

5 TITLE: CLOSED CAVITY PISTON FOR HYDROSTATIC POWER
UNITS AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

This invention relates to a closed cavity piston for a
10 hydrostatic power unit. More specifically and without
limitation, this invention relates to a new method of
manufacturing a closed cavity piston by using metal
injection molding techniques to form the body of the closed
cavity piston and then sinterbonding an end cap on the
15 piston body.

A closed cavity piston is a piston that includes one or
more sealed hollow compartments within the piston. The
reduced piston weight provided by the hollow compartments
allow for greater hydrostatic shaft speeds, whereas the
20 closed piston end reduces the amount of compressed oil
volume in the hydrostatic unit and improves volumetric
efficiency and control of swash plate moments. The piston
includes a central tube for lubrication and an internal
sphere that contacts an external sphere of a mating slipper.
25 The piston also has either a deformable region near the
piston sphere for joining the piston onto the slipper, or a
deformable region near the slipper sphere for retaining the
slipper to the piston depending on whether the piston is
male or female.

30 There are several methods for manufacturing closed
cavity pistons for hydrostatic units, but these methods have
several cost and technical disadvantages. One method
consists of positioning a hollow tube within a hollow piston
body and attaching the tube to the piston body with one or
35 more washers that extend radially between the outer wall of
the tube and the inner wall of the piston body. The steps
of this method include machining bar stock to create a one-

5 piece hollow piston with integral stem, and then securing
the stem with a washer. Next, a welder inertia welds a
round slug onto the end of the piston. Finally one drills a
hole through the stem over the length of the piston. This
manufacturing method is very expensive and not practical for
10 pistons with small diameters.

Another method is described in U.S. Patent No.
6,314,864 and it consists of joining a piston cap to a
piston body by welding or brazing. Compared to the method
previously described, this method is less expensive and can
15 be applied to small diameter pistons. Still, the
manufacturing equipment required to join the cap and body is
relatively expensive and the joining process requires an
additional manufacturing step subsequent to the metal
injection molding process. Furthermore, the joining method
20 introduces additional radial alignment between the piston
socket center and the piston body center that could
interfere with methods used to join the piston onto the
mating slipper.

Because of recent improvements in metal injection
25 molding techniques, making hydraulic components with these
techniques has become feasible. The basic process of metal
injection molding is that a desired shape may be created by
carving the shape into two blocks of mold. This forms the
outer surface of the product that is to be produced.
30 Metallic mold inserts that may be repeatedly used form the
interior of the product. Metal powder and non-metallic
binding material are then injected into the mold and heated
to form the shape dictated by the mold and the insert.
After removing the product from the mold, debinding of the
35 product occurs. The debinding process separates the
metallic particles from the non-metal particles. After

5 debinding, the product is sintered. Sintering is a process
by which the metallic powder may be formed into a coherent
mass without melting the material. The same sintering
process may be used to join together two or more components
in contact with each other. This joining method, or
10 "sinterbonding" process, is superior to conventional methods
for combining metal injection molded components because
other methods result in poor bond strength. The present
invention uses metal injection molded components that are
sinterbonded to produce a new closed cavity piston.

15 Thus, it is a primary object of the present invention
to provide a new closed cavity piston that improves upon the
state of the art.

Another object of the present invention is to minimize
the amount of hydraulic fluid that flows through a closed
20 cavity piston body.

Yet another object of the present invention is to
optimize surface geometries between the closed cavity body
and end cap to aid sinterbonding the two together.

Another object of the present invention is to provide a
25 magnetic end cap that can capture magnetic particles present
in a hydrostatic unit.

Yet another object of the present invention is to use a
metal injection molding process and sintering to improve
upon the state of the art.

30 Another object of the present invention is to provide a
method of manufacturing a closed cavity piston that is
inexpensive.

Yet another object of the present invention is to
provide a method of manufacturing a closed cavity piston
35 that can be made with great speed and efficiency.

5 Another object of the present invention is to provide a method of manufacturing a closed cavity piston using metal injecting molding to form all of the components.

 Yet another object of the present invention is to provide a method for sinterbonding metal injected molding
10 objects together to form a closed cavity piston.

 Another object of the present invention is to provide a method for manufacturing a closed-cavity female piston that minimizes radial misalignment between the piston socket center and the center of the main piston body.

15 Yet another object of the present invention is to provide a joining technique that requires, at most, modification of the processes already employed in the metal injection molding process.

 These and other objects, features, or advantages of the
20 present invention will become apparent from the specification and claims.

BRIEF SUMMARY OF THE INVENTION

 The present invention is a closed cavity piston design
25 that can be manufactured inexpensively. The new design consists of a piston body and an end cap. Both components are manufactured using metal injection molding techniques. The piston body includes a central hollow stem and spherical socket that are integral to the rest of the piston body.
30 The end cap is joined to the piston body using a sinterbonding process that metallurgically bonds the piston body and end cap contacting surfaces.

 The sinterbonding process may take place during the normal sintering operation used in the processing of the
35 metal injection molding components, requiring little, if any, additional processing time. Special fixturing and

5 loading may be required during the debinding and/or sintering process to bring the cap and body into contact and to ensure a complete bonding between the end cap and the body.

10 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of the closed cavity piston and end cap.

Fig. 2 is a sectional view of a closed cavity piston and slipper taken along line 2 in figure 1.

15 Fig. 3 is a perspective view of a metal injection molding mold.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates to a closed cavity piston
20 10 for reciprocation in the rotating cylinder block of a hydrostatic unit, such as a pump or a motor. Fig. 1 shows a closed cavity piston 10 having an end cap 12. Closed cavity piston 10 has an elongated body 14 that receives end cap 12 at open end 15. The piston body 14 may include tapered
25 surface 16 at the open end 15, an end with a spherical cavity 18, and a hollow stem 20. The tapered surface 16 is used to align the end cap 12 and the body 14 together and to maximize the contact area between the two parts during the sinterbonding process, resulting in a more robust joint.
30 The tapered surface 16 and tapered lip portion 22 of end cap 12 may differ slightly to ensure that complete contact is made as the two components are integrated. The tapered lip 22 and tapered surface 16 may be integrated either by mechanical means external to the parts, or through the
35 formation of the parts during the sintering process. End cap 12 also has an opening 23 that aligns with hollow stem

5 20 forming a lubrication path through the piston. Opening
23 and stem 20 have corresponding tapered mating surfaces.

The end cap 12 may consist of a magnetic material to
capture contaminants within the hydrostatic unit. The
magnetic properties of the end cap 12 may also be used for
10 other purposes, i.e., sensing the position and motion of the
piston. Use of a magnetic end cap requires a reduction in
the end cap 12 diameter to ensure that contaminants do not
come between the piston outside diameter and the block bore.

It should also be appreciated that in an alternative
15 embodiment the end cap 12 can have a non-tapered lip that
optimizes the geometries between the end cap 12 and the body
14 to create a matingly fit to enhance the sinterbonding
process.

Fig. 2 shows a cross section of a closed cavity piston
20 10 that can be manufactured using metal injection molding
and sinterbonding an end cap 12 to the body 14. The piston
10 has a slipper 26 pivotably attached to the piston. The
slipper 26 can include a portion of a spherical ball that
engages a ball socket recess in the piston body 14, or one
25 skilled in the art will appreciate that the slipper 26 could
be equipped with a ball socket recess and the mating surface
would be formed as a portion of a spherical ball in the
piston. Fig. 2 shows a piston that has a ball socket recess
28 that mates with a ball socket 30 that is on the slipper
30 26. Slipper 26 also has a fluid passageway 32 that fluidly
connects with hollow stem 20.

The hollow stem 20 extends longitudinally throughout
the entire body 14. Closed cavity piston 10 also has one or
more hollow compartments 34 within its body 14.

35 Fig. 3 shows a typical metal injection mold 60. The
mold 60 shapes the outer surface of the piston body 14 while

5 an insert core (not shown) is used to shape the interior of the piston body 14. The end cap 12 is created in a similar mold 60 that shapes the end cap 12.

In the manufacturing process the body 14 and the end cap 12 of the closed cavity piston 10 are separately
10 manufactured using a metal injection molding process. Next the body 14 is sintered to form the proper metallic bonding. During this process an end cap 12 is sinterbonded to the open end 15 of the piston body 14. Therefore, the only fluid outlet the piston 10 has is through the opening 23,
15 insuring the rest of the piston 10 is plugged. It should also be appreciated that because of the use of metal injection molding techniques little if any machining of the sintered piston assembly is required. The metal injection molding and sinterbonding processes allow for a more
20 efficient and cost effective process for creating a closed cavity piston. Thus all of the objects of the present invention have been accomplished.

It will be appreciated by those skilled in the art that other various modifications could be made to the device
25 without departing from the spirit and scope of this invention. All such modifications and changes fall within the scope of the claims are intended to be covered thereby.

5 What is claimed is:

1. A closed cavity piston comprising:

an elongated cylindrical body having a first end adapted to receive a slipper, a second end, and at least one longitudinally elongated hollow compartment;

10 a bore longitudinally disposed through the elongated cylindrical body;

an end cap secured to the second end of the elongated cylindrical body and having a central opening that aligns with the bore.

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2. The closed cavity piston of claim 1 wherein the elongated cylindrical body is created using a metal injection molding process.

20 3. The closed cavity piston of claim 1 wherein the end cap is secured to the elongated cylindrical body by sinterbonding the end cap to the body.

4. The closed cavity piston of claim 1 wherein the opening
25 of the end cap is circular.

5. The closed cavity piston of claim 6 wherein the perimeter of the circular opening corresponds to the perimeter of the bore.

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6. The closed cavity piston of claim 1 wherein the end cap is a washer.

7. The closed cavity piston of claim 1 wherein the closed
35 cavity piston is a male piston.

5 8. The closed cavity piston of claim 1 wherein the closed cavity piston is a female piston.

9. The closed cavity piston of claim 1 wherein the end cap is made of magnetic material.

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10. A method of manufacturing a closed cavity piston steps comprising:

metal injection molding an elongated cylindrical body having a first end adapted to receive a slipper, a second end,
15 and at least one longitudinally elongated hollow compartment;

metal injection molding an end cap having a central opening; sinterbonding the end cap to the elongated cylindrical body.

20 11. The method of claim 10 wherein the end cap has a tapered surface that matingly engages the second end of the elongated cylindrical body to aid in the sinterbonding of the end cap to the elongated cylindrical body.

25 12. The method of claim 10 wherein the end cap has a lip that matingly engages the second end of the elongated cylindrical body to aid in the sinterbonding of the end cap to the elongated cylindrical body.