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PERMANENT MAGNET MHD PUMPS COMPUTED AS LINEAR PUMPS

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The method consists in modeling rotating permanent magnet pumps as they ware linear pumps. This in necessary due to used method, which consist in keeping the magnetic field steady and use a high velocity for the molten metal.

Keywords: Inventor, ANSYS, MHD, Lead

1. Introduction

Modeling magneto-hydro-dynamic (MHD) flow can be difficult. The main concern consists in finding a method that will provide an easy way and be in the same time accurate. The analytical approach is a fast method but the results are not all the time reliable due to complexity of the problem. The numerical approach is more elaborate, more time consuming, but the results are more reliable [1].

A MHD Computation Fluid Dynamics (CFD) involves an electrical conducting fluid (molten metal in our case) and a moving magnetic field [2]. Solving this type of problem in FLUENT mean that the solution will be solved as transient, in which case we have to specify for each time step the values of magnetic field intensity for each node. In this case, the magnetic field generated by ANSYS APDL will be computed for each time step.

A more simplify solution is to keep steady the magnetic field and move the electrical conducting liquid, molten lead in our case. Having a stationary magnetic field and move the molten metal in the presence of magnetic field will imply solving a CFD case as a stationary one.

The current papers present a better solution for modeling U shape MHD pumps for molten lead. The method consists in modeling rotating permanent magnets pumps as they ware linear and the walls treated as symmetry. The challenging of modeling U shape MHD pump type consists in finding an optimum between inlet velocity and precision due to U shape for high inlet velocity the pressure drop generated by friction between internal fluid layers is grater then the pressure drop generated by external magnetic field. For low inlet velocity under couple of meter per seconds the results are reliable but for high velocity the shape

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of the channel will generate more pressure lose then the pressure lose generated by the magnetic field.

Due to high speed rotating velocity of the rotor, up to 10 000 rpm, the equivalent linear velocity at the outside edge of the rotor is about 100m/s. The velocity of magnetic field is quite high relative to molten liquid velocity inside the pipe.

2. Pump geometry

As any mechanical pump, is made by two groups of components. One group of components represents the stator (stationary components) and the other is the rotor (components that are spinning). The stator is made of one component, which is a U shape pipe with flanges at the end of pipe. The rotor group is made of several components, some of them are essential components as magnets, magnetic york, and the others are only to keep in place the others.

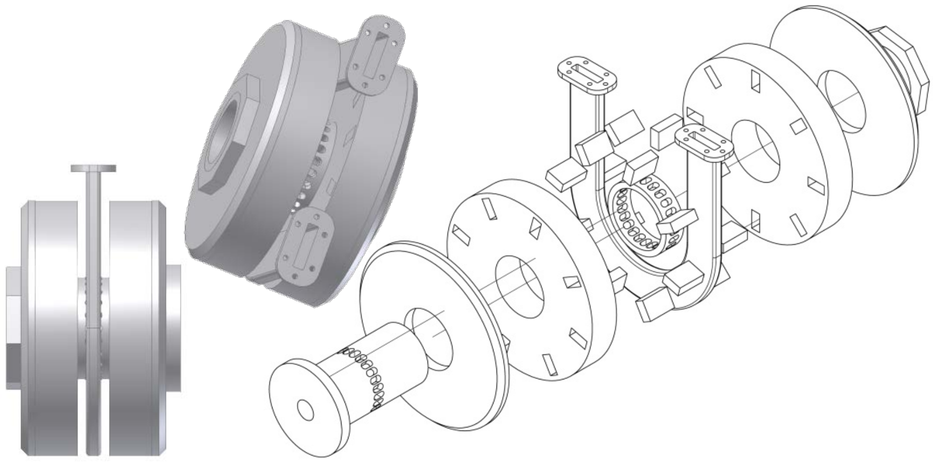

Fig. 1. Permanent magnets MHD pump design, assembled, two images on left side and disassembled on the right part.

In Fig. 1 on the right image are presented the structural pump components. Starting from the left side of the components image the first one is the central axial pivot, which has the role of keeping all the components in an axial lineament and transfers the power from the motor to pump rotor. The second component, disk shape, is the first magnetic york, which is used to conduct the magnetic field from one magnet to the other. The third component is the magnets bracket, which is meant to keep in place the magnets when the pump is spinning and the centrifugal force tries to displace the magnet outside the pump. The forth components are the first row of magnets, eight of them, positioned with the north pole alternated. The other row of magnets, bracket and magnetic york are positioned mirrored referenced on plane situated on the U shape pipe. The central component, which is situated on the central part of the U shape pipe is the spacer. His role is to maintain certain distance between brackets, magnetic york and magnets.

The pump is design to maintain certain temperature at the magnets surface. This is achieved by blowing air in the space between pipe and magnets. The air is pump by an industrial fan to the central pivot, which has side holes to permit the air going outside.

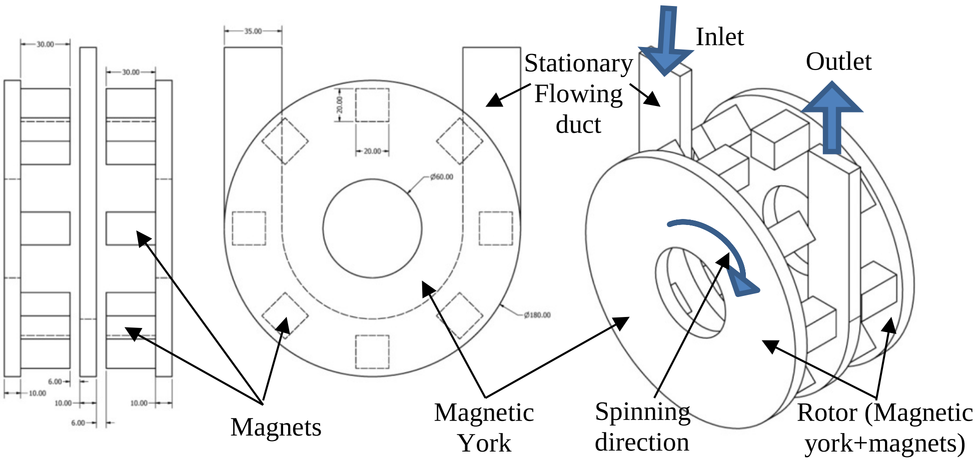

Fig. 2. MHD pump components, used for MHD flow computing and dimensions

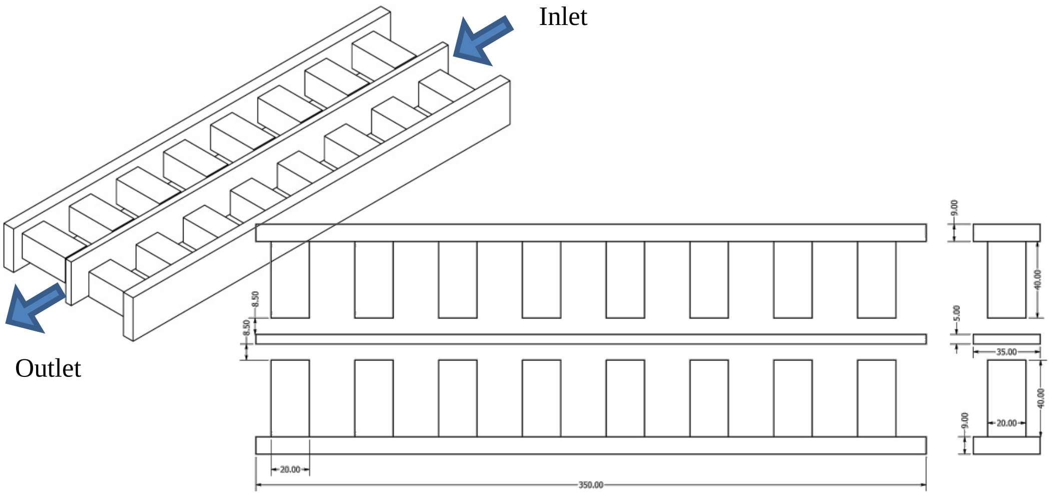

Fig. 3. Equivalent linear MHD pump

The dimensions of the central pipe are: length 350 mm, high 10 mm, width 35 mm.

3. CFD model implementation

The method solving this CFD model is use an equivalent linear geometry instead of circular geometry, figures 2 and 3. This linear geometry is free of pressure drop due to different velocity between internal flowing layers. A stationary magnetic field and imposes a high velocity to the liquid metal. To remove the influence of the drag force between liquid and pipe walls we set the walls as moving walls, and the speed was set as the value of the inlet velocity.

Table 1

Parameters values for different pump configuration

Criteria	Number of magnets	Clearance [mm]	Magnet thickness [mm]
1	12	6	20
2	10	6	20
3	8	6	20
4	8	4	20
5	8	8	20
6	8	10	20
7	8	6	10
8	8	6	30

The default case is the case number 3, with 8 permanent magnets configuration, has a clearance of 6 mm between duct wall and each side of spinning magnets. Magnets thickness is the dimension of the magnet side which is in the direction parallel with the flowing direction.

Software used as tool chain

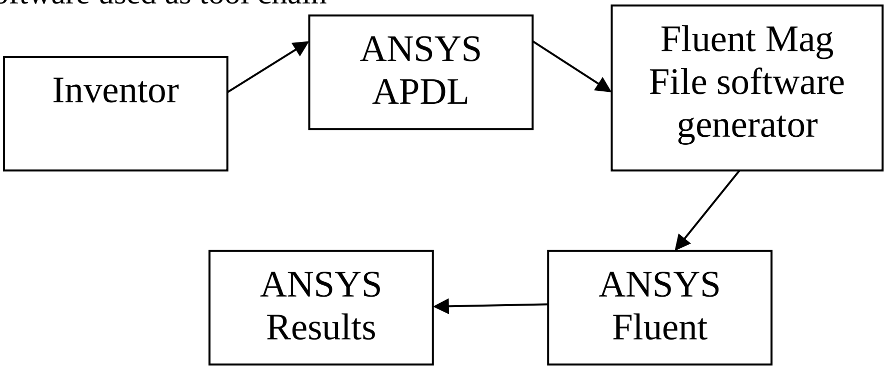

Fig. 4. Tool chain software used for CFD

Fig. 4 presents the software used to implement the MHD-CFD models.
For geometry Inventor was used as computation aid design (CAD)[3] for mechanical design, design of magnetic components used for ANSYS APDL [4] and linear pipe design for Fluent.
The second software used in this chain of software is ANSYS APDL, as magnetic field generator. This software is able to compute the magnetic field distribution in the region surrounding the magnets.
The third software is homemade, design to combine some files generated by ANSYS APDL in one file compatible with Fluent, MHD module [6].
The fifth software used is FLUENT; this is CFD software, which is able to compute the MHD pressure drop.
The last software used is ANSYS RESULTS; this software is used to extract data for printing as graph, tables or contours.

ANSYS APDL

Material properties
Permanent magnets residual induction is 1.1 T, relative magnetic permeability of the magnetic york is 1000.

Fluent Mag File software generator

Fluent Mag File software generator it is software developed using LabVIEW [5]. The software is able to read ANSYS APDL output files and process all the information inside these files and in the end is going to create another type of file, which is compatible with Fluent MHD. The software has many features included as magnetic field vectors 3D view, including ability to rotate the view in space, but also the ability to compute the geometrical enclose of the domain.

ANSYS Fluent

Material properties
The liquid metal is considerate lead. The properties of melted lead are 10560 Kg/m^3 for density, 0.00222 kg/m-s for dynamic viscosity and 10^6 1/ohm-m for the electrical conductivity.

Initial and boundary condition
All evaluations for presented MHD pump are computed using as input velocity the value of 20 m/s. We have used only one value for inlet velocity because from other previous evaluations the pressure drop is linear proportional with the inlet

velocity. The 20 m/s inlet velocity correspond to a rotational velocity of 2600 rpm for a mean radius of 72.5 mm for the bending radius of the U shape pipe.

4. Results

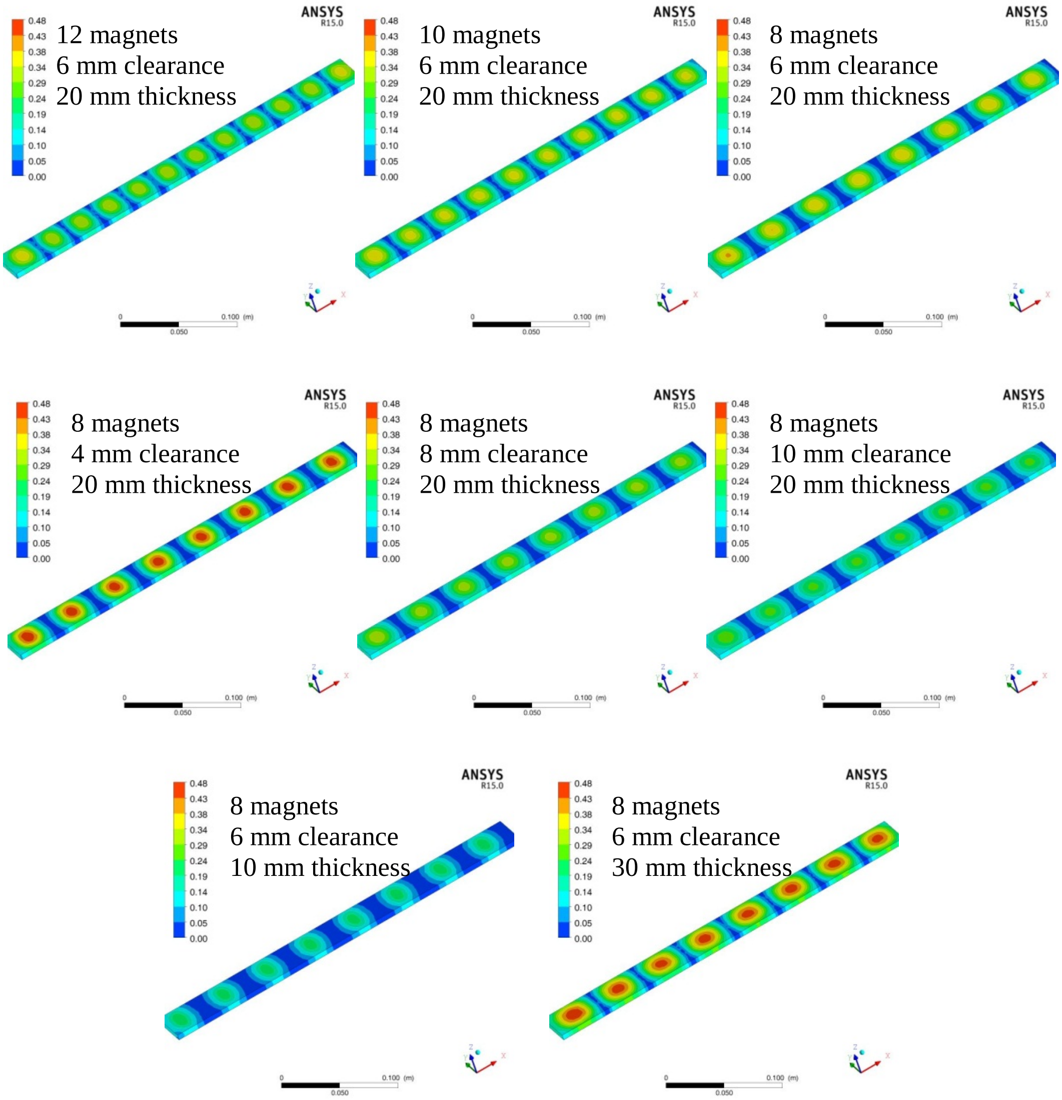

Fig. 5. Permanent magnets magnetic field comparison. The measurement unit is Tesla.

Fig. 5 presents the magnetic field distribution, generated by the neodymium permanent magnets. Results are computed using ANSYS APDL and results are processed using ANSYS POST-Pro.

The first tree images (from the first row if images) are for the configuration whit 12, 10 and 8 magnets. The color represents the intensity of the magnetic field.

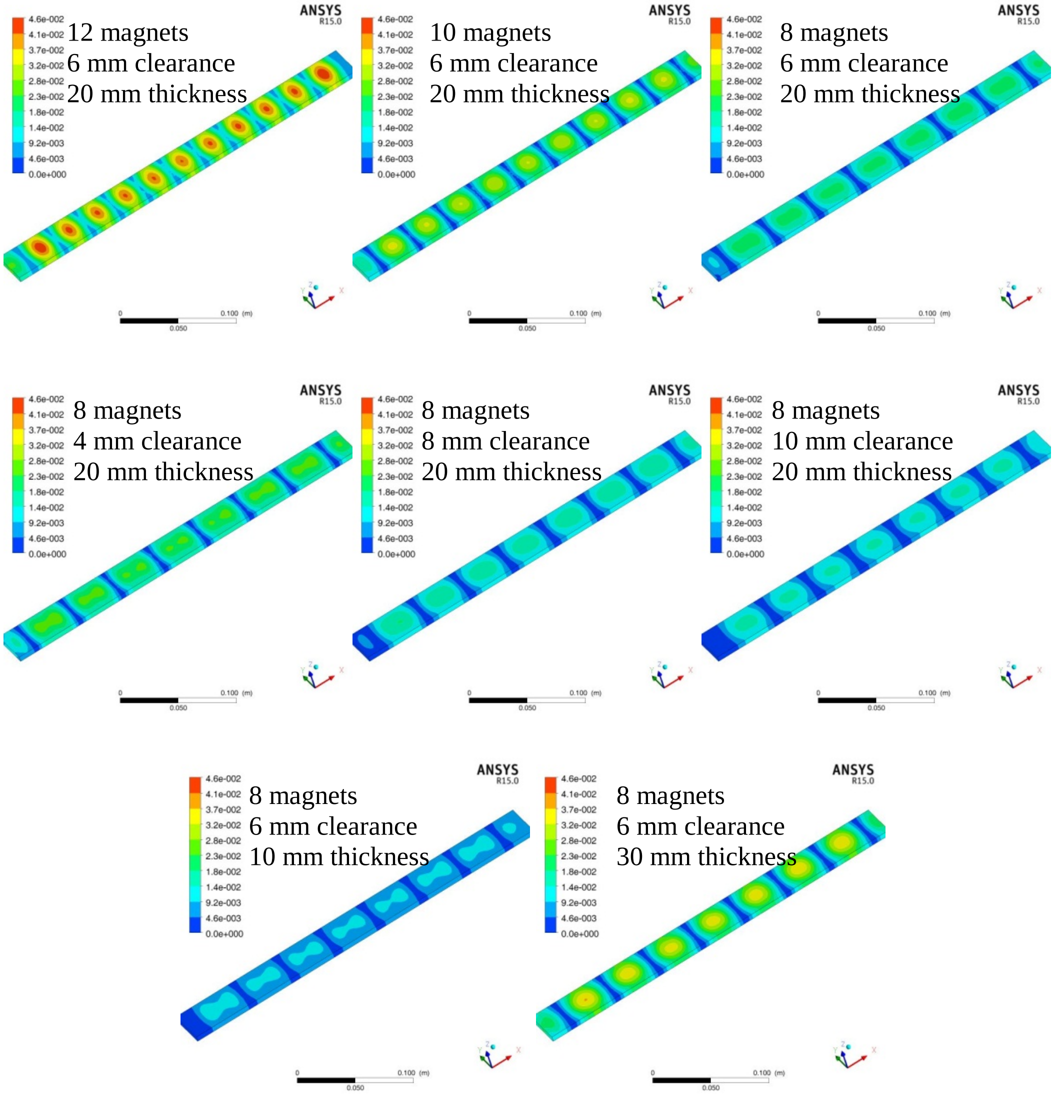

Fig. 6. Magnetic field induced by liquid metal flowing in presence of a magnetic field. The measure unit is Tesla.

The above figure (Fig. number 6), represent the induced magnetic field. This magnetic field is generated by the moving conducting liquid in the presence of the magnetic field, presented in Fig. 5. When a conducting liquid or solid is moving in the presence of a magnetic field is going to generate electric current. The current is generated in the space under the pole of the magnet and is going to close the electric circuit moving in the other direction in the space between magnets

from the same set of magnets. These types of currents are known as Eddy currents.
Results computed using ANSYS FLUENT and processed in ANSYS POST-Pro

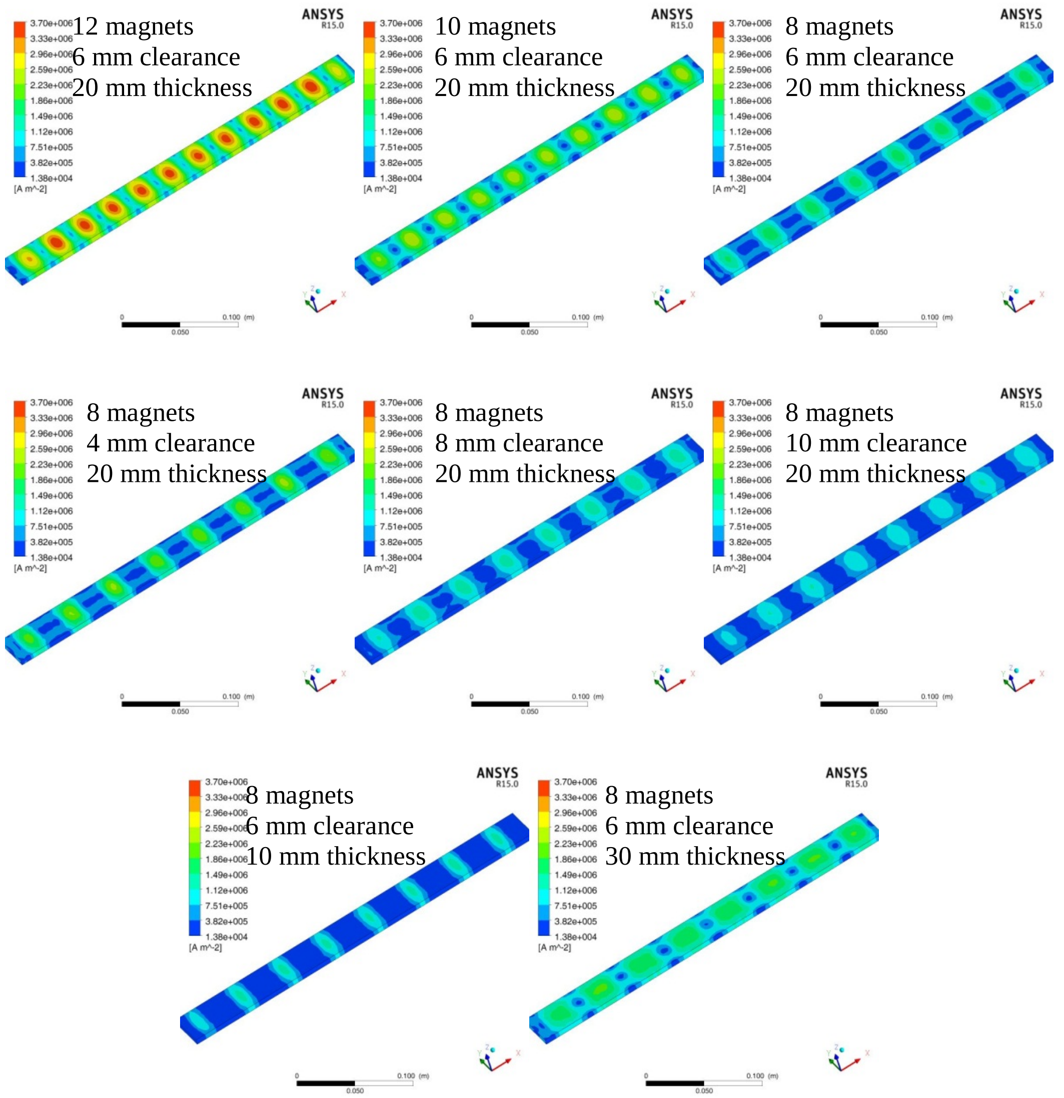

Fig. 7. Current density. The measure units it is A/m^2.

Fig. 7 presents the current density witch is form inside the melted lead due to flowing in presence of a magnetic field. The maximal density of current is in the space between magnets from opposite side of the rows. The minimal value is standing between magnets from same row, which are positioned with alternating polarization.

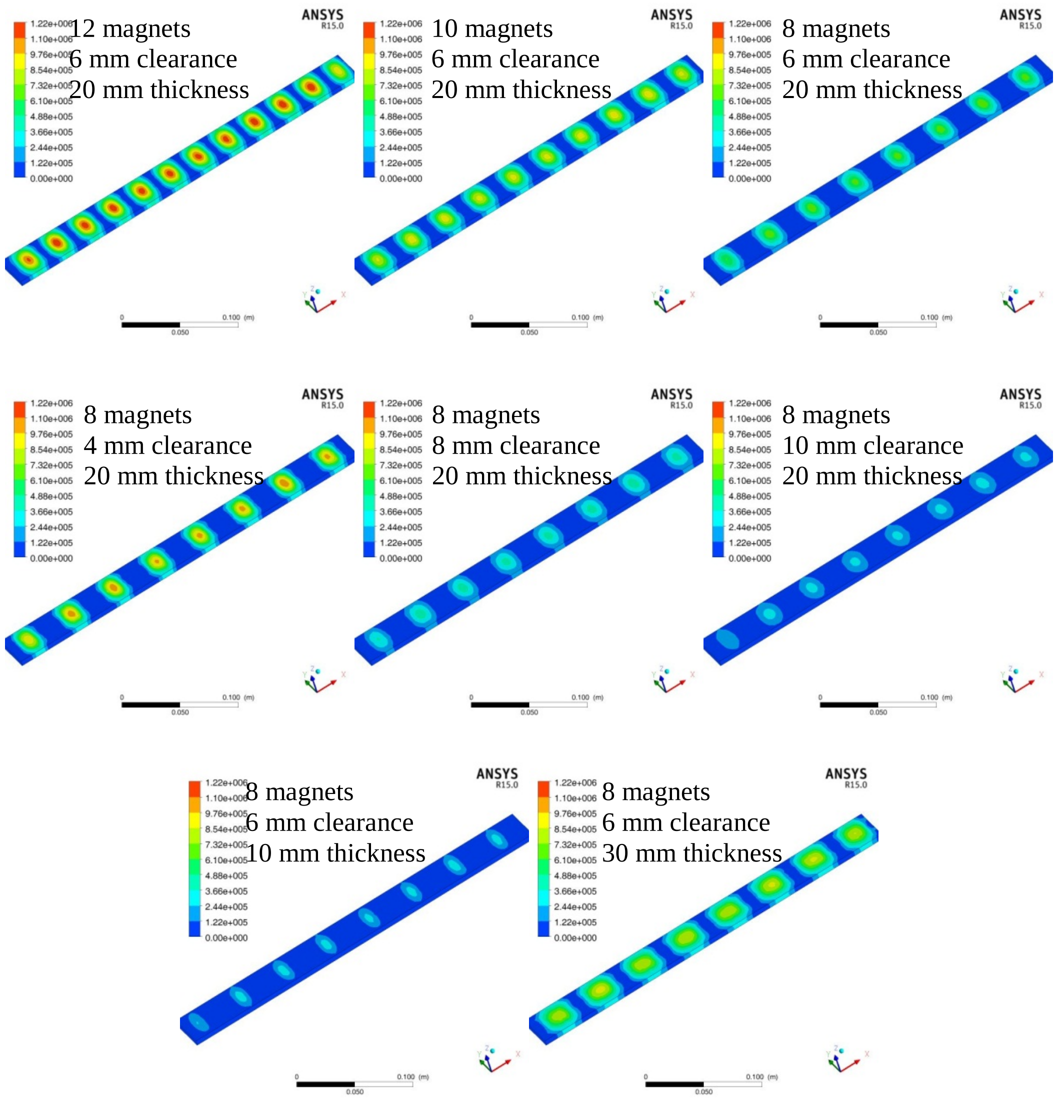

Fig. 8. Generated force. The measure units is N/m^3.

Fig. 8 presents the resulting force between two magnetic fields; one is the initial magnetic field generated by the permanent magnets and the other one generated by the current, which is generated in the flowing fluid. The generated currents inside the molten metal are named Eddy currents. These forces are creating the pressure generation.

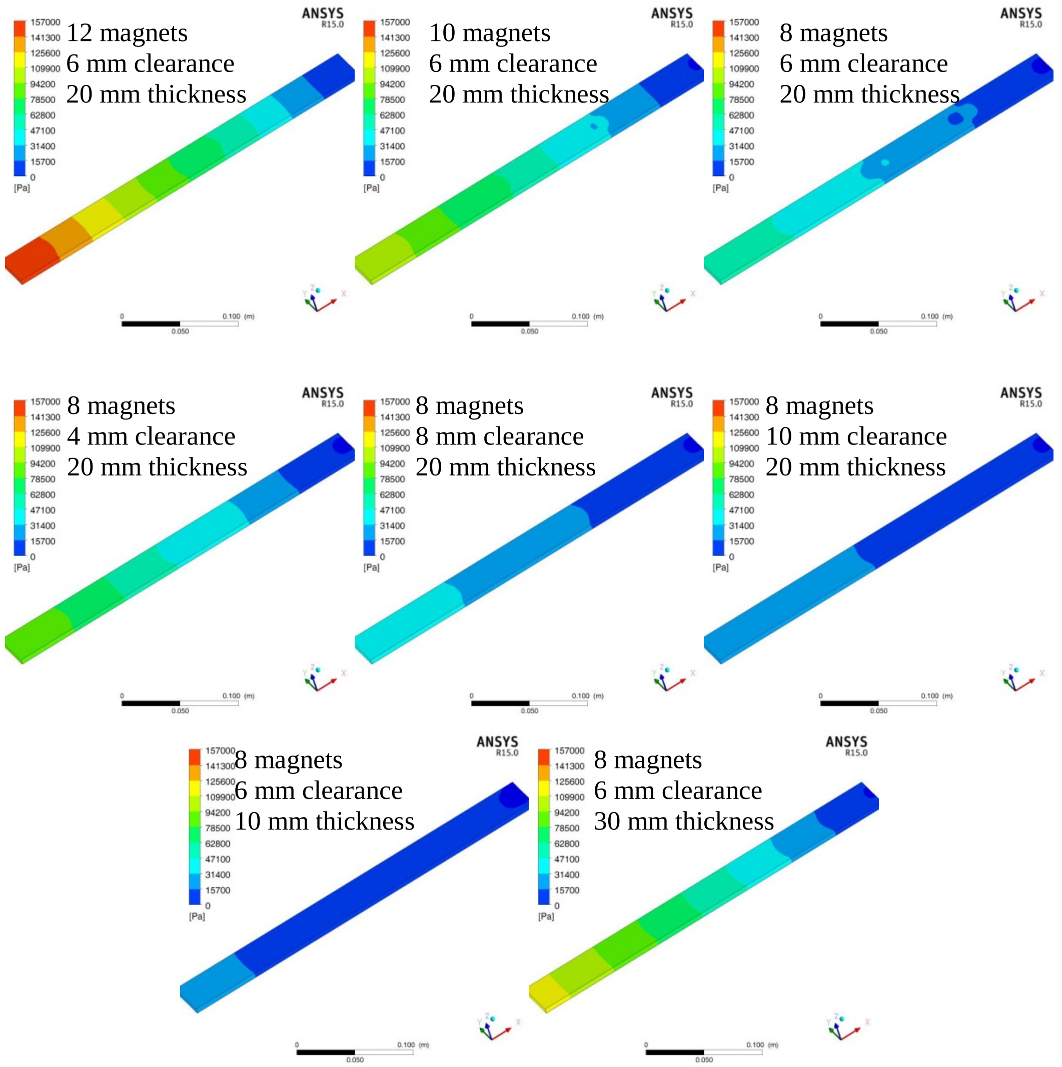

Fig. 9. Generated pressure by presented MHD pumps.

The most important parameter that is characterizing a MHD pump is the pressure that the pump is generating. This aspect is presented in figure 9. The measure unit is Pascal. The inlet is located in the down left side of each channel side. Because the method solving the CFD is based on the two important condition inlet velocity and output pressure, the output pressure is set to zero, all other pressures are computed in respect with the outlet pressure, is visible that the highest value is at the inlet.

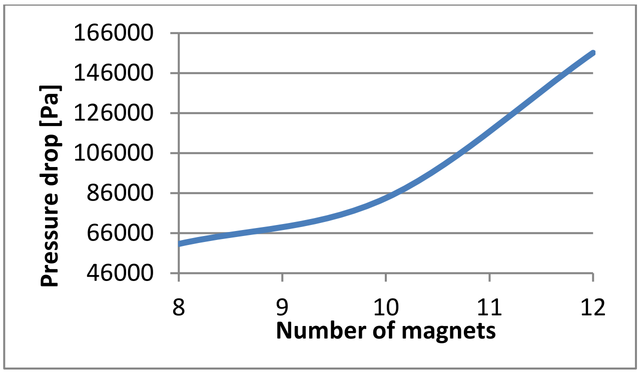

Fig. 10. Generated pressure related to number of magnets

Table2

Generated pressure for each case

Criteria	Generated pressure [Pa]
1	156151
2	83562
3	60623
4	89791
5	41418
6	28800
7	19246
8	152457

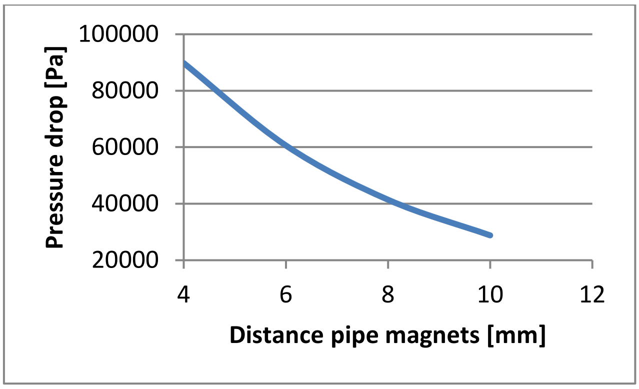

Fig. 11. Generated pressure related to distance between pipe and magnets.

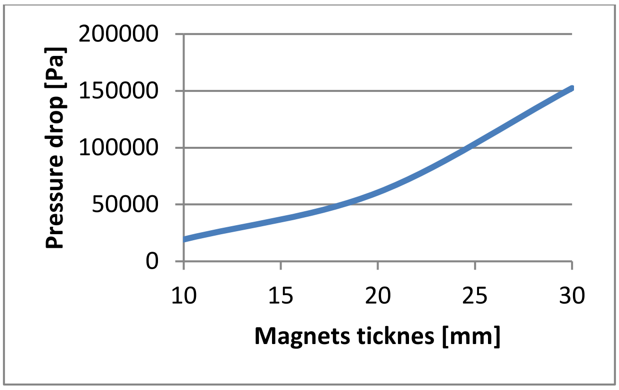

Fig. 12. Generated pressure related to magnets thickness in strait flow direction.

Table 2 presents the pressure generated for each case implemented. Figure 10 presents the relationship between pressure and the number of magnets on each row of magnets. Increasing the number of magnets is generating more current in

the molten liquid volume. The increasing current in the liquid mass is going to increase the strength of the Eddy current, in response the attraction force between magnet and Eddy current is increasing proportional.
Figure 11 describe the relationship between pressure and clearance between magnets and pipe walls. For practical reasons is tot possible to use the minimal distance between magnets and pipe walls due to high temperature of molten liquid inside the pipe.
The figure number 12 present pressure variations according to magnets thickness. The thickness of the magnets is the dimension parallel to flowing direction. Increasing the magnets thickness is the same as increasing the magnetic flux inside the liquid. This in turn will result in generating more current which will generate more attraction force between magnets and Eddy currents. The result will be more drag forces in the mass of molten metal.

5. Conclusions

Simplifying the model give us the possibility of solving a complex problem, but also helps us decreasing the number of elements which in turn was able to decrease of time necessary to reach desired convergence criteria.

Designing a pump having a configuration with more magnets but keeping enough space between magnets to allow eddy currents to form is the best configuration for a permanent magnets MHD pump. The distance between magnets is recommended to be the same as magnets thickness. Decreasing to much the distance between magnets is going to force the current to use other path of traveling inside the molten liquid, diminishing the size of Eddy currents.

R E F E R E N C E S

[1] *B. N. Morley*, Magneto-Hydro-Dynamic Effects In Liquid Flows.
[2] IV International Workshop on Materials for HLM-cooled Reactors and Related Technologies, ROMA, ITALY, May 21-23, 2007.
[3] *C. Stancescu*, Modelarea parametrica si adaptativa cu Inventor (Paramerical and adaptative design using Inventor), Fast, Bucuresti,2014.
[4] ANSYS , ANSYS APDL User Guide.
[5] National Instruments, LabVIEW User Manual.
[6] ANSYS. ANSYS FLUENT Magnetohydrodynamics (MHD) – Module Manual.