Alexandria Engineering Journal (2016) **55**, 1347–1358

HOSTED BY ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

REVIEW

Review of magnetohydrodynamic pump applications

O.M. Al-Hababheh *, **M. Al-Saqqa, M. Safi, T. Abo Khater**

Department of Mechatronics Engineering, Faculty of Engineering and Technology, The University of Jordan, Jordan

Received 1 May 2015; revised 23 February 2016; accepted 3 March 2016
Available online 24 March 2016

KEYWORDS

Magnetohydrodynamic (MHD) pump;
Seawater pump;
Molten metal pump;
Molten salt pump;
Nano-fluid Pump;
Micro-pump

Abstract Magneto-hydrodynamic (MHD) principle is an important interdisciplinary field. One of the most important applications of this effect is pumping of materials that are hard to pump using conventional pumps. In this work, the progress achieved in this field is surveyed and organized according to the type of application. The literature of the past 27 years is searched for the major developments of MHD applications. MHD seawater thrusters are promising for a variety of applications requiring high flow rates and velocity. MHD molten metal pump is important replacement to conventional pumps because their moving parts cannot stand the molten metal temperature. MHD molten salt pump is used for nuclear reactor coolants due to its no-moving-parts feature. Nanofluid MHD pumping is a promising technology especially for bioapplications. Advantages of MHD include silence due to no-moving-parts propulsion. Much progress has been made, but with MHD pump still not suitable for wider applications, this remains a fertile area for future research.

Contents

1. Introduction 1348
   1.1. Definition. 1348
   1.2. Theory of operation 1348
   1.3. Overview of MHD pump applications 1350
2. Seawater pumping 1350
3. Molten metal pumping. 1353
4. Molten salt pumping 1354
5. Nanofluid pumping 1355

* Corresponding author.
E-mail addresses: o.habahbeh@ju.edu.jo (O.M. Al-Hababheh), mohsaqqa2@hotmail.com (M. Al-Saqqa), alsarise@yahoo.com (M. Safi), tutu_khater@hotmail.com (T. Abo Khater).
Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.03.001
1110-0168

6. Conclusion 1356
References 1357

1. Introduction

From space ships to military submarines and power generation; high speed electromagnetic propulsion is widely used and studied. For example, some propulsion systems require pumping force without any moving parts. Other systems like space ships have no air and not enough fuel to thrust. Systems with very high temperature like molten metal or liquid can be driven or steered using MHD force. MHD force can provide thrusting force for plasma thruster used in space ships. On the other hand, conductive metals and molten salts can generate power using MHD principle. Therapeutic MHD can be used as a micro-pump for blood pumping to maintain sugar level in blood. MHD micro-pumps have attracted interest from researchers and technology companies, as it can solve most of the problems of moving micro-parts. Some applications of magneto-hydrodynamics are shown in Fig. 1.

1.1. Definition

The basic principle of MHD is straightforward; a unidirectional current is established through an electrically conducting fluid such as seawater. Then, a high intensity magnetic field perpendicular to the current is imposed through the fluid. This combination of orthogonal magnetic field, electric field, and a relative motion of ions results in a Lorentz force with direction defined by the cross product of current and magnetic field vectors. If the device containing the electromagnet and the enclosure is fixed, the fluid is essentially pumped. However, if the device is free or has minimal resistance to motion, it will recoil according to Newton's second law of motion. In this case, the device is referred to as pump-jet or thruster. The major structural components of MHD pump are inlet nozzle, main body, and nozzle diffuser, as shown in Fig. 2. The superconducting magnet and electrodes are arranged in the main body such that electric and magnetic fields are orthogonal. Some advantages and disadvantages of MHD pumps as opposed to conventional pumps are summarized in Table 1.

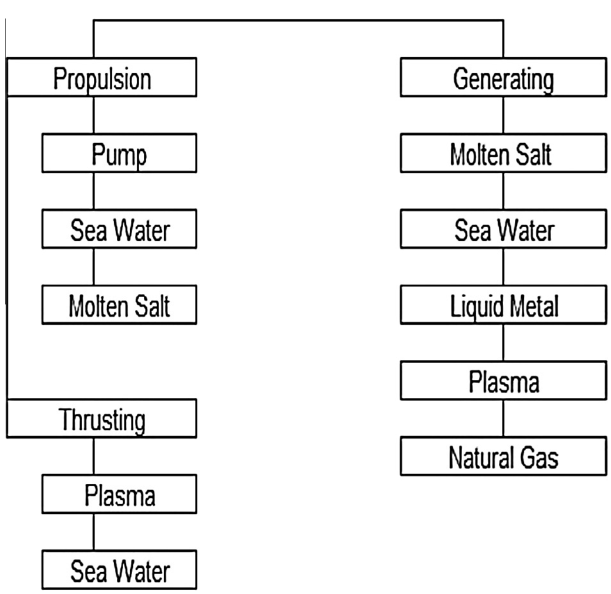

Figure 1 Magneto-hydrodynamics applications.

1.2. Theory of operation

In this section, a simplified mathematical description of an ideal MHD pump is provided. This also serves to introduce some of the basic terms and concepts. Recent research revealed some complications which may reduce the efficiency of an MHD pump. The following equations are applicable to any fluid of scalar electrical conductivity s (S/m) at a given point, and velocity vector V (m/s). If the fluid is subjected to the combination of electric field vector E (V/m), and magnetic flux density vector B (T), then the induced electric current density J (A/m^2) is a vector with a magnitude and direction defined by:

$$J = s(E + V \times B) \quad (1)$$

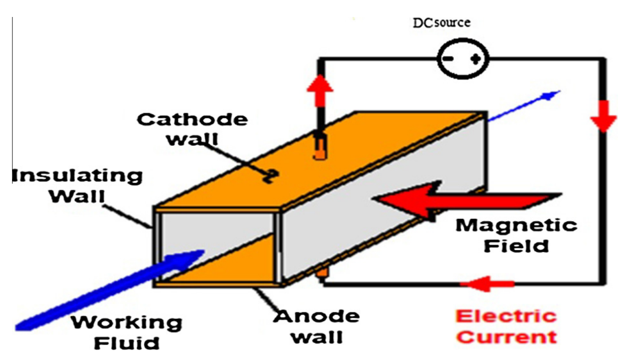

Figure 2 MHD pump components.

Table 1 Advantages and disadvantages of MHD pumps.

Advantages	Disadvantages
– Simple and compact – Can stand very high temperature environments – Silence due to no-moving-parts – More reliable since there are no moving parts – High efficiency – Short transient time – Minimal maintenance required – Easier fabrication at micro-scale – High power density	– Superconductor technology challenges prevents wider use – Reverse flow at end of magnetic field – Large magnets is a major expense – Lack of accurate analytical models – Non-homogeneous distribution of the fluid velocity profile and instability of the flow under certain operating conditions [1]