chromium, zirconium, hafnium, boron, and silicon.

Due to the extremely high refractory nature of the refractory metal carbide alloy, it is applied by a plasma jet flame.

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A second preferred alloy has as its base material molybdenum and has the following formulation:

	Percent by weight
Molybdenum -----	65 to 90
Nickel -----	7 to 25
Chromium -----	1 to 6
Boron -----	.3 to 1.5
Silicon -----	.2 to 1.5
Iron with small amounts of carbon and cobalt -----	Balance

A specifically preferred mixture has the following composition:

	Percent by weight
Molybdenum -----	75
Nickel -----	17.5
Chromium -----	4.12
Boron -----	0.94
Silicon -----	1
Iron with small amounts of carbon and cobalt -----	Balance

These alloys, when plasma arc flame spray applied, will provide bands having the desired characteristics. The alloys are sprayed into the axially narrow bands and thereafter honed flush with the cylinder wall rather than being sprayed into axially wide bands because their hardness and tensile strength creates adverse stress effects in honing when applied in axially wide bands. Such axially wide bands, as have been exhibited in the prior art, exhibit stress deformations as a result of honing when formed with the above alloys applied by the plasma arc flame spray technique. Further, the stress on the bands caused during the honing can break the bond between the hard facing metal of the band and the walls of the groove in the cylinder liner. For these reasons, the bands are preferably axially narrow, having an axial dimension of less than one-half inch.

One of the major difficulties encountered with the prior art was lubrication between the coating and the piston rings. In the absence of retained lubrication, start-up resistance and frictional wear is excessive. This is a deficiency encountered in smooth surfaced materials such as chromium or in detonation flame spray applied materials which have been found to have extremely low surface porosity.

Oxy-fuel flame spray applied coatings as well as plasma arc flame spray applied coatings may have sufficient total porosity levels to retain lubricant but exhibit different porosity size characteristics. For example, in one test, comparing oxy-acetylene applied molybdenum with plasma-applied molybdenum, it was found that the oxy-acetylene applied molybdenum had an overall porosity percentage of approximately 21 as measured by a mercury intrusion porosimeter. However, that sample had a 13% porosity with the pores having a size of .01 to .1 microns; a 6% porosity with a pore size measuring from .1 to 2.0 microns; and a 2% porosity with a pore size measuring from 2 to 10 microns. Alternatively, the plasma arc flame spray applied molybdenum had a total porosity of 18% with a 16% porosity of pore sizes between .01 and .1 micron in size; approximately a 2% porosity with pore sizes between .1 and 2.0 microns; and a less than .10% porosity with pore sizes between 2 and 10 microns. It can therefore be seen that considering porosity, the same material applied by different flame spray techniques will have different characteristics.

In a cylinder liner coating, porosity is necessary to retain lubricant. In spite of this, too large a porosity percentage will provide a coating which has a deteriorating face. That is, a coating which has a large porosity percentage may be wear-deficient. Another factor to be considered is the pore size. If the pore sizes are too small,

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as for example .01 to .1 micron in size, they may be unable to retain a sufficient amount of lubricant. On the other hand, if the pores are large, as for example 2 to 10 microns in size, they will be able to retain abrasive grit. It is therefore desirable to obtain a coating which has a sufficient porosity level to retain the desired amount of lubricant with the majority of the pores having a size of approximately from .1 to 2 microns in size.

In the above-mentioned test, specific compositions of the two preferred alloys were checked for porosity. It was found that the tungsten carbide alloy had approximately 13% total porosity with a 2% total porosity with pores having a size from .01 to .1 micron; 9.5% porosity with pores having a size from .1 to 2.0 microns, and 1.5% porosity with pores having a size from 2 to 10 microns. The molybdenum based alloy had a total porosity of approximately 15% with a total porosity of 3% having pore sizes of from .01 to .1 micron; total porosity of approximately 9.9% having pores of approximately .1 to 2.0 microns in size and a total porosity of 2.1% having pore sizes from 2 to 10 microns.

It can therefore be seen that the two preferred alloys set out hereinbefore have both advantageous porosity levels and pore size distributions. Further, these hard facing metals have desired characteristics with respect to hardness, tensile strength and bond shear strength and when applied in accordance with the teachings of this invention, provide superior results as cylinder liner wear band materials.

The hard-facing inlays or inlay bands 31 and 32 may be alloys formed in situ in the grooves and the facing metal is bonded to the tube metal along an interface which may include a bonding material different than the hard-facing metal. The resulting alloy may be somewhat porous to retain oil. As shown, the inlay bands 31 and 32 are positioned to extend on both sides of the top fire ring 22 at the top of the piston stroke and on both sides of the bottom oil ring groove 24 at the bottom of the piston stroke.

Instead of single inlay bands 31 and 32 the engine cylinder may be provided with a plurality of narrower bands to extend along the same areas as the wider bands. Thus as shown in FIG. 3, the modified engine liner sleeve 13A has portions identical with the sleeve 13 marked with the same reference numerals but instead of the single groove 29 at the top of the liner and the single groove 30 near the bottom of the liner, three grooves 33 are provided at the top of the liner and three similar grooves 34 are provided at the bottom of the liner with each groove being separated by an ungrooved land 35 composed of the cylinder wall 27. The grooves 33 are filled with the hard-facing metal to form the bands 36 while the grooves 34 are filled with the same or different hard-facing metal to form the bands 37. The bands 37 will generally have the same thickness as the bands 31 and 32, but their axial height will be in the nature of $\frac{1}{16}$ to $\frac{1}{4}$ inch with the lands 35 being of similar height or less. In a preferred arrangement, the bottom band 36 and the top band 37 may be a bit wider than the other two bands since these areas first receive the respective compression and oil controlled rings and the dwell thereon is greater than on the other bands.

Engine cylinder liners equipped with the inlay bands of this invention will far outlast conventional engine liners and will reduce scuffing of the piston rings because of their high temperature resistance at the critical areas in the top of the liner.

Although I have herein set forth my invention with respect to certain specific principles and details thereof, it will be understood that these may be varied without departing from the spirit and scope of the invention as set forth in the hereunto appended claims.

I claim as my invention:

1. A piston cylinder sleeve for use in combination with a reciprocable piston received therein, the piston having

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a plurality of axially spaced piston rings in sliding engagement with the inner surface of said sleeve, the sleeve comprising: a metal cylinder having a plurality of axially spaced annular grooves in the inner surface thereof, said grooves filled with a hard facing metal embedded therein providing a plurality of axially spaced annular hard facing metal bands, said bands having inner surfaces flush with the inner surface of said cylinder, said bands positioned in said cylinder and dimensioned to surround at least some of said rings when said piston is at the top of its stroke, and additional hard-facing metal bands provided in axially spaced grooves in said sleeve, said additional bands positioned and dimensioned to surround at least some of said rings when the piston is at the bottom of its stroke.

2. An internal combustion engine cylinder liner sleeve for use in connection with a piston having a stroke terminating adjacent one end of the sleeve and carrying a plurality of axially spaced annular piston rings riding on the inner surface of the sleeve during said stroke including a top fire ring adjacent the head of the piston, said sleeve comprising a gray cast iron tube with a carbon content between 3 to 3½ percent, a silicon content between 1.8 to 2.2 percent, and a manganese content between .6 to 1 percent, said sleeve having an annular grooved zone around the inner periphery thereof adjacent and axially spaced from the end of the sleeve receiving the piston at the top of its stroke, said zone having a top extremity below the top of the piston at the top of its stroke and extending inwardly of the tube from the said top extremity to surround the top fire ring of the piston as it approaches the top of the stroke and to extend beyond the fire ring at the very top of the stroke, a porous oil retaining plasma arc spray-applied hard facing metal consisting of a refractory metal alloy including from 25 to 55 percent tungsten carbide, from 4 to 8 percent cobalt, from 25 to 45 percent nickel, from 3 to 7 percent chromium, from 1 to 7 percent aluminum, from .5 to 3 percent boron and the balance substantially all iron, filling said grooved zone and bonded to said iron tube terminating flush with the inner peripheral surface of the tube and having a radial depth of .002 to .010 inch, and said spray applied alloy having a total porosity of at least 13% with at least 15% of the pores having a size between .1 to 2.0 microns.

3. An internal combustion engine cylinder liner sleeve for use in combination with a piston having a plurality of axially spaced annular piston rings riding on the inner surface of the sleeve in reciprocating sliding engagement therewith, said sleeve comprising a gray cast iron tube, at least one axially narrow annular groove around the inner periphery of said tube adjacent and axially spaced from one end thereof a porous plasma arc flame spray applied refractory metal alloy band filling said groove and bonded to the said tube, said groove being positioned at a level in the sleeve and dimensioned to surround the top piston ring operating in the sleeve at the top of the stroke of the piston, said band having a total porosity of at least 13% with at least 51% of the pores having a size between .1 and 2.0 microns, and said groove having an axial length of less than .5 inch.

4. A piston cylinder liner sleeve for use in combination with a reciprocable piston received therein, the piston having a plurality of axially spaced piston rings in sliding engaging with the inner surface of said sleeve, the sleeve comprising a metal cylinder having a plurality of axially spaced annular grooves in the inner surface thereof adjacent and axially spaced from one end thereof, said grooves filled with a porous plasma arc flame spray applied hard facing metal embedded therein, providing a plurality of axially spaced annular hard-facing metal bands, said bands having inner surfaces flush with the inner surface of said cylinder, said bands positioned in said cylinder and dimensioned to surround at least some of said rings when the piston is at the top of its stroke, said bands having a least 13% total porosity with a majority of the pores having a

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size between .1 to 2.0 microns, and each of said bands having an axial dimension from ¼ to ¾ inch separated by lands of said sleeve, the bottom-most of said bands surrounding a portion of said piston when the piston is at the top of its stroke.

5. The sleeve of claim 4 wherein at least three of said bands are provided and the bands comprise a refractory metal alloy including from 25 to 55 percent-by-weight tungsten carbide, from 4 to 8 percent-by-weight cobalt, from 25 to 45 percent-by-weight nickel, from 3 to 7 percent-by-weight chromium, from 1 to 7 percent-by-weight aluminum, and from .5 to 3 percent-by-weight boron, the remaining being substantially all iron.

6. An internal combustion engine cylinder liner sleeve for use in connection with a piston having a stroke terminating adjacent one end of the sleeve and carrying a plurality of axially spaced annular piston rings riding on the inner surface of the sleeve during said stroke including a top fire ring adjacent the head of the piston, said sleeve comprising a grey iron tube having an annular grooved zone around the inner periphery thereof adjacent and axially spaced from the end of the sleeve receiving the piston at the top of its stroke, said zone having a top extremity below the top of the piston at the top of its stroke and extending inwardly of the tube from the said top extremity to surround the top fire ring of the piston as it approaches the top of the stroke and to extend beyond the fire ring at the very top of the stroke, a porous oil retaining plasma arc spray-applied hard facing metal consisting of a refractory metal alloy including from 65 to 90 percent-by-weight molybdenum, 7 to 25 percent-by-weight nickel, 1 to 6 percent-by-weight chromium, .3 to 1.5 percent-by-weight boron, .2 to 1.5 percent-by-weight silicon, and the balance iron with small amounts of carbon and cobalt, filling said groove zone and bonded to said iron tube terminating flush with the inner peripheral surface of the tube and having a radial depth of .002 to .010 inches, said alloy being porous with at least 15 percent total porosity and the majority of the pores having a size between .1 and 2.0 microns.

7. The sleeve of claim 4 wherein at least three of said bands are provided and the bands comprise a refractory metal alloy including from 65 to 90 percent-by-weight molybdenum, 7 to 25 percent-by-weight nickel, 1 to 6 percent-by-weight chromium, .3 to 1.5 percent-by-weight boron, .2 to 1.5 percent-by-weight silicon, and the balance iron with small amounts of carbon and cobalt.

8. The sleeve of claim 4 wherein at least three of said bands are provided and the bands comprise a refractory metal alloy including 75 percent-by-weight molybdenum, 17.5 percent-by-weight nickel, 4.12 percent-by-weight chromium, 0.94 percent-by-weight boron, 1 percent-by-weight silicon, and the balance iron with small amounts of carbon and cobalt.

9. An internal combustion engine liner sleeve for use in connection with a piston having a stroke terminating adjacent one end of the sleeve and carrying a plurality of axially spaced piston rings riding on the inner surface of the sleeve during said stroke, said sleeve comprising a cast iron tube having an annular grooved zone around the inner periphery thereof adjacent and axially spaced from the end of the sleeve receiving the piston at the top of its stroke, said zone having a plurality of circumferential ring-shaped grooves therein, said grooves filled with a porous plasma arc flame spray applied refractory metal alloy bonded to said tube, said metal alloy having an inner diameter periphery level with the inner diameter periphery of the tube, said grooves axially spaced apart providing circumferential rings of cast-iron tube material alternating with the refractory metal filled grooves for the extent of the zone, and said alloy having a total porosity of at least 13% with at least the majority of the pores having a size between .1 and 2.0 microns.

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