Experimental and numerical analyses of the magnetic field spatial measurement inside an electromagnetic pump channel duct

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Abstract

In the framework of the French Alternative Energies and Atomic Energy Commission (AEC) R&D program developing the Advanced Sodium Technological Reactor for Industrial Demonstration (ASTRID), it has been proposed to use in secondary cooling circuit an electromagnetic induction pump (EMP) due to its superior safety features such as: no moving parts in liquid metal and absolutely hermetic construction. However, detailed studies should be carried out in order to master operation of EMP and prevent undesirable phenomenon called MHD instability, which influence both the pump efficiency and operation.

Keywords: PEMDYN; ALIP, magnetic field; numerical and experimental analyses;

Introduction

In the last three years AEC have been in charge of the design studies, engineering and construction of a new sodium loop named PEMDYN devoted to the AEC experimental high flowrate EMP. This experimental EMP is designed to have similar magneto hydrodynamics characteristic to those attended for ASTRID secondary loop, in order to dispose of experimental results which validates numerical models used for the pre-dimensioning, with the main objective to develop and qualify a numerical finite element model of electromagnetic instabilities of ALIP.

This prototype is an Annular Linear Induction Pump (ALIP) designed for the studies for different magnetic circuit configurations and hydraulic configurations. The inner core can be removed to implement sensors or replaced with a second inductor where coils are embedded in laminated ferromagnetic core, for a better understanding and quantification of additional MHD effects and instabilities of double supplied ALIP.

The present work describes the current status of the experimental and numerical analyses to detect and investigate flow instabilities of the liquid sodium in the innovative ALIP in the PEMDYN loop (Fig 1). The aim of present paper is to present the analysis of the 3D measurement of the magnetic fields along a path inside the ALIP channel, measured with Hall sensor, to numerical finite element models built to achieve the goal of deeper understanding of the interdependent phenomena specific to electromagnetic pumps operation. These measurements are obtained before the operative condition in order to retrieve as much information as possible about electromagnetic pumps behavior in a simplifying hypothesis that does not take into account the fluid dynamics to define to the full exploitation of electromagnetic models.

ALIP is asynchronous electrical machine which uses traveling magnetic field to create EM force and motion of liquid metal. Induced magnetic field in EMIP is a function of liquid metal velocity, therefore magnetic field measurement contain information about the flow structure in the channel. A specific device was designed for the 3D measurement of the AC magnetic fields within the channel, show in the Fig2. This device has several important advantages: no metallic component, small size, high signal/noise ratio due to the hall sensor, 3D AC magnetic measurement for 3 points simultaneously inside the channel, access to 7 azimuths measured inside the channel.

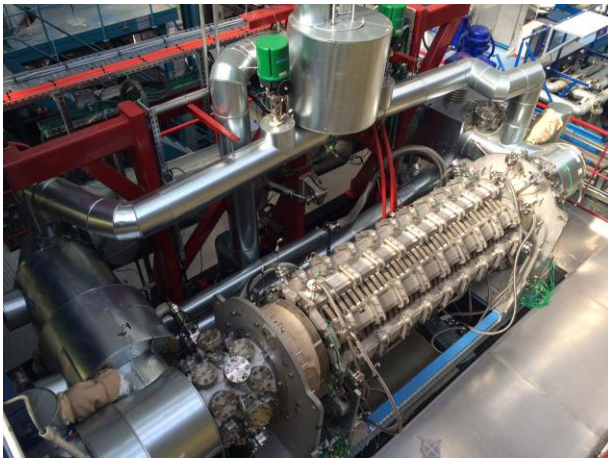

Fig1: ALIP of the PEMDYN loop

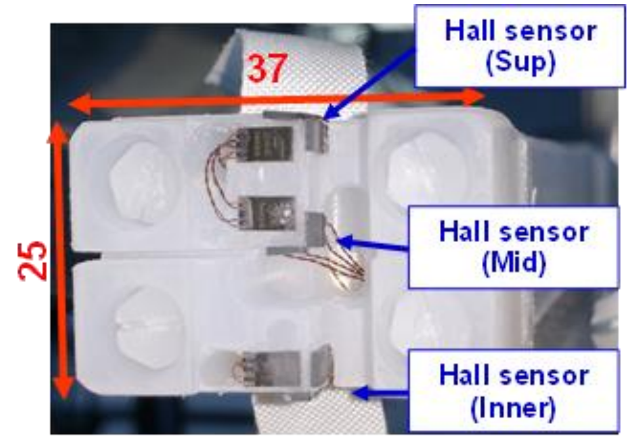

Fig2: Magnetic field sampler head used in experiment

The result of fitting modulus of magnetic field in the centre of channel is shown in fig. 3. Overall agreement in the inductor zone is acceptable.

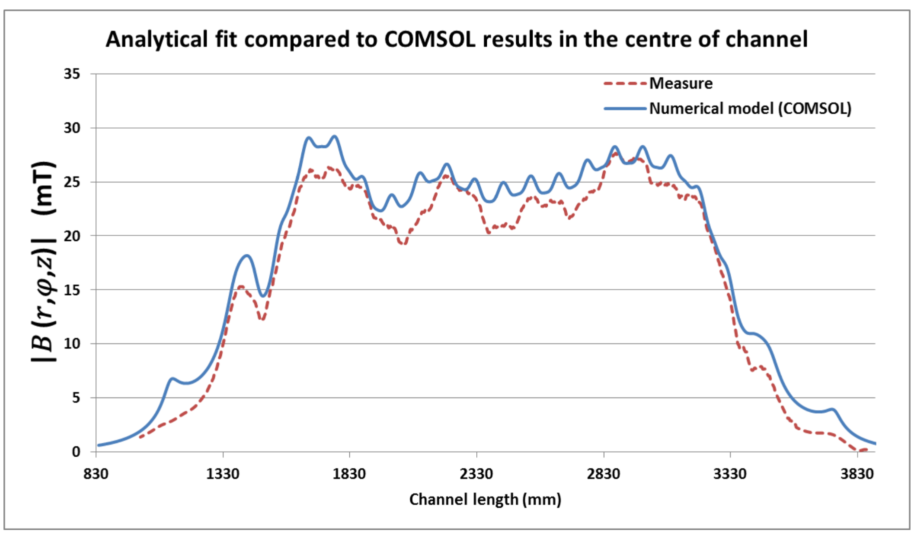

Fig 3: Analytical fit compared to COMSOL results in the centre of channel

The next step is to implement MHD sensor around the channel and to build numerical models that couple the electromagnetism and the fluid dynamics, namely the two interdependent physics that govern the magneto hydrodynamic flow through channels of electromagnetic pumps.