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A Review on Squeeze Casting

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ABSTRACT: This review paper discusses about squeeze casting in all its aspects: its history and growth, its specific processes and machinery, including its major parameters; its metallurgical characteristics including its porosity, recrystallation and grain refining; its mechanical properties; the mechanical characteristics of the various processes and the advantages and disadvantages of the squeeze casting. Squeeze casting has more potential to generate fewer faulty casting components of the many other casting techniques available. Squeeze casting (SC) is a general term for defining a manufacturing technique where solidification is encouraged in a reusable die under high pressure. Without the feeding system, drivers, gates and so on, shrinkagging compensating devices, riser can be carried out press, the yield is quite high, with practically no recycled scrap. Components made by SC are thin seeded with an outstanding finish on the top, almost without porosity. These are available in different shapes and sizes. With contrast to traditional coatings and more modern casting methods, the mechanical properties of these pieces have been significantly improved.

KEYWORDS*:* MMCs, Pressure die-casting, Porosity, Squeeze casting (SC), Shrinkagging.

I.INTRODUCTION

Casting is the efficient way of transferring raw materials to parts that can be readily used. One of the main drawbacks for traditional or even more modern casting methods is the development of defects such as porosity, for instance, high pressure die-casting. Furthermore, hot-tear, A-and V-segregates and banding defects could potentially result in the creation of a crack while the as-cast component is in service. Therefore, new casting methods were created to overcome these limitations. Squeeze casting has a greater potential to create fewer defective casting components amongst the many such casting technologies available.

Squeeze casting (SC) is the common term used to describe a manufacturing process, which encourages solidification in a reusable die under high pressure. Although squeeze casting is the accepted term in this process, it is understood to be "extrusion casting," "air squeezing," "pressure crystallization" and "squeeze formation." Chernov first proposed in 1878 that steam pressure should be added to molten metal and that this should be improved. Nevertheless, the selling of the squeeze casting has recently been accomplished in view of its century-old innovation and is focused mostly in Europe and Japan. It is used primarily to produce parts for or without reinforcement in high integrity technologies [1]. Technique of pressurized solidification of Al alloy in reusable dies produced in the United Kingdom by GKN Engineering. The pressure is removed so that the metal fills the cavity and the pressure is sustained until the solidification is complete (31-108 MPa); in this process, a die set is mounted on the hydraulic press and pre-heated. Forms outside undercuts can be produced and through-holes are necessary for retractable side cores. The squeeze casting is seen also as a net or near to net-shaped route of production, since the produced products can be readily used during use or after slight post-manufacture treatments.

There are worldwide research centers, parallel to commercialization, which actively seek to further improve and leverage these networks and near-networks [2], [3]. This is evidenced by the publishing in several technical and scientific journals of more than 700 papers. Which include primarily metal compositions MMCs focused on aluminum and magnesium alloys. The squeeze casting is now the most common manufacturing route for MMC objects according to Crouch.

The engineering components produced by SC are generally fine, with excellent surface finishing and nearly no porosity. These are available in a variety of shapes and sizes. By contrast with traditional castings and advanced casting

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lines, the mechanical qualities of those materials are significantly improved. According to Pennington, the yield strength is 10–13 percent increased, as are elongation and fatigue strength up to 30–80 percent. Similar to die-casting, dimensional accuracy is 0.23 mm per 100 mm to 0.6 mm per 300 mm. The engineering components produced by SC are generally fine, with excellent surface finishing and nearly no porosity [4]–[6]. These are available in a variety of shapes and sizes. By contrast with traditional castings and advanced casting lines, the mechanical qualities of those materials are significantly improved. According to Pennington, the yield strength is 10–13 percent increased, as are elongation and fatigue strength up to 30–80 percent. Similar to die-casting, dimensional accuracy is 0.23 mm per 100 mm to 0.6 mm per 300 mm. SC-manufactured components are also claimed for better solder ability and thermal treatability. Moreover, because it is possible to carry out squeeze casting without any feeder system, drivers, walls, etc. and retraction compensation systems, risers the return is quite significant with no scrap for recycling.
Finally, unlike forging, a single action operation with lower energy needs manufactures squeeze cast components.

Process outline:

The squeeze casting process consists of the following steps:

1. A pre-determined quantity of molten metal is placed on the Bed of a hydraulic press into a pre heated die-cavity.
2. To close the die cavity and press the liquid metal, the press is triggered. This is done really quickly and makes the molten metal solidified under heat.
3. The strain is retained on the metal until it is completely solidified. Not only does this improve the heat flow rate, but also primarily helps reduce macro / micro shrinkage porosity. Since the nucleation of the gas porosity depends on the pressure, the deposition of porosity in the molten metal is limited because of the dissolution of hydrogen.
4. The punch is finally removed and the part thrown away.

Squeeze casting's Mechanics:

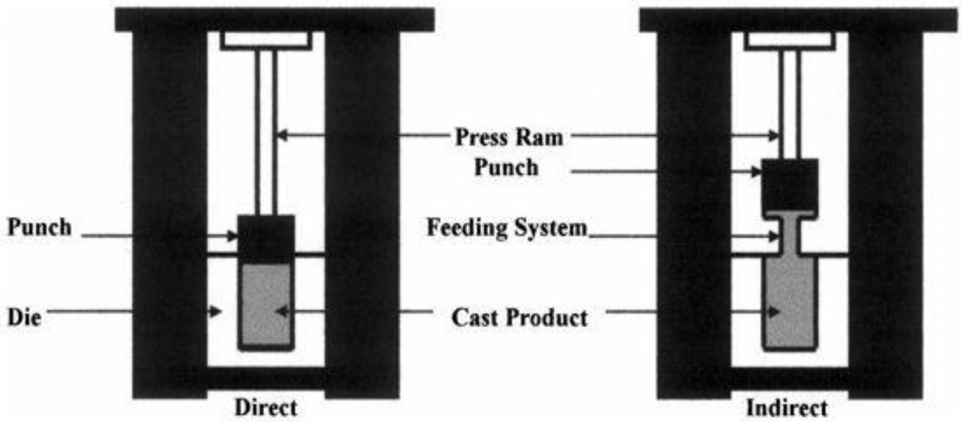
3.1. The die

The die-itself and, most specifically, the construction of the die, including the choosing of an appropriate mould medium, production process, adequate heat treatment and maintenance, are the most important elements of permanent mould casting such as die-casting or squeeze casting. Squeeze casting dies are subjected to extreme cyclic and thermal loads that cause thermal fatigue, fracture, oxidation, degradation and denture [4], [7]. The essence and the features of a death depend heavily on the particular alloy to be cast. H13 tool steel is now a commonly used building material, but the steel typically needs to have good hot strength, high temperature tolerance, ample strength and, in particular, a high level of cleanliness and consistent microstructure. Fig 1, 2 shows the direct and indirect squeeze casting and two formats of squeeze casting process respectively.

3.1. The carting process: key feature

- Casting directly

Fig.1: Schematic Diagram to Illustrate the Direct and Indirect Modes of the Squeeze Casting Process



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- Casting indirect pinch

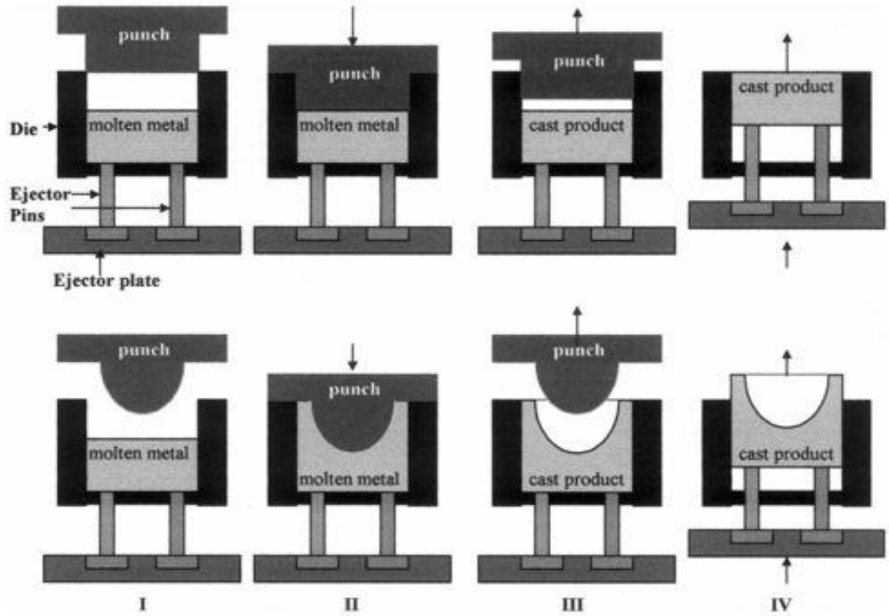

Fig.2: Schematic Diagram to Show Two Forms of the Direct Squeeze Casting Process

Due to the fluid metal shifting initiated by punch movement without the movement of metals and with the movement of metals, two additional modes can be distinguished in the direct mode [1], [8]. As shown in the frame. The second type is more flexible and can be used to install a broad range of formed parts, often known as the backward method, whereas the first form is suitable for ingot-type elements that have no motions from metal to metal.
The squeeze casting method can be graded based also on the following features, in addition to the molten metal displacement type.

Type of equipment:

In different parts of the world, various squeeze casting machines are used. These either are designed by the scientists themselves, or are produced on a mass-production basis by machine tools firms. The direct SC-machine is simple and straightforward, but indirect machines are usually divided into following categories:

i. Vertical injection and closing,
ii. Horizontal injection and closing of the die,
iii. Horizontal injection and vertical injection of the die.

Timing of pressure application:

Thus squeeze casting is known to be the squeezing of molten metal, it can also be used for the forming of semi-solids, and therefore further classification may therefore be envisaged as: I prior to crystallization starting and (ii) following the start of crystallization, which can also be defined as semi-solid pressing.
Picture. Fig. 3 outlines the various squeeze mechanism types.

Process parameter:

The most important process parameter is the alloy itself. Because of its direct effect on die itself, the structure and physical characteristics of the alloy are important. The combined effect of the coefficient of heat transfer on the die material includes the melting temperature [9], [10], and the thermal conductivity of the alloy. However, the alloy determines that the casting parameters like the die temperature are chosen which directly affects the die life. Thus, for low temperature melting alloys of aluminum and magnesium squeeze casting is usually used.
In addition to the casting alloy composition which determines its freezing range and affects the quality of finished components, it is also important to monitor the casting parameters very carefully in order to produce an acoustic casting. Die-temperature and pouring temperature and super-heat are the main process parameters, although the level of

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pressure used is also important. The intrinsic portability of the alloy is of little or no consequence because the metal is cast under heat.

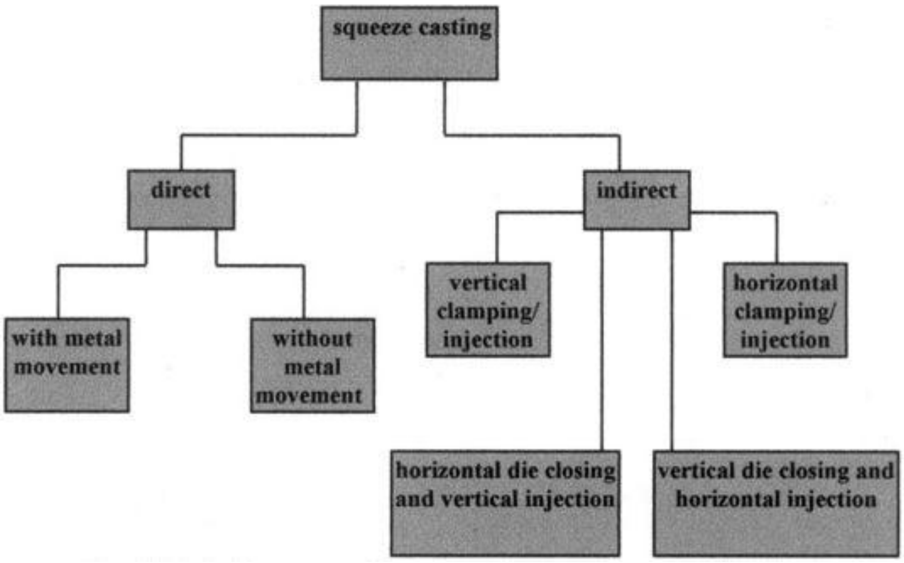

Fig.3: Block Diagram to Show the Squeeze Classifications

The cleanliness of the metal in relation to the presence of inclusions, the motion of metals within the die which may cause friction, the die surface and the length of the time the pressure is applied, i.e. the so-called dead time, form other essential parameters. Of aluminum and magnesium alloys the die temperature is typically between 200°C and 300°C, while the pressure is between 30 and 130 MPa. Normally graphite-based is the lubrication medium, e.g. die paint. Thanks to the casting metal rubbing against the die-wall, heat transfer coefficients are extremely high.

Theoretical background: effect of pressure on the solidification behavior of alloys:

The pressure application should affect the phase relationships of an alloy system during solidification. The Clausius–Cla- peyron equation may be deduced from this,

$$\frac{\Delta T_f}{\Delta P} = \frac{T_f(V_l - V_s)}{\Delta H_f}$$

In the case of Tf the balancing temperature of the melting, Vl and Vs are the liquid and solid, respectively, different quantities, and AHf is the fusion latent gas. The effects of pressure on the freezing point are roughly estimated as follows, by replacing the appropriate thermodynamic equation for volume2:

$$P = P_0 \exp\left(\frac{-\Delta H_f}{RT_f}\right)$$

The constants of P0, AHf and R. Tf should therefore rise with increased pressure. In respect to a mechanical approach, this transition is expected to take place because the distance from the atom is decreased by increasing pressure and thus the atomic motion is constrained. The inter solubility of materials and the solubility of impurities and trace elements will also improve with time. The estimates have been experimentally confirmed with a fluid temperature increase of up to 9 ° C for pure Al / Si binary alloys at 130 MPa. At the same time, these predictions have been verified. In comparison, the eutectic point is moved to the left that is to say to higher. As a result of these phase graph improvements, the microstructure and the mechanical properties of SC-fabricated parts have improved significantly. Grain processing is evident in squeeze cast parts. Nevertheless, they are very specific in their understanding of such processing. Fig 4 shows the influences of instant cooling and application of pressure on the AI-Si Phase diagram.

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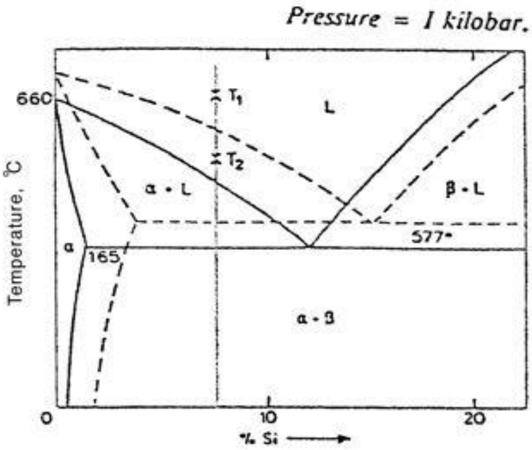
The application of pressure undoubtedly decreases the air gap between the solidification metal and the ceramic mold and thus raises the contact area. This may be the primary method for

Fig.4: The Effect of Rapid Cooling and the Application of Pressure on the AI-Si Phase Diagram



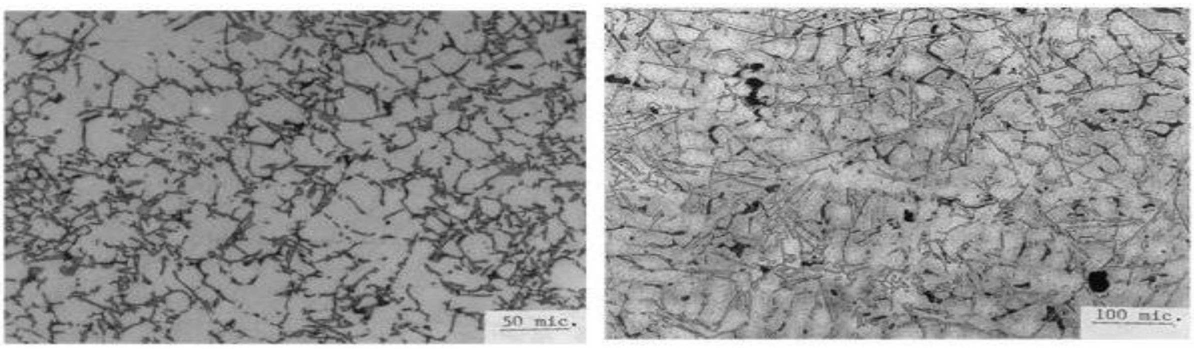
Increasing a heat transfer coefficient. It refers to the analyses of the numerical models to test the flow and heat transfer properties of molten metal in the casting process. The thermo-physical properties of the molten metal under applied pressure have changed slightly.

At Tm< Tm< AT temperature pressure is applied, then the prevailing process would be undercooling. If at the start of crystallization, i.e. Temperature T < Tm, the effect of undercooling remains significant. Of example, in the case of aluminum alloys, a certain trace element of Sr, P, Na or even Tri or B might have huge effects on the microstructure scale. The composition of the solidifying alloy is also quite significant. Apply the pressure of temperature at Tm Tm AT to the prevailing cycle. When the crystallization ends, i.e. the undercooling effect remains important at T < tm temperature. For example, a trace element of Sr, P, Na, or even Tri or B, for aluminum alloys could have enormous effect affecting the size of the microstructure. There is also a large structure of the solidifying alloy. In addition, the fine structure and superior mechanical properties of SC components are caused by (i) improvements in the mold alloy's undercooling mechanism, (ii) changes in the composition and percentage of the solidifying alloy's forming processes, (iii) changes in the coefficient of thermal transfer between the mold and the solidifying alloy and (iv) changes in the density of alloy.

Squeeze cast alloys: microstructure and properties:

As described above, squeeze cast products have better mechanical characteristics than conventionally cast counterparts because of their higher density, finer scale of grain and more homogeneous[22,28,32,33,33] microstructure. Furthermore, die thermal limitations restrict squeeze casting to aluminum and magnesium alloys primarily at light and low melting points, while copper alloys[36], cast iron[24,37] and[14] also have been squeezed. Fig 5 shows the optical micrographs to show the as-cast structure of LM24 AI-Si alloy- 1) Squeeze cast LM24, and conventional as-cast LM24.

Fig.5: Optical Micrographs to Show the As-Cast Structure of LM24 AI-Si Alloy- a) Squeeze Cast LM24, And a) Conventional As-Cast LM24



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The application of pressure has a significant impact on phase morphology in cast alloys such as flake graphite, with increased pressure, to compressed graphite. With Al-Si alloys, the probable

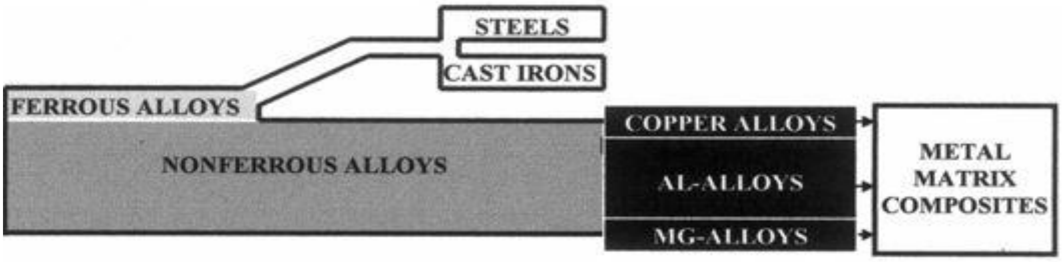

Fig.6: Schematic Diagram to show the Alloys Used for Squeeze Casting

Morphology is fibrous silicone. A standard LM24 Al-Si alloys cast microstructure is shown in the fig 6 Together with its historically casted equivalent, the silicone morphologic and grain structure variations are underlined. Squeeze cast products are therefore expected to have superior mechanical linkages, as shown in Table 1.

Some authors found developing alloys for SC conditions to be important. In order to improve its composition to squeeze castings, Lee et al have tested a new alloy framework of Al –Si–Cu–Mg that possesses good cast ability and outstanding mechanical properties. The alloy chosen was Al–12 wt. % Si –3 wt. % Cu –0.7 wt. % Mg that showed an increase in hardness, stress and elongation of 10 to 20% in contrast with gravity cast products. Improvements to the Sr, Ti and B Alloy have improved the elongation by 40 percent, although there have been no significant changes in wear resistance.

Table 1: Tensile Properties of Conventional and Squeeze Cast Alloys

Alloy	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
AA603-T6 [38]	260	330	≤10
A336-T6 [39]	220	300	≤10
LM24 (SC) [40]	–	210 T 3	2–2.3
7010 chill cast-T6 [41]	468–488	323–326	4.7–3.9
7010 squeeze cast-T6 (30 MPa) [41]	470–490	330–363	10–14

Squeeze casting gives new opportunities, especially in the field of compo-sites, to manufacture advanced materials. Most publications are for squeeze casting MMCs. There are important publications.

Squeeze cast may be used in the manufacture of bi-metals where cast iron inserts, for example, can be inserted into parts of the Al alloy to improve wear resistance. Up to now, applications were wheels, pistons and disks for the brake.

Direction for further development:

According to the process features and the die size, the use for direct SC is very limited: the overall casting weight typically does not exceed 10 kg. The reverse process is more industrial-sensitive, since it enables the creation of complex casts for the automotive sector such as alloy wheels. The development of VSC-machines, the use of the squeeze casting process was considerably expanded. Complex castings such as alloy wheels with virtually no internal defects were made. The coat is not necessary and up to 100 MPa metal pressures during solidification are added. The system power limits the overall casting size. Nevertheless, due to its low filling speed and premature solidification of the fused metal, it is difficult to cast thin fragments with a wall thickness of less than 4 mm. Therefore, the flexibility of the shape of the cast component is reduced, which can be caused by problems with casting.

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II.CONCLUSIONS

Several reports on the squeeze casting process indicate that it is still being successfully developed. The bulk of the publications deal with aluminum and magnesium-based alloys and their matrix-oriented composites in particular. Therefore, the key trends in the production of the squeeze casting, machinery and alloys can be said to be connected with the fabrication of advanced materials, particularly in Al-and Mg-based alloys and composites. There are certain advances with respect to high temperature alloys like cast-iron, while lighter alloys like Al and Mg are of particular importance.

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