Study of heat exchanger by using Fluid Structure Interaction Method

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***Abstract* — In this study, the research is planned in finding how to calculate the fluid induced stresses over shell and also to calculate heat transfer and pressure drop in shell side using fluid structure interaction (FSI) method. Comparison will be carried out for performance parameters like computational time and accuracy of results between hex and tetrahedral element types using Ex-Sight software for FSI method.**

***Keywords*— circumferential stress, pressure drop and heat transfer coefficient, Hexahedra mesh**

I.INTRODUCTION

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. In Shell tube heat exchanger baffles are one of the most important parts, it increasing the flow area of contact with tubes to achieve heat transfer rate from one fluid to another and also support to tube which are mounted horizontally inside shell (1-2-3). There are different type of baffle arrangement and mostly segmental baffle are used in shell and tube heat exchanger causes the shell side fluid to flow in a zigzag across tube this action improve heat transfer by creating turbulence flow in shell side but it increasing pressure drop at shell side so that in this case it requires more pumping power result to increasing electricity consumption. Large flow eddy formed due to zigzag flow patterns, fouling occur in dead zone on baffle side, high pressure drop and low heat transfer coefficient at shell side.

Another type of arrangement is helical baffle and it developed by Lutcha and Nemcansky (1). Above these all loses overcome by helical baffle and helical baffle consist of two major types continuous and non-continuous. Non continuous are not commonly used due to difficulty in design and manufacturing.

II.PROBLEM IN PRESENT NUMERICAL ANALYSIS

a. Till now the helical baffle heat exchangers analysis research was carried out for a single cycle. But, this analysis for a single cycle is not possible in segmental baffle type as there is no standardization in choosing the cycle start and cycle length, which are the key factors affecting the results.
b. Due to high computational time for a complete heat exchanger model, it is followed to carry out analysis for a single cycle to reduce computational time. This induces higher inaccuracies for parameters like pressure drop and heat transfer coefficient for both types of heat exchangers.
c. The heat exchanger model is generally done with tetrahedral mesh for numerical simulation, even though tetrahedral mesh has several shortcomings. The issues are
    1. More computational time as tetrahedral element have more edges.
    2. Inability to define tetrahedral boundary layer unlike hex element, which is a serious limitation for computational fluid dynamic.
d. In segmental baffle, fluid will not flow along baffle; rather it will directly impact/hit the baffle which results in overall stress increment over shell unlike helical baffles. This investigation is only possible by FSI solve and not by CFD solver.

III.REMEDY FOR ABOVE PROBLEM

In this paper, we are considering whole model for both segmental and helical baffle type heat exchangers analysis. Hex dominant mesh is chosen for both helical and segmental heat exchangers for flow side and Tetrahedral mesh for structural side so that computational time will be reduced with a better mesh quality. FSI solver will be used to compute these analyses.

Object of this analysis is to numerically compare the stresses, pressure drop and heat transfer coefficient parameters among these two heat exchangers.

IV.GEOMETRY FOR FSI COMPUTATION

Geometric model is built in Catia V5 part design with baffle angle parameterized as shown in fig.1 & 2. Present segmental and helical baffle heat exchanger has 24 tubes.

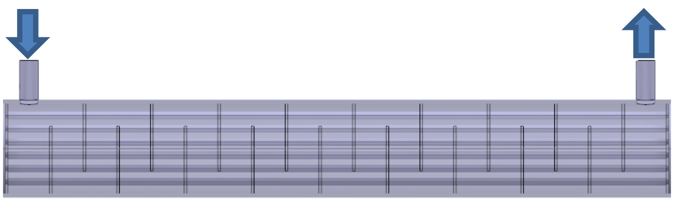

Fig.1 Catia V5 Model of Segmental baffle heat exchanger

The helical pitch (B) is determined by following equation,

$$B = \pi D_i \tan \beta$$

Where β is helix angle and D_i is the inner diameter of shell (5)

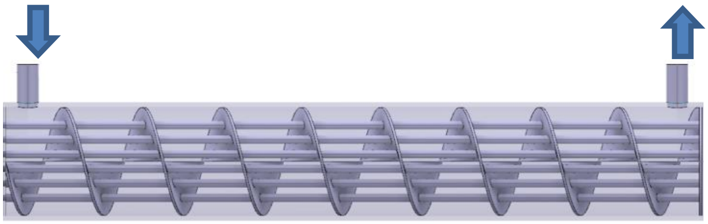

Fig.2 Catia V5 Model of Helical baffle heat exchanger

Geometry Notation	Segmental Baffle	Helical Baffle
Shell Outer Diameter	167mm	167mm
Shell Outer Diameter	153mm	153mm
Shell Length	1123mm	1123mm
Tube Inside Diameter	9.5mm	9.5mm
Tube Outside Diameter	12.5mm	12.5mm
No of tube	24	24
Tube layout	Rectangular	Rectangular
Tube Pitch	22.5	22.5
Baffle thickness	4mm	4mm
Nozzle Outside Diameter	35mm	35mm
Nozzle Inside Diameter	32mm	32mm
Head Length	100mm	100mm
Baffle Cut	20%	-
No of Baffle	17	5turns
Baffle Spacing	57mm	224mm

Specification of heat exchanger

V.NUMERICAL MODELING OF FSI

It is multi-physics capability which provides run-time coupling between multiple solvers. Data is exchanged between the domains in a synchronized manner through a common physical interface region, called interface. Two solvers start at the same time and exchange the data after every time step simultaneously refer fig.3 and 4.

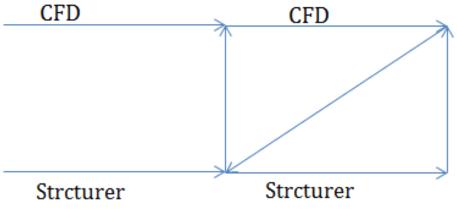

Fig.3Coupling of the solver

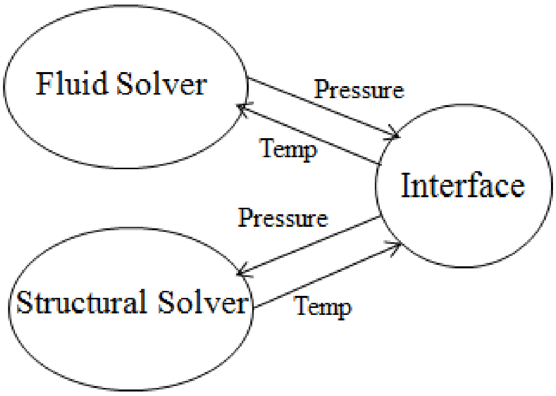

Fig.4 Co-Simulation engine for FSI

FSI is nothing but co-simulation engine, as we are going to use CFD solver as well as STANDARD solver. It runs sequentially as both the solvers starts simultaneously and after one cycle the result is transferred from one solver to other solver fig.5.

VI.BOUNDARY CONDITION AND SIMULATION SETUP

No-slip boundary condition is applied on the inner walls of shell. Velocity inlet and pressure outflow boundary conditions are applied on the inlet and outlet for both the heat exchangers. Water is considered as working fluid in both heat exchangers.

Following assumptions are made:

- Fluid flow and heat transfer processes are turbulent and transient in state.
- Natural convection induced by the fluid density variation will be neglected.
- Tube wall temperatures are kept constant in structure side.
- Hence the heat loss to the environment will totally neglected by insulating the heat exchanger.

Boundary	Boundary Type	Conditions
Inlet Shell	Mass flow inlet	60 lpm
Outlet Shell	Pressure Outlet	0 gauge pressure
Shell Wall	Wall	Adiabatic
Baffle Wall	Wall	Adiabatic
Whole HE	Initial temperature	24 deg.
Tube wall	Wall temperature	65 deg.
Interaction	Shell	Adiabatic

Boundary condition of flow side

In Structure side, both the ends of heat exchanger will be clamped with zero DOF and the initial temperature will be set at 24 deg. Tube wall temperatures will be maintained at a constant temperature 65 deg. and interactions will be provided with the internal diameter of shell. Carbon steel material is used for both the heat exchangers.

Boundary	Boundary Type	Conditions
Whole HE	Initial temperature	24 deg.
Clam the HE	Clamp	0 DOF
Tube wall	Wall temperature	65 deg.
Interaction	Shell	Adiabatic

Boundary condition of structure side

We are going to use same boundary conditions for segmental as well as helical baffle heat exchanger to find out the circumferential stresses, heat transfer coefficient and pressure drop. The efficient heat exchanger will be found out based on the comparison of a helical type with segmental type out.

VII.CONCLUSION

In literature, heat exchanger performance was analysed based on heat transfer coefficient and pressure drop parameters, but no one deliberated the life or reliability of heat exchanger by considering the computational issues and solver capability. In this paper, we will be clarifying how to calculate the life of heat exchanger based on circumferential stress; heat transfer coefficient and pressure drop by using FSI. The reduction in computational time with a higher accuracy results using hexahedron dominant mesh are also going to be discussed.

REFERENCES

1. Lei, Y.G., He, Y.L., Li, R. and Gao, Y.F., “Effect of baffle inclination angle on flow and heat transfer of a heat exchanger with helical baffles”, Chemical Engineering and Processing, 47, 2008, pp. 2336-2345.
2. Peng, B., Wang, Q. W., Zhang, C., Xie, G. N., Luo, L. Q, Chen, Q. Y. and Zeng, M., “An experimental study of Shell-and-Tube heat exchangers with continuous helical baffles”, Journal of Heat Transfer, 129, 2007, pp. 1425-1431.
3. Stehlik, P. and Wadekar, V. V., “Different strategies to improve industrial heat exchange”, Heat Transfer Engineering, 23 (6), 2002, pp. 36-48.
4. Shinde, S. and Pancha, M. H., “Comparative Thermal Performance Analysis of Segmental Baffle Heat Exchanger with Continuous Helical baffle Heat Exchanger using Kern Method”, International Journal of Engineering Research and Application , 2 2012, pp. 2264-2271
5. Lei, Y.G., He, Y.L., Li, R. and Gao, Y.F., “Effect of baffle inclination angle on flow and heat transfer of a heat exchanger with helical baffles”, Chemical Engineering and Processing, 47, 2008, pp. 2336-2345.
6. User Manual - Contents and Simulation Apps
7. Zhang, L., Xia, Y., Jiang B., Xiao, X. and Yang, X., “Pilot experimental study on shell and tube heat exchangers with small-angles helical baffles”, Chemical Engineering and Processing, 69, 2013, pp. 112-118.
8. Xiao, X., Zhang, L., Li, X., Jiang, B., Yang, X. and Xia, Y., “Numerical investigation of helical baffles heat exchanger with different Prandtl number fluids”, International Journal of Heat and Mass Transfer, 63, 2013, pp. 434-444.
9. Zhang, J. F., He, Y. L. and Tao, W. Q., “3D numerical simulation on shell-and-tube heat exchangers with middle-overlapped helical baffles and continuous baffles – Part II: simulation results of periodic model and comparison between continuous and non-continuous helical baffles, International Journal of Heat and Mass Transfer, 52, 2009, pp.5381-5389

