Comparison of COMSOL simulation of annular linear induction pump with mesh / matrix and equivalent circuit based methods

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INTRODUCTION: Electromagnetic pumps are used in pumping of liquid metals in nuclear reactors and in metallurgical applications. One such type of pump is annular linear induction pump (ALIP). In this pump, a linear traveling magnetic field is produced by means of 3-phase distributed windings and interaction of this traveling magnetic field with liquid metal kept in an annular duct results in pumping force on liquid metal.

Design of these pumps is usually done electrical equivalent circuit [1] and thereafter hydraulic effects are taken into account separately. On the finalized design, detailed calculations are usually carried out using in-house developed codes.

MODELING & SIMULATION: A 2-Dimensional model of the pump was made in COMSOL and solved in time-harmonic domain. The simulation of ALIP has been done in the following three stages in COMSOL.

a. First Navier Stokes equations are solved for flow and the velocity profile is obtained for the specified flow.

b. Electromagnetic force is computed for the velocity obtained in *a*.

c. Flow equations are once again solved for the electromagnetic force obtained in *b* and the pressure developed by the pump is obtained.

The electromagnetic force produced in the liquid metal is coupled to the fluid flow by adding the electromagnetic force to the Navier-Stokes equation as a volume force. Then the resultant pressure obtained from solving Navier Stokes equation yields the pressure developed by the pump. The hydraulic losses are already accounted in the Navier Stokes equation.

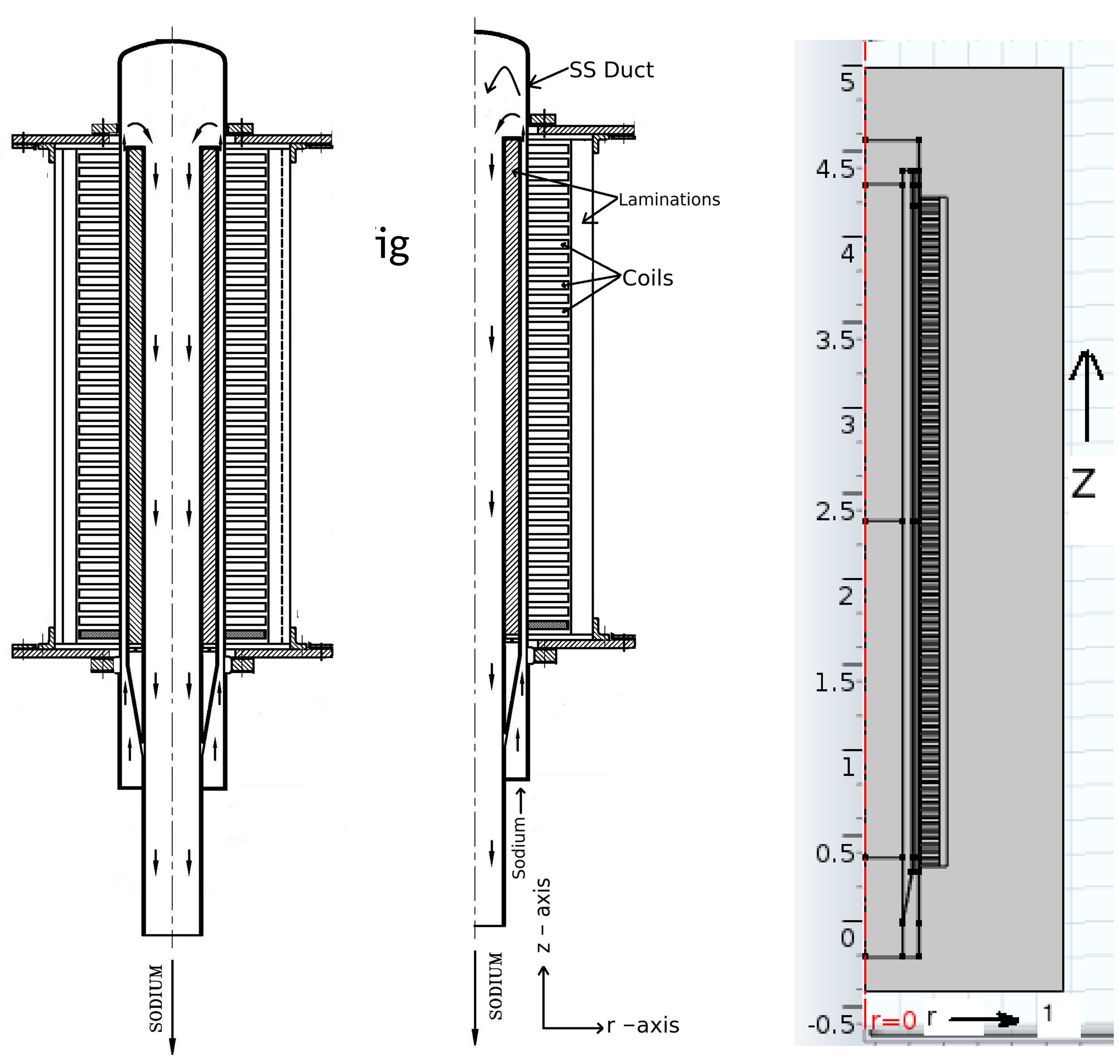

Figure 1. 2-Dimensional Approximation of pump geometry and its modeling in COMSOL

RESULTS: The simulation was carried at a sodium temperature of 459 °C which is temperature given in ref [2]. The results obtained are compared with results of the computation using the electrical equivalent circuit and also with results of mesh/matrix method [2]. The head vs flow characteristics (Fig. 2) is like that of a lossy induction motor. The pressure predicted by equivalent circuit approach [1] is much larger than that predicted by other two approaches. This may be because at large gap for sodium flow, the effect of skin depth as well as end effects become prominent which are not sufficiently accounted for in equivalent circuit model. Some deviations are obtained in the pressure vs flow characteristics between COMSOL and mesh/matrix method. This may be due to non-availability of all finer geometrical details.

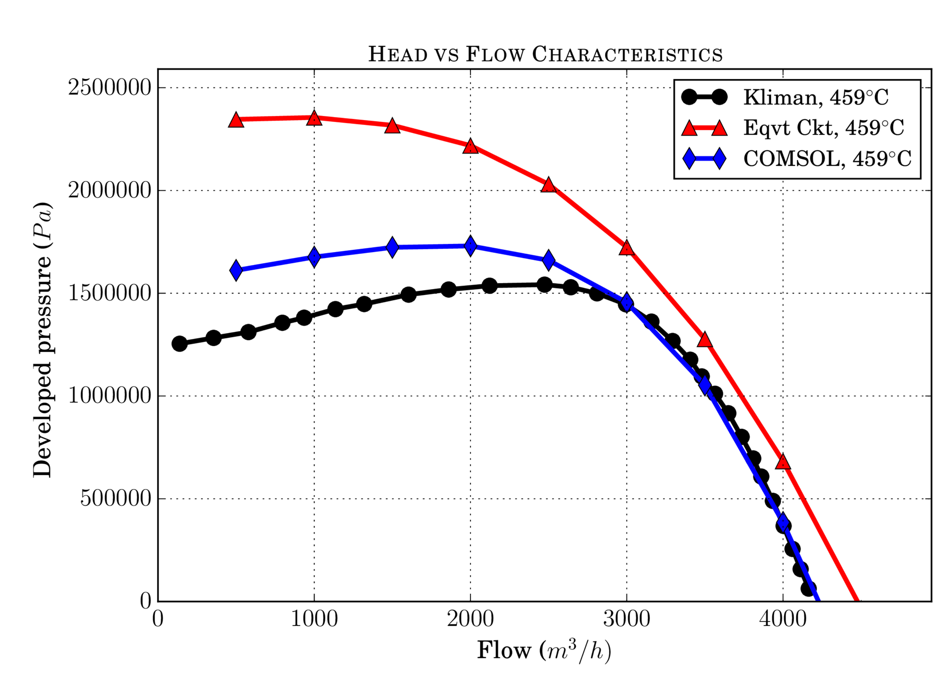

Figure 2. Comparison of Pressure vs flow Characteristics of the pump

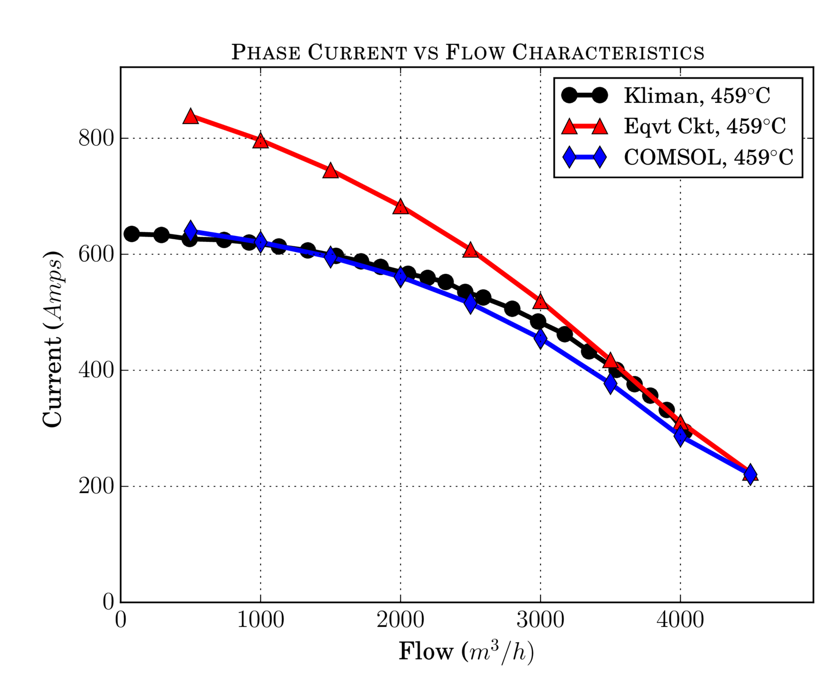

Figure 3. Phase current vs flow Characteristics of pump

Variable	Value	Units
Flow	3294	m³/h
Rated Pressure	1.262	MPa
Fluid Temperature	459	°C
Line Voltage	3236	V
Sodium Gap	32.3	mm

Table 1. Parameters of Pump

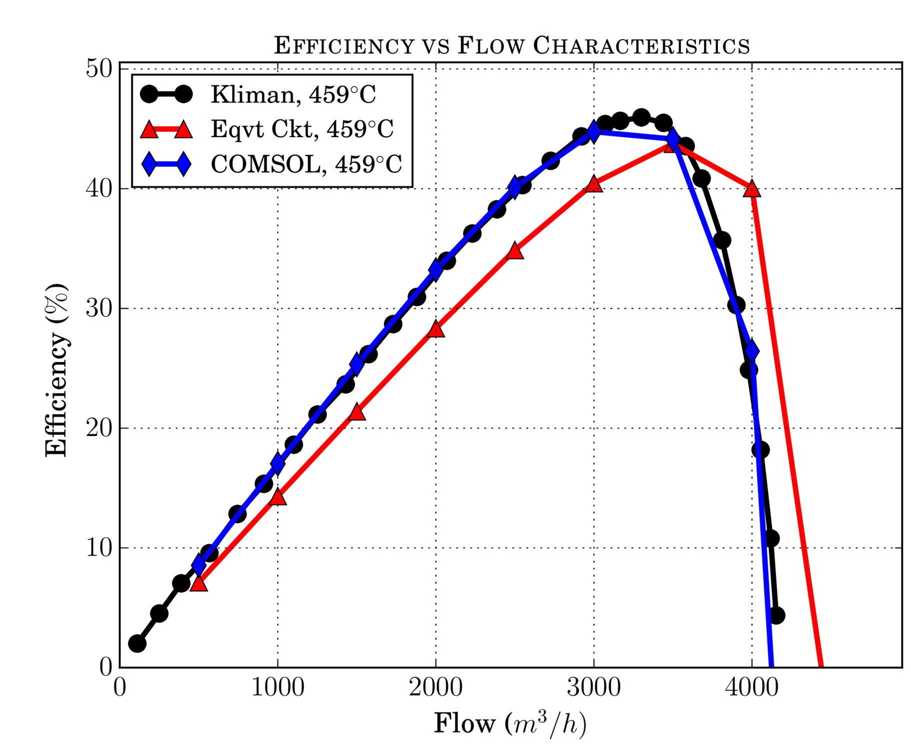

Figure 5.Efficiency vs Flow Characteristics of pump

CONCLUSIONS: The developed model of the pump is able to take into account many effects which are not included in the traditional electrical equivalent circuit based design approach and results also compare well with results available in literature.

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