Electromagnetic pump

Pump that operates on the principle that a force is exerted on a current-carrying conductor in a magnetic field. The high electrical conductivity of the liquid metals pumped (liquid metals are used as the heat-transfer media in some nuclear reactors and magnetohydrodynamic systems) allows a pumping force to be developed within the metals when they are confined in a duct or channel and subjected to a magnetic field and to an electric current. These pumps are designed principally for use in liquid-metal-cooled reactor plants where liquid lithium, sodium, potassium, or sodium-potassium alloys are pumped. Other metallic and nonmetallic liquids of sufficiently high electrical conductivity, such as mercury or molten aluminum, lead, and bismuth, may also be pumped in nonnuclear applications. The absence of moving parts within the pumped liquid eliminates the need for seals and bearings that are found in conventional mechanical pumps, thus minimizing leaks, maintenance, and repairs, and improving reliability. In liquid-metal-cooled nuclear reactor plants, electromagnetic pumps with a capacity of up to several thousand gallons per minute have operated without maintenance for decades. See also: Magnetohydrodynamics; Nuclear power; Nuclear reactor.

The major classifications of electromagnetic pumps, either conduction or induction, are based on the method employed to cause the electric current to flow in the pumped liquid.

**Direct-current conduction pumps**

In this simplest form of electromagnetic pump the liquid-containing pump duct has two heavy electrodes to provide a path for direct current to be conducted at a right angle to the direction of pumping force in the duct. A magnetic field generated by either a permanent magnet or electromagnet is impressed across the duct at the location of the electrodes in a direction at right angles to both the current flow and the pumping direction. This orthogonal arrangement of current, magnetic field, and pump duct produces a force in the liquid which is dependent on the magnitude of the current, magnetic field, and the length of the current path in the liquid. It is also possible to arrange the duct so that the current flowing in the liquid also produces the required magnetic field (that is, the self-induced pump). The physical arrangement of the conduction pump allows only a single passage of current between electrodes, resulting in a relatively short length of current path in the liquid. To compensate, the current must be very high (thousands of amperes), thus requiring special dc power supplies such as homopolar generators. However, the very low voltage allows special electrical insulation to be used, which is suitable for high-temperature (1500°F or 800°C) operation. See also: Magnetic field.

In addition to the externally energized dc conduction pump described above, there are two other unique pump design concepts of the dc conduction pump family in use or under development. In the thermoelectric electromagnetic pump, the current in the duct is generated by thermoelectric elements attached to the duct electrodes which are driven by the temperature difference between the duct and a heat sink. The major application of thermoelectric electromagnetic pumps is in the liquid-metal loops of space reactors. See also: Thermoelectricity.

The second design concept is the flow coupler. In this design a dc conduction pump duct in a secondary (driven) loop is directly coupled to a magnetohydrodynamic generator located in an adjacent parallel duct of a primary (driving) loop to which it is connected by appropriate buswork. Both ducts lie in a magnetic field produced by a permanent magnet or electromagnet. The initial use of this concept was to drive small auxiliary loops in experimental liquid-metal facilities. However, with the advent of liquid-metal pool reactors the concept is being studied as a means of circulating the primary coolant in the pool.

**Alternating-current conduction pump**

This pump uses a pump duct, magnetic field, and electrode arrangement similar to the dc conduction pump, except that the magnetic field is produced by an ac (single-phase) electromagnet and the current is produced by the transformer action of the same or separate single-phase electromagnet with a secondary (step-down) winding of usually one turn. The heavy secondary winding connects to the electrodes. With the sinusoidal magnetic field and duct current in phase with each other, a pumping force will be developed. This design can be operated directly from normal single-phase ac power equipment since it has an integral transformer to develop the necessary high current. It too can have a high-temperature application. See also: Electromagnet; Transformer.

**Helical induction pump**
This pump closely resembles a polyphase squirrel-cage ac induction motor in principle and operating characteristics. The fluid channel is formed by helical vanes encased in a concentric cylinder and is analogous to the rotor of a conventional motor. Arranged around the periphery of the outer cylinder is a polyphase multipole winding which is similar to the stator of an induction motor. The polyphase winding creates a rotating magnetic field which induces a current in the liquid metal, and this current in turn reacts with the magnetic field to produce a force on the fluid tending to rotate it in the duct. However, the fluid is channeled by the helical vanes, forcing it to produce an axial pressure and resultant axial flow in the duct. The helical induction pump is used in applications requiring higher pressures and lower flows than the linear induction pumps described below. See also: Induction motor

**Linear induction pumps**

These pumps use a stationary polyphase ac winding to produce a traveling magnetic field that induces a current in the liquid. The reaction between the induced current and the traveling magnetic field causes the liquid to follow the traveling magnetic field. The force generated in the liquid is confined in the duct, producing a linear flow.

Two principal designs are the flat linear and the annular linear induction pumps. The flat linear induction pump has a rectangular duct connected to inlet and outlet nozzles. Several liquid-metal-cooled reactors use such pumps in their main heat transport systems. The annular induction pump design has a cylindrical duct formed by two concentric tubes. These pumps are designed for loop application. They are temperature-limited with conventional electrical insulation and in most cases require a separate cooling system for the electrical windings. However, for application to pool- or tank-type liquid-metal-cooled reactors, there is considerable interest in the design and development of large submersible self-cooled (windings cooled by the liquid being pumped) linear induction pumps.

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