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(54) **Squeeze casting of pistons.**

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Description

The invention relates to the squeeze casting of aluminium alloy pistons of the kind including inserts which are spaced axially from the crown of the piston, such as inserts for forming reinforced piston ring grooves.

The squeeze casting of metals is a process which has been known for many years. It is a process in which molten metal is fed to a die, then the die is closed and pressure applied to the molten metal as it solidifies. The pressurising force may be as much as several hundred tons. Such a solidification is capable of producing a casting which is stronger than similar castings produced by conventional gravity die casting and whose structure is particularly homogeneous.

In view of these advantages, squeeze casting has long been considered for the production of pistons of aluminium or aluminium alloy for internal combustion engines or compressors since it offers the possibility of producing pistons of superior strength to gravity die cast pistons; strength which has only previously been achievable by the use of the more expensive and complicated forging processes, which have thus only found application for the production of special purpose pistons such as pistons for racing cars.

Although the proposal to squeeze cast such pistons has been in existence for many years, it has not achieved any wide commercial use because of various production difficulties which have been encountered.

Among these difficulties are the incorporation into squeeze cast pistons of inserts which are spaced axially from the crown of the piston, such as piston ring groove reinforcement inserts. Such inserts are, in general, annular in shape and are made of a material more resistant to wear than the aluminium or aluminium alloy of the piston. The insert extends around the piston at a location between the top of the skirt and the crown and, in a finished piston, has one or more piston ring grooves formed in the insert.

U.K. Patent Specifications Nos. 2 090 779A and 2 090 780A both relate to the incorporation of such inserts. In these specifications the pistons are squeeze cast crown-up (that is to say with the crown towards the upper end of a lower die member), and the insert has tabs which engage a projection within the lower die member before the molten metal is poured into the lower die member. The lower part of this die member is shaped to form the skirt of the piston.

After the molten metal is poured into the lower die member, an upper die member closes the die and applies pressure to the molten metal while it is solidifying.

U.K. Patent Specification No. 2 072 065A also relates to the incorporation of such inserts. Once again the piston is squeeze cast crown-up with the insert placed on several projections formed integrally with the lower die member. The molten metal is poured into the lower die member and the upper die member closes the die and applies pressure to the molten metal while it is solidifying.

The squeeze casting processes described in these specifications has a number of disadvantages.

A first is that the molten metal will in general solidify from the bottom of the die upwards and there can be variations in the rate of solidification across the cross-sectional area of the piston. This may mean that, since the insert is towards the top of the casting, where the variations will be greatest, part of the insert will be in solidified metal while other parts will be in molten metal and this can cause stress in the insert which may lead to warping, distortion and cracking. This is exacerbated in crown-up casting by a significant depth of molten metal below the insert which, during solidification, contracts away from the insert which is firmly supported by the projections of the lower die member.

With the lower die member projections only supporting the insert over a small proportion of its peripheral length (typically about 4%) and with no support being given by the solidifying and contrasting metal beneath, the insert is likely to be distorted, cracked or broken by the squeeze force. This cannot be counteracted by increasing the number or size of the supporting projections since this would prevent simultaneous downward movement of the insert with the solidifying and contracting metal which is essential to obtain the required bonding between the insert and the metal.

In U.K. Patent Specifications Nos. 2 090 779A and 2 090 780A, this problem of contraction is sought to be overcome by arranging for the tabs to break during solidification, so allowing the insert to move. However, this arrangement does not solve the problem of differential solidification (indeed, because some projections may break before others, the risk of warping and cracking may be increased). In addition, any projections that do not break correctly may score the lower die member and this is clearly undesirable.

In U.K. Patent Specification No. 2 072 065A no provision is made for accommodating either differential solidification or contraction.

A second disadvantage is that since the part of the die forming the skirt of the piston is at the lower end of the die, the molten metal which first enters the die passes to the skirt defining die portions and does not receive pressure until the remainder of the die has been filled and the second die member lowered to close the die. Because of this, and because of the thinness of the piston skirt, the molten metal forming the piston skirt will generally solidify at least partially before pressure is applied. This causes the piston to have a skirt portion which is not squeeze cast but only gravity die cast so lacking the strength and homogeneous structure of the remainder of the piston. This could lead to piston failure under severe conditions.

It is also a disadvantage that the insert is towards the top of the die because any impurities such as dross and oxides tend to rise to the top of the die and these can both interfere with the bond between the cast metal and the insert and reduce the quality of the metal in the crown of the piston; which is the part of the piston subject to the most adverse conditions when in use.

According to the invention, there is provided a method of manufacturing a piston for an internal combustion engine or compressor by a squeeze casting process, and of the kind comprising the steps of forming upper and lower die members, placing in said lower die member a piston ring groove reinforcement, filling the lower die member with molten metal under gravity, closing said lower die member with the upper die member and solidifying the molten metal under pressure, characterised in that the die forming step comprises forming the lower die member with a base which is a required external shape of a crown of the piston to be manufactured, the placing step comprising placing the piston ring groove reinforcement adjacent to but spaced from said base before the lower die member is filled with molten metal.

The following is a more detailed description of some embodiments of the invention, by way of example, reference being made to the accompanying drawings, in which:—

Figure 1 is a schematic cross-sectional view of a crown-down squeeze casting apparatus at the commencement of squeeze casting process for forming a piston for an internal combustion engine;

Figure 2 is a similar view to the view of Figure 1, but showing the apparatus at the end of a first stage; and

Figure 3 is a simlar view to the view of Figures 1 and 2, but showing the apparatus towards the end of the squeeze casting process.

Referring to Fig. 1, the squeeze casting apparatus comprises a lower die member 10 and a movable upper die member 11 mounted above the lower die member 10.

The lower die member 10 has an internal shape which is generally the required external shape of a piston for an internal combustion engine, while the upper die member 11 is formed with a projection 12 which defines a required internal shape of the piston.

The lower die member 10 contains a number of spaced lugs 13 closely adjacent the lower end of the lower die member 10 and, before casting, an annular reinforcement 14 is rested on the lugs 13. The reinforcement 14 may be of a ferrous material and may be an annular piston ring groove reinforcement insert or an expansion control insert.

The molten metal 15 is then fed into the lower die member 10. The amount of molten metal 15 is metered to ensure that there is sufficient to form a piston of the required dimensions but that there is not a large excess.

The upper die member 11 is then moved in a first stage of movement from the retracted position shown in Fig. 1 to the position shown in Fig. 2 in which the upper die member 11 is closely adjacent the surface of the molten metal. The speed of movement may be typically about 200 millimetres a second so that there is only the minimum delay in the application of pressure to the molten metal. When in the position shown in Fig. 2, the upper die member 11 is then slowly lowered in a second stage of the movement into the molten metal 15 to the position shown in Fig. 3. The speed of this movement may be typically between 1 and 10 millimetres per second depending upon the geometry of the casting being made. The speed of movement of the upper die member 11 in its second stage is as high as possible commensurate with satisfactory casting production.

The upper die member 11 then applies a squeeze force, typically of 200 to 300 tons, to the molten metal while it solidifies. This produces a strong homogeneous structure. Any contraction in the metal as it solidifies is taken up by movement of the upper die member.

The pressure is retained until solidification is completed. The upper die member 11 is then withdrawn and the cast piston removed from the lower die member 10 for finish machining.

Because the insert 14 is towards the lower end of the lower die member 10, it is in the first part of the piston to be solidified. This means that there is no substantial differential solidification around the insert, thus reducing the incidence of warping and cracking of the insert. In addition, since the depth of metal below the insert is very small, the amount of movement caused by contraction is very small; far less than would be the case if the insert were at the upper end of the lower die member 10. THe insert 14 is remote from the upper die member 11 and so there is no possibility of any interference between the upper die member 11 and the insert 14. There is also much less chance of the impurities such as dross and oxides in the molten metal interfering with the bond between the molten metal and the insert, because all these impurities rise to the surface. Further, molten metal feed with minimum turbulence into the lower die member 10 is afforded by the unrestricted space with the insert 14.

In addition, during molten metal feed and before squeezing, there is a deliberate overflow of molten metal to make sure that the die is full. In crown-up squeeze casting, with the insert at the top of the lower die member, it is necessary to pour the molten metal into the centre of the lower die member, so that the insert does not interfere with molten metal flow. This pouring must also be above the final level of the molten metal in the lower die member 10. This complicates pouring and can cause undesirable levels of turbulence in the molten metal within the lower member 10.

In the crown-down squeeze casting process now described the molten metal can be fed into the lower die member 10 at the wall of the die member 10 and at or adjacent the final metal level. This makes filling less complicated than in crown-up casting and also helps to minimise turbulence.

The skirt 17 (see Fig. 3) of the piston is at the upper end of the lower die member 10. This means that the skirt is formed from the last portion of the molten metal poured into the lower die member 10. Because of this, and because the upper die member 11 is moved into the pool of metal in the lower die member 10 before it solidifies, there is no possibility of the skirt metal having solidified before pressure is applied. This ensures that the skirt is always fully squeeze cast. It allows the skirt to be made as thin as required without any possibility of a gravity die cast skirt being formed.

It will be appreciated that the upper and lower die members 10, 11 may be heated before squeeze casting to ensure that there is no premature solidification of the molten metal 15. In addition, they may be cooled during casting to ensure as rapid as possible solidification of the molten metal once pressure has been applied by the upper die member 11.

It will be appreciated that the upper and lower die members may have any desired construction to facilitate the production of various piston geometries. It will also be appreciated that the piston ring groove reinforcement insert may be of any required configuration and that a similar method could be used to incorporate an expansion control insert, although, in this latter case, it may be necessary to support the insert on the upper die member.

Claims

1. A method of manufacturing a piston for an internal combustion engine or compressor by a squeeze casting process, and of the kind comprising the steps of forming upper and lower die members (10, 11), placing in said lower die member (10) a piston ring groove reinforcement (14), filling the lower die member with molten metal (15) under gravity, closing said lower die member with the upper die member and solidifying the molten metal under pressure, characterised in that the die forming step comprises forming the lower die member (10) with a base which is a required external shape of a crown of the piston to be manufactured, the placing step comprising placing the piston ring groove reinforcement (14) adjacent to but spaced from said base before the lower die member (10) is filled with molten metal (15).

2. A method according to claim 1, characterised in that the movement of the upper die member (11) is in two stages, the first stage being from a retracted position to a position adjacent the surface of the molten metal (15) and the remaining movement being the second stage, the speed of the upper die member (15) in the first stage being faster than the speed of movement of the upper die member (11) in the second stage and the speed of movement of the upper die member (11) in the second stage being sufficiently slow to prevent splashing of the molten metal as the upper die member enters the molten metal (15).

3. A method according to claim 2, characterised in that speed of the upper die member (11) in the first stage is about 200 mm per second.

4. A method according to claim 2 or claim 3, characterised in that the speed of the upper die member (11) in the second stage is between 1 and 10 mm per second.

5. A method according to any one of claims 1 to 4, characterised in that the upper die member (11) is heated before closing the lower die member (10).

6. A method according to any one of claims 1 to 5, characterised in that the upper and lower die members (10, 11) are cooled during solidification of the molten metal (15).

7. A method according to any one of claims 1 to 6, characterised in that the die forming step comprises providing the lower die member (10) with lugs (13) for supporting and locating thereon the piston ring groove reinforcement insert (14).

Patentansprüche

1. Verfahren zum Herstellen eines Kolbens für eine Brennkraftmaschine oder einen Komproessor durch einen Preßgießvorgang, und won der Art enthaltend die Schritte: Ausbilden oberer und unterer Formenteile (10, 11), Einsetzen in das untere Formenteil (10) einen Kolbenringnuteinsatz (14), Füllen des unteren Formenteils mit geschmolzenem Metall (15) unter Schwerkraft, Schließen des unteren Formenteils mit dem oberen Formenteil und Erstarren des geschmolzenen Metalls unter Druck, dadurch gekennzeichnet, daß der Formenausbildungsschritt enthält: Ausbilden des unteren Formenteils (10) mit einer Basis, die eine benötigte äußere Gestalt einer Krone des herzustellenden Kolbens hat, daß der Einsetzschritt enthält: Einsetzen des Kolbenringnuteinsatzes (14) benachbart aber im Abstand von der Basis, bevor das untere Formenteil (10) mit dem geschmolzenen Metall (15) gefüllt wird.

2. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die Bewegung des oberen Formenteils (11) in zwei Stufen erfolgt, wobei die erste Stufe von einer zurückgezogenen Position zu einer Position benachbart der Oberfläche des geschmolzenen Metalls (15) reicht und die verbleibende Bewegung die zweite Stufe ist, wobei die Geschwindigkeit des oberen Formenteils (11) in der ersten Stufe schneller ist als die Bewegungsgeschwindigkeit des oberen Formenteils (11) in der zweiten Stufe und die Bewegungsgeschwindigkeit des oberen Formenteils (11) in der zweiten Stufe ausreichend langsam ist, um ein Verspritzen des geschmolzenen Metalls zu vermeiden, wenn das obere Formenteil in das geschmolzene Metall (15) eintritt.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die Geschwindigkeit des oberen Formenteils (11) in der ersten Stufe etwa 200 mm pro Sekunde ist.

4. Verfahren nach Anspruch 2 oder Anspruch 3, dadurch gekennzeichnet, daß die Geschwindigkeit des oberen Formenteils (11) in der zweiten Stufe zwischen 1 und 10 mm pro Sekunde beträgt.

5. Verfahren nach einem der Ansprüche 1 bis 4,

dadurch gekennzeichnet, daß das obere Formenteil (11) vor dem Schließen des unteren Formenteils (10) aufgeheizt wird.

6. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die oberen und unteren Formenteile (10, 11) während der Erstarrung des geschmolzenen Metalls (15) gekühlt werden.

7. Verfahren nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß der Formenausbildungsschritt enthält: Versehen des unteren Formenteils (10) mit Ansätzen (13) zum Abstützen und Halten des Kolbenringnuteinsatzes (14) darauf.

Revendications

1. Méthode de fabrication d'un piston pour moteur à combustion interne, ou pour compresseur, par un procédé de moulage sous pression, du type comportant des étapes dans lesquelles on forme des éléments de coquille supérieur et inférieur (10, 11), on place dans ledit élément de coquille inférieur (10), un renfort (14) pour gorge de segment de piston, on remplit, par gravité, l'élément de coquille inférieur avec du métal en fusion (15), on ferme ledit élément de coquille inférieur au moyen de l'élément de coquille supérieur et l'on fait solidifier, sous pression, le métal en fusion, caractérisée en ce que l'étape de formation de coquille comporte la formation de l'élément de coquille inférieur (10) en le dotant d'une base qui est une forme extérieure requise du sommet d'un piston à fabriquer, l'étape de mise en place comportant le fait de placer le renfort (14) pour george de segment de piston à une position voisine, mais espacée de ladite base, avant le remplissage de l'élément de coquille inférieur (10) avec le métal en fusion (15).

2. Méthode selon la revendication 1, caractérisée en ce que le mouvement de l'élément de coquille supérieur (11) comporte deux étapes, la première étape étant d'une position rétractée à une position adjacente à la surface du mètal en fusion (15), et la deuxième étape étant le reste du mouvement, la vitesse de l'élément de coquille supérieur (11) au cours de la première étape étant plus grande que la vitesse du mouvement de l'élément de coquille supérieur (11) au cours de la deuxième étape, et la vitesse du mouvement de l'élément de coquille supérieur (11) au cours de la deuxième étape étant suffisamment lente pour empêcher la projection de métal en fusion lorsque l'élément de coquille supérieur pénètre dans le métal en fusion (15).

3. Méthode selon la revendication 2, caractérisée en ce que la vitesse de l'élément de coquille supérieur (11) au cours de la première étape est de l'ordre 200 mm par seconde.

4. Méthode selon la revendication 2 ou la revendication 3, caractérisée en ce que la vitesse de l'élément de coquille supérieur (11) au cours de la deuxième étape est comprise entre 1 et 10 mm par seconde.

5. Méthode selon l'une quelconque des revendications 1 à 4, caractérisée en ce que l'élément de coquille supérieur (11) est chauffé avent de former l'élément de coquille inférieur (10).

6. Méthode selon l'une quelconque des revendications 1 à 5, caractérisée en ce que les éléments de coquille supérieur et inférieur (10, 11) sont refroidis pendant la solidification du métal fondu (15).

7. Méthode selon l'une quelconque des revendications 1 à 6, caractérisée en ce que l'étape de formation de coquille comporte le fait de minir l'élément de coquille inférieur (10) de saillies (13) pour supporter et positionner sur elles l'insert de renforcement (14) pour gorge de segment de piston.

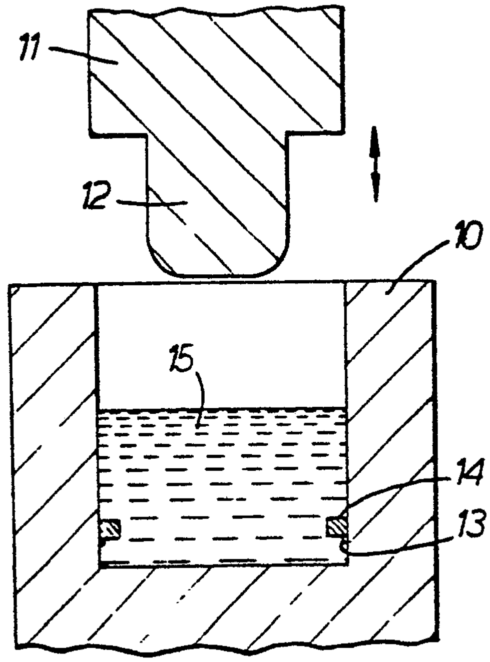

FIG. 1.

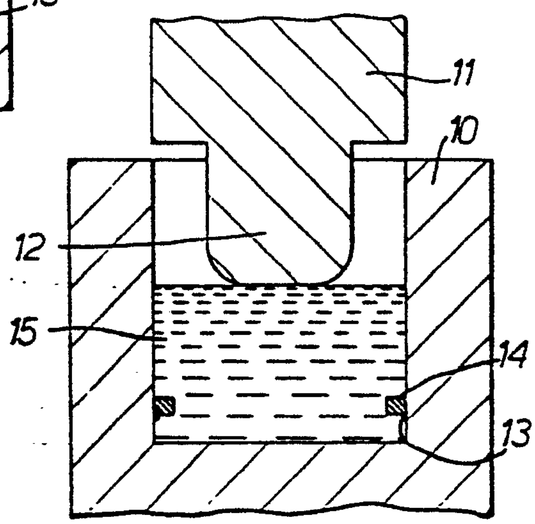

FIG. 2.

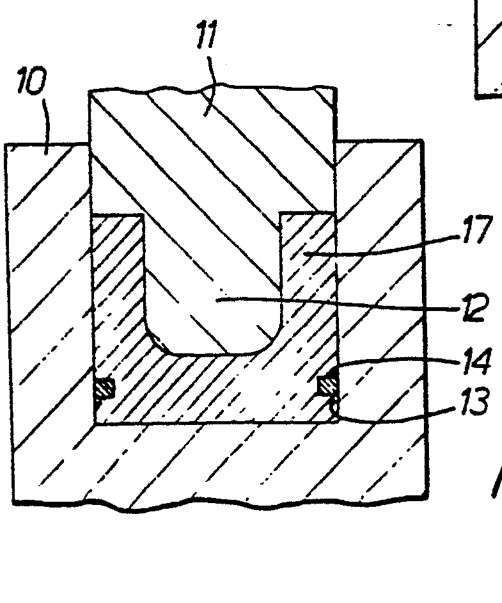

FIG. 3.