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DIE CASTING HYDRAULIC FLUIDS

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GENERAL INFORMATION

Die casting is the process of forcing molten metal, under high pressure, into mold cavities (which are machined into dies). Most die castings are made from non-ferrous metals, specifically zinc, copper, aluminum, magnesium, lead, and tin based alloys, although ferrous metal die castings are possible. The die casting method is especially suited for applications where a large quantity of small-to-medium-sized parts is needed with good detail, a fine surface quality, and dimensional consistency. Advances in technology have allowed die cast machine manufacturers to produce machines capable of casting pieces with weights up to 45 kilograms. This level of versatility has placed die castings among the highest volume products made in the metalworking industry.

There are four major steps in the die casting process. First, the mold is sprayed with lubricant and closed. The lubricant helps to control the temperature of the die and also assists in the removal of the casting. Second, molten metal is shot into the die under high pressure; between 10-175 MPa (1,500-25,000 psi). Once the die is filled, clamping pressure is maintained until the casting has solidified. Third, the die is opened and the shot is ejected by the ejector pins (shots are different from castings because there can be multiple cavities in a die, yielding multiple castings per shot). Finally, the scrap, which includes the gate, runners, sprues and flash, must be separated from the casting(s). This is often done using a special trim die in a power press or hydraulic press. An older method separates by hand or by sawing, in which case grinding may be necessary to smooth the scrap marks. A less labor-intensive method is to tumble shots if gates are thin and easily broken; separation of gates from finished parts must follow. This scrap is recycled by remelting it. Approximately 15% of the metal used is wasted or lost due to a variety of factors.

The high-pressure injection leads to a quick fill of the die, which is required so the entire cavity fills before any part of the casting solidifies. In this way, discontinuities are avoided even if the shape requires difficult-to-fill thin sections. This creates the problem of air entrapment, because when the mold is filled quickly there is little time for the air to escape. This problem is minimized by including vents along the parting lines; however, even in a highly refined process there will still be some porosity in the center of the casting.

Most die casters perform other secondary operations to produce features not readily castable, such as tapping a hole, polishing, plating, buffing, or painting.

There are two basic types of die casting machines: hot-chamber machines and cold-chamber machines. The machines are rated by how much clamping force they can apply. Typical ratings are between 400 and 4,000 short tons.

HOT-CHAMBER MACHINES rely upon a pool of molten metal to feed the die. At the beginning of the cycle, the piston of the machine is retracted which allows the molten metal to fill the “gooseneck.” The gas- or oil-powered piston then forces this metal out of the gooseneck into the die. The advantages of this system include fast cycle times (approximately 15 cycles a minute) and the convenience of melting the metal in the casting machine. The disadvantages of this system are that high-melting point metals cannot be utilized, and aluminum cannot be used because it picks up some of the iron while in the molten pool. Due to this, hot-chamber machines are primarily used with zinc, tin, and lead-based alloys. Hot chamber machines produce smaller parts and tend to have lower hydraulic pressures.

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COLD-CHAMBER MACHINES are used when the casting alloy cannot be used in hot-chamber machines; these alloys include aluminum, magnesium, copper, and zinc alloys with a large composition of aluminum. These machines work by first melting the material in a separate furnace. Then a precise amount of molten metal is transported to the cold-chamber machine where it is fed into an unheated shot chamber (or injection cylinder). The shot is then driven into the die by a hydraulic or mechanical piston. The biggest disadvantage of this system is the slower cycle time, due to the need to transfer the molten metal from the furnace to the cold-chamber machine.

The dies used in die casting are usually made out of hardened tool steels, because cast iron cannot withstand the high pressures involved. Due to this, the dies are very expensive, resulting in high start-up costs. Dies may contain only one mold cavity or multiple cavities of the same or different parts. There must be at least two dies to allow for separation and ejection of the finished workpiece; however, it is not uncommon for there to be more sections that open and close in different directions. Dies also often contain water-cooling passages, retractable cores, ejector pins, and vents along the parting lines. These vents are usually wide and thin (approximately 0.13 mm or 0.005 in) so that when the molten metal starts filling them, the metal quickly solidifies and minimizes scrap. No risers are used because the high pressure ensures a continuous feed of metal from the gate. Recently there has been a trend to incorporate larger gates in the die and to use lower injection pressures to fill the mold, and then increase the pressure after it is filled. This system helps reduce porosity and inclusions.

HYDRAULIC SYSTEMS

From a hydraulics perspective, die cast machines today are designed to run on fire resistant hydraulic fluids. Specifically, the vast majority of the machines are designed to operate on water glycol (HFC) type fluids. Because molten metal is held at the shot end of the machine, and because of the relative close proximity of die casting cells (die casting machine, quench tank if used and trim press) to one another in a die casting shop, mineral oil is not the hydraulic fluid of choice in this mature market. The fire resistant fluid selected for a die casting operation should have maximum resistance to flame propagation, because machines are close together and because the space between machines is typically used as an aisle for employees. While water glycol fluids offer exceptional fire resistance per fluid dollar spent, there are a number of physical, chemical and performance properties that work against HFC fluids in today's die casting market place.

Water is the fire resistant component in an HFC fluid. While water is formulated into these solution-type products to provide excellent fire resistance, the presence of water also creates performance issues for the fluid. Water does not have the lubricating film strength of mineral oil or various synthetic lubricating base stocks. This limits the maximum operating pressure of the hydraulic system. Since the vast majority of the die cast machines manufactured globally use vane type pumps (vane pumps are quieter than piston pumps; an important consideration in today's manufacturing environment where OSHA noise limits are enforced), the normal maximum operating pressure for a die cast machine is in the area of 2,500 psi (about 170 bar) depending on the pump. Water glycol fluids, because of their poor film strength, are not rated for full pressure in the majority of today's hydraulic pumps. QUNITOLUBRIC® polyol esters, on the other hand,

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offer die casters greater lubrication and film strength because they do not contain water. This increases system performance, extends pump life and improves productivity.

Another drawback of using water glycol hydraulic fluids is the high vapor pressure of water. Water-based fluids are more prone to cavitation than synthetic fire resistant hydraulic fluids. Cavitation is defined as the phenomenon of formation of vapor bubbles in a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure. Cavitation is usually divided into two classes of behavior: inertial (or transient) cavitation, and non-inertial cavitation. Inertial cavitation is the process where a void or bubble in a liquid rapidly collapses, producing a shock wave. Such cavitation often occurs in pumps, propellers and impellers. In the die casting process, cavitation typically occurs at the inlet of the pump. If the system is designed with negative head (the level of the fluid is below the pump), a pressure less than atmospheric pressure develops as the fluid is lifted to the pump's inlet. A further reduction in the effective pressure over the fluid is encountered as the fluid accelerates from its speed in the inlet piping to the angular velocity of the pump's rotating group. The presence of an inlet strainer and the resulting flow restriction can also contribute to the fluid being exposed to a pressure below atmospheric pressure. Any or all of these conditions can cause a high vapor pressure fluid, like water glycol, to boil or cavitate at the pump's inlet. The resulting bubbles in the fluid can have a devastating affect on the pump as well as all system hardware. Use of anhydrous synthetic fire resistant fluids virtually eliminates vapor pressure concerns.

As stated earlier, water glycol fluids use water as the fire resistant component of their formulation. This means that all other materials used in the blending and compounding of the final fluid must be water

soluble. This total water solubility of a water glycol fluid can present problems in an industrial setting. Local municipalities as well as state and federal agencies now monitor all water leaving an industrial site for processing. The water is analyzed for such things as phenol content, FOG (fats, oils and grease), heavy metals and BOD (biological oxygen demand) and COD (chemical oxygen demand). If a water glycol fluid finds its way into a waste water stream, it cannot be removed by standard waste treatment methods. Water glycol fluids contribute heavily to increased BOD and COD in effluent. Many die casters are faced with treatment surcharges from their local POTW (publicly owned treatment works) because of the presence of water glycol fluids in their effluent. Synthetic polyol ester fluids contain no water have a specific gravity that is less than 1.0, and they float on water. Polyol ester fluids can be removed from waste water using standard emulsion breaking technology incorporated by most POTWs. Synthetic polyol ester fluids offer the consumer an alternative to paying costly waste treatment surcharges. While water glycol fluids are today's standard in the die casting industry, there is a growing case for the use of polyol ester fluids. Increased component life, increased productivity and reduced waste treatment costs should offset an increase in the price per gallon of hydraulic fluid.

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