Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 3, March -2017

Numerical investigation of heat transfer characteristics of a Nano fluid in a circumferential fin tube heat exchanger

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Abstract — *Numerical Investigation of heat transfer and pressure drop for circumferential finned tube heat exchanger is presented in this paper considering Al2O3 Nano fluid as base fluid. The required thermo-physical properties were measured and used in CFD using UDF (User Defined Functions). The results of numerical simulation are compared with that of experimental results in order to verify the accuracy of code used in CFD.*

Further numerical simulation is carried out for 2% volume fraction of Nano particles at different Reynolds number. Thermo-Hydraulic Performance factor a measure both heat transfer and pressure drop has decreased as Reynolds number augmented. But for all Reynolds number Thermo-hydraulic performance factor obtained proves us that usage of Nano fluid is beneficial.

Keywords- *Nano Fluid, Thermo hydraulic properties, User Defined Functions, Volume fraction*

I. INTRODUCTION

A heat exchanger is a device used for affecting the process of heat exchanger between the two fluids that are at different temperatures. Heat Exchangers are useful in many engineering processes like those in refrigeration and air-conditioning system, power system, food processing systems, chemical reactors and Space or aeronautical applications. The enhancement of heating or cooling in an heat exchanger may create a saving in energy, reduce process time, reduce the pumping power

There are several methods to improve the heat transfer efficiency of the heat exchanger. Some methods are utilization of extended surfaces, application of vibration to the heat transfer surfaces, and usage of micro channels. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid. Commonly used heat transfer fluids such as water, organic liquids (e.g., ethylene glycol, tri-ethylene-glycols, refrigerants, etc.), oils and engine lubricants, bio fluids, polymeric solution etc. have relatively low thermal conductivity, when compared to the thermal conductivity of solids. High thermal conductivity of solids can be used to increase the thermal conductivity of a fluid by adding small solid particles to that fluid.

Nano fluid is a new kind of heat transfer medium, containing nanoparticles (1-100 nm) which are uniformly and stably distributed in a base fluid. These distributed nanoparticles generally metal or metal oxides greatly enhance the thermal conductivity of the Nano fluid, increases conduction and convection coefficients, allowing for more heat transfer. The nanoparticle material includes chemically stable metals (e.g., gold, copper), metal oxides (e.g., alumina, silica, zirconia, and titanium), oxide ceramics (e.g., Al_2O_3, and CuO), metal carbides (e.g., SiC), metal nitrides (e.g., AIN, SiN) , carbon in various forms (e.g., diamond, graphite, carbon nanotubes, and fullerene) and other functionalized nanoparticles.

II. REVIEW OF LITERATURE

A r j u m a n d Ad i l[1] in his paper described that the Minichannel flow of Nano fluids has been predicted considering Nano fluid as a single phase homogeneous mixture. The homogeneous mixture model for the Nano fluid holds good to predict the average Nusselt number and friction factor in case of laminar flow. Hence, the present computational model can be a good alternative approach to predict heat transfer and pressure drop characteristics of mini channel flow using Nano fluids. Also, the error in prediction of Nusselt number is less if we consider Brownian motion in our computational model, which is within 4%.

It has been observed that Nano fluids can be used in many applications due to the enhancement in heat transfer. By using Nano fluids, the heat exchanging devices especially in electronic cooling applications may be made more energy efficient and compact. Although the exact mechanism of heat transfer by Nano fluids is still unclear and there are challenges like Nano fluids stability and production cost, it has a promising future in industry applications.

M. Esfandiary [2] in their study discussed that the problem of turbulent forced convection flow of water-alumina Nano fluid in a uniformly heated pipe has been thoroughly investigated. In numerical study, single and two-phase models have been used. In single-phase modeling of Nano fluid, thermal and flow properties of Nano fluid have been considered to be dependent on temperature and volume fraction. Effects of volume fraction and Reynolds number ($3000<Re<9000$) on convective heat transfer coefficient and pressure drop were investigated for various axial locations of the tube.

Numerical results have shown that the inclusion of nanoparticles into the base fluid produced a considerable augmentation of the heat transfer coefficient that increases with an increase of the volume fraction and Reynolds number. Moreover, the increase of volume fraction has no effects on the coefficient of friction, but it decreases with increasing Reynolds number. Comparison of numerical results with experiments shows that the results of single- phase analysis is near to the experimental results.

III. EXPERIMENTAL SET UP

In this setup consists of the small tube of diameter 16 mm in a shell of diameter 60 mm. The tube consists of the 13 circumferential circular fins of diameter 38 mm with an offset distance of 50 mm between the fins. Thickness of the fin is 1 mm, tube thickness is 1.5 mm .tube inner diameter is 16 mm and outer diameter 19 mm .material of the tube is copper. Glass wool and asbestos are used to completely insulate the outer surface of the shell of the heat exchanger. Here a counter flow heat exchanger is used. Pressure gauges and thermocouples are used to find the pressure drop and temperatures at the conditions .The experimental setup was shown in the next slide. The experimental Setup is as shown in the Fig. 1.

Fig. 1 Experimental Set up

IV. COMPUTATION ANALYSIS

Numerical Investigation of heat transfer and pressure drop for circumferential finned tube heat exchanger is presented in this paper considering Al_2O_3 Nano fluid as base fluid. The required thermo-physical properties were measured and used in CFD using UDF (User Defined Functions). The results of numerical simulation are compared with that of experimental results in order to verify the accuracy of code used in CFD.

Further numerical simulation is carried out for 2% volume fraction of Nano particles at different Reynolds number. Thermo-Hydraulic Performance factor a measure both heat transfer and pressure drop has decreased as Reynolds number augmented. But for all Reynolds number Thermo-hydraulic performance factor obtained proves us that usage of Nano fluid is beneficial. The objective of the present CFD analysis is to

•The required thermo-physical properties were measured and used in CFD using UDF (User Defined Functions).
•Numerical simulation is carried out for 2% volume fraction of Nano particles at different Reynolds number.
•Validation of the results.

The geometry is created in ANSYS ICEM CFD as per the given data for each of the model and a domain is created to encompass the flow inside the domain to the walls of the body. In order to study domain independence, three cylindrical domains are considered in trial and error method taking the distances from nose and tail ends of the model and taking the radius from the axis of the model. Three dimensional hexahedral grids were generated to discretize the body and the domain.

Three dimensional segregated implicit solvers is used in the present analysis, the k-ω, k-ϵ turbulence models in addition to the continuity and momentum equations were used as governing equations. Boundary conditions used in the present analysis are inlet as velocity inlet, outlet as outflow, far field, and body as walls. All the three models are computed in the solver Fluent. The solution is iterated until the coefficient of drag (Cd) converges. The solution was stopped when changes in solution variables from one iteration to the next is negligible. Solution is iterated till the convergence is observed. Then forces and moments results were extracted from it. This data is saved as the data file in the solver itself.

Geometry and Domain are created in ANSYS 15.0. Blocking and Meshing is done. Checking the mesh quality and saving the file to solver Fluent. Export it into Fluent software. Computing and monitoring the solution in Fluent. Examine and save the results. The geometric model for the heat exchanger is as shown in the Fig. 2.

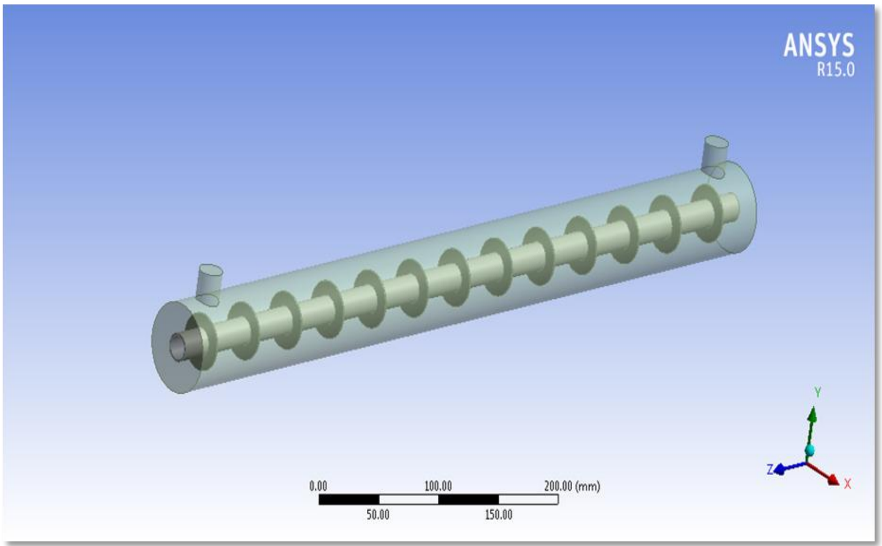
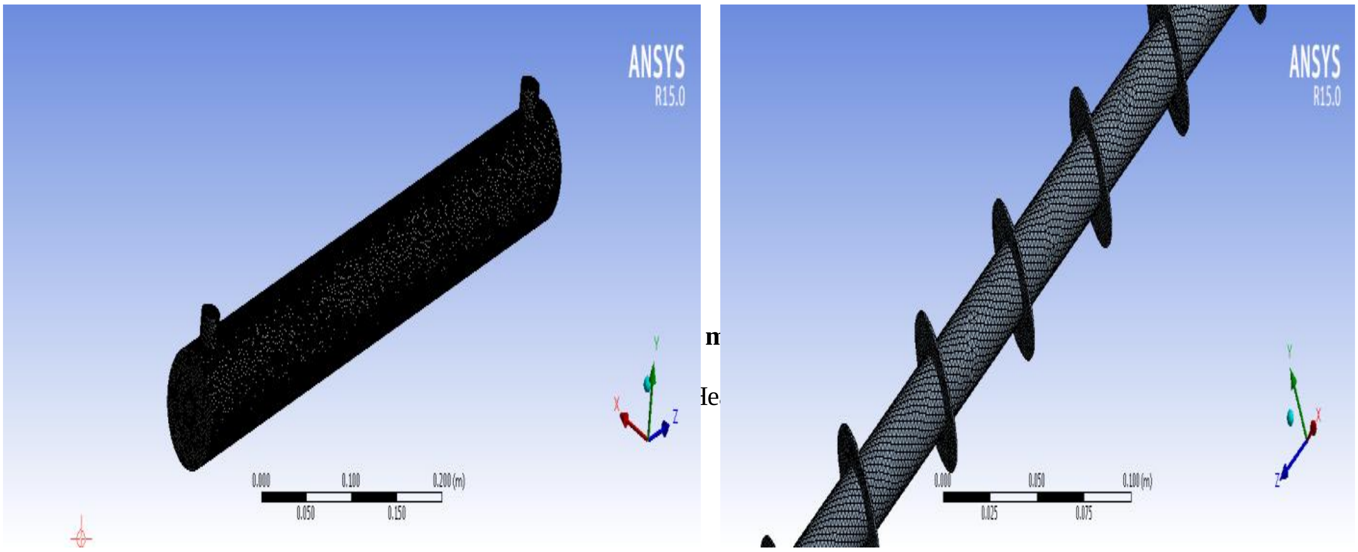


Fig. 2 Geometric model of the Heat Exchanger

The meshed model for the heat exchanger is as shown in the Fig. 3



S. No	ZONE	TYPE
1	In_in	Mass-flow inlet
2	In_out	Pressure outlet
3	In_inner_wall	Wall
4	In_outer_wall	Wall
5	Of_in	Mass-flow inlet
6	Of_out	Pressure outlet
7	Outer adiabatic wall	Wall

Fig. 4 Boundary Conditions of the Heat Exchanger

The Pressure Contours for the Heat Exchangers as shown in the Fig. 5

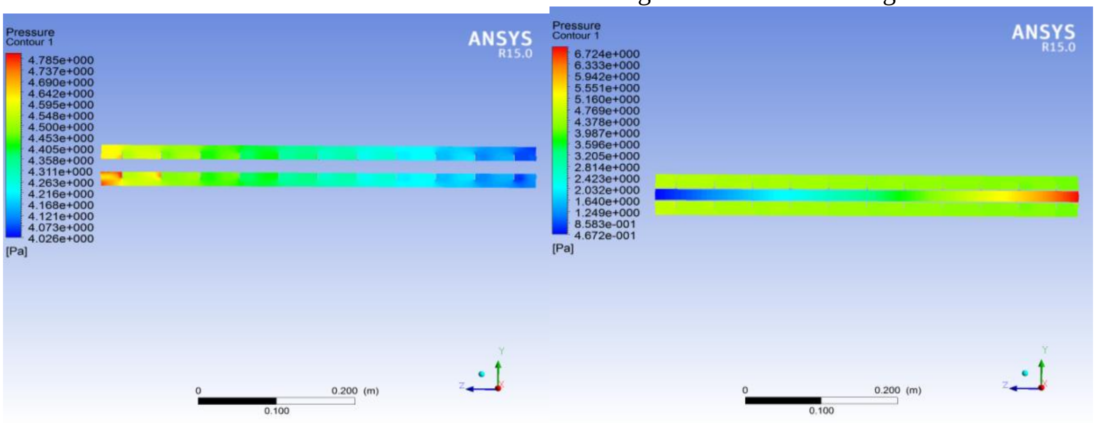


Fig. 5 Pressure Contours for the Heat Exchanger

The Temperature Contours for the Heat Exchanger is as shown in the Fig. 6

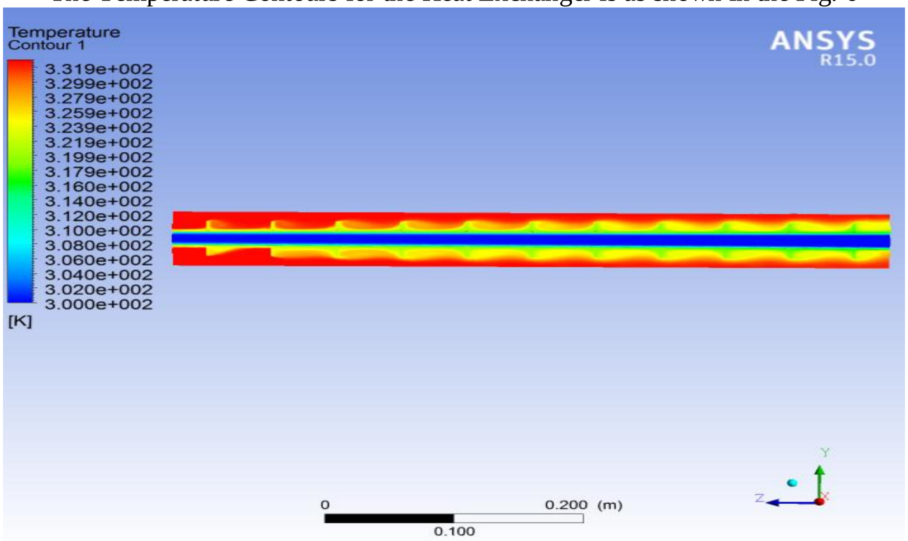


Fig. 6 Temperature Contours for the Heat Exchanger

V. REGRESSION ANALYSIS

In statistical modeling, regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed. Most commonly, regression analysis estimates the conditional expectation of the dependent variable given the independent variables – that is, the average value of the dependent variable when the independent variables are fixed.

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. However this can lead to illusions or false relationships, so caution is advisable; for example, correlation does not imply causation.

Many techniques for carrying out regression analysis have been developed. Familiar methods such as linear regression and ordinary least squares regression are parametric, in that the regression function is defined in terms of a finite number of unknown parameters that are estimated from the data. Nonparametric regression refers to techniques that allow the regression function to lie in a specified set of functions, which may be infinite-dimensional.

The performance of regression analysis methods in practice depends on the form of the data generating process, and how it relates to the regression approach being used. Since the true form of the data-generating process is generally not known, regression analysis often depends to some extent on making assumptions about this process. These assumptions are sometimes testable if a sufficient quantity of data is available. Regression models for prediction are often useful even when the assumptions are moderately violated, although they may not perform optimally. However, in many applications, especially with small effects or questions of causality based on observational data, regression methods can give misleading results.

In a narrower sense, regression may refer specifically to the estimation of continuous response variables, as opposed to the discrete response variables used in classification. The case of a continuous output variable may be more specifically referred to as metric regression to distinguish it from related problems.

Regression models:

Regression models involve the following variables:

- The unknown parameters, denoted as β, which may represent a scalar or a vector.
- The independent variables X.
- The dependent variable, Y.

In various fields of application, different terminologies are used in place of dependent and independent variables.

A regression model relates Y to a function of X and β.

The approximation is usually formalized as $E(Y \mid X) = f(X, \beta)$. To carry out regression analysis, the form of the function f must be specified. Sometimes the form of this function is based on knowledge about the relationship between Y and X that does not rely on the data. If no such knowledge is available, a flexible or convenient form for f is chosen.

Assume now that the vector of unknown parameters β is of length k. In order to perform a regression analysis the user must provide information about the dependent variable Y:

• If N data points of the form (Y, X) are observed, where $N < k$, most classical approaches to regression analysis cannot be performed: since the system of equations defining the regression model is underdetermined, there are not enough data to recover β.

• If exactly $N = k$ data points are observed, and the function f is linear, the equations $Y = f(X, \beta)$ can be solved exactly rather than approximately. This reduces to solving a set of N equations with N unknowns (the elements of β), which has a unique solution as long as the X are linearly independent. If f is nonlinear, a solution may not exist, or many solutions may exist.

• The most common situation is where $N > k$ data points are observed. In this case, there is enough information in the data to estimate a unique value for β that best fits the data in some sense, and the regression model when applied to the data can be viewed as an over determined system in β.

In the last case, the regression analysis provides the tools for:

1. Finding a solution for unknown parameters β that will, for example, minimize the distance between the measured and predicted values of the dependent variable Y (also known as method of least squares).
2. Under certain statistical assumptions, the regression analysis uses the surplus of information to provide statistical information about the unknown parameters β and predicted values of the dependent variable Y.

The experimental data is tabulated as shown in the Table 1.

Table 1. Experimental Data

S. No	$m_{c\,in}$ (kg/s)	$m_{h\,in}$ (kg/s)	$T_{c\,in}$ (k)	$T_{c\,out}$ (k)	$T_{h\,in}$ (k)	$T_{h\,out}$ (k)	$T_{h\,out}$ (k) (simulated)
1	0.013857	0.017	300	305.8	333	327.6	328.5
2	0.016	0.02	300	305.1	333	328.2	329.7
3	0.018	0.023	300	304.6	333	329.5	330.4
4	0.021	0.026	300	303.4	333	330.8	331.5

Nu_{avg} vs. Re Relation:

Fig. 7 shows the variation of Average Nusselt Number versus Reynolds Number for Different Volume Fraction%.

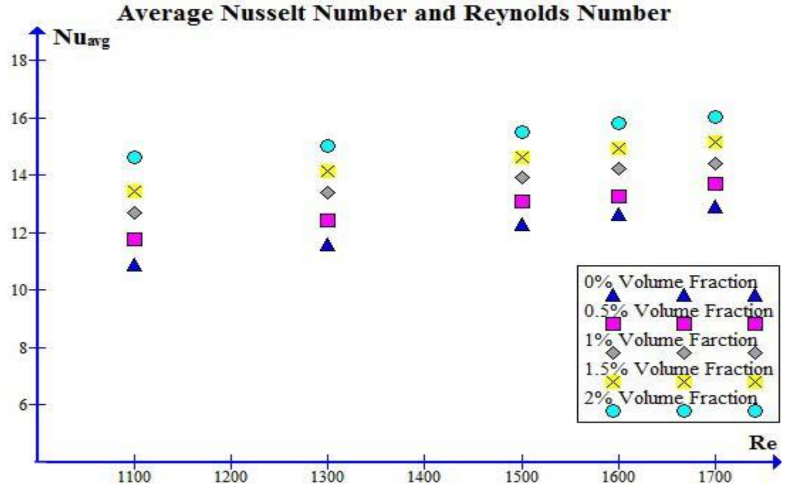


Fig. 7 Average Nusselt Number versus Reynolds Number for Different Volume Fraction%

VI. CONCLUSIONS

The following conclusions can be outlined by considering homogenous mixture flow for Nano fluid. Heat transfer Rate is been increased as Reynolds number is augmented for given laminar regime. Pressure drop in the circumferential finned tube has also been increased by Reynolds number. The augmentation of heat transfer rate at low Reynolds number is high compared to high Reynolds number. Thermo-Hydraulic performance factor is in the range for the respective Reynolds number and shows the advantage in using Nano fluids for increasing the heat exchanger performance.

REFERENCES

[1] Arjumand Adil, Sonam Gupta, and Pradyumna Ghosh, "Numerical Prediction of Heat Transfer Characteristics of Nano fluids in a Mini channel Flow", Journal of Energy Volume 2014, Article ID 307520, 7.

[2] M. Esfandiary, A. Habibzadeh, H. Sayehvand, "Numerical Study of Single Phase/Two-Phase Models for Nano fluid Forced Convection and Pressure Drop in a Turbulence Pipe Flow", Trans. Phenom. Nano Micro Scales, 4(1): 11-18, Winter - Spring 2016.

[3] Payam Rahim Mashaei, Seyed Mostafa Hosseinalipour, and Mehdi Bahiraei, "Numerical Investigation o f Nano fluid Forced Convection in Channels with Discrete H eat Sources", Hindawi Publishing Corporation Journal of Applied Mathematics Volume 2012.

[4] Hooman Yarmand, Samira Gharehkhani, Salim Newaz Kazi, Emad Sadeghinezhad, and Mohammad Reza Safaei, "Numerical Investigation of Heat Transfer Enhancement in a Rectangular Heated Pipe for Turbulent Nano fluid", Hindawi Publishing Corporation, The Scientific World Journal, Volume 2014.

[5] Mohammad Nazififard, Mohammadreza Nematollahi, Khosrow Jafarpur, and Kune Y. Suh, "Nu mer ical Simulat i on of Water-Based A lumina Nanofluid in Sub channel Geometry", Science and Technology of Nuclear Installations, Vo lume 2012.

[6] S. J. Palm, G. Roy, and C. T. Nguyen, "Heat transfer enhancement with the use of nanofluids in radial flow cooling systems considering temperature-dependent properties," Applied Thermal Engineering, vol. 26, no. 17-18, pp. 2209–2218, 2006.

[7] J. A. Eastman, S. R. Phillpot, S. U. S. Choi, and P. Keblinski, "Thermal transport in ," Annual Review of Materials Research, vol. 34, pp. 219–246, 2004.

[8] 8. S. J. Kim, I. C. Bang, J. Buongiorno, and L. W. Hu, "Surface wettability change during pool boiling of nanofluids and its effect on critical heat flux," International Journal of Heat and Mass Transfer, vol. 50, no. 19-20, pp. 4105–4116, 2007.

[9] 9. J. Buongiorno and B. Truong, "Preliminary study of waterbased nanofluid coolants for PWRs," Transactions of the American Nuclear Society, vol. 92, pp. 383–384, 2005.

[10] 10. J. Buongiorno, L. W. Hu, G. Apostolakis, R. Hannink, T. Lucas, and A. Chupin, "A feasibility assessment of the use of nanofluids to enhance the in-vessel retention capability in light-water reactors," Nuclear Engineering and Design, vol. 239, no. 5, pp. 941–948, 2009.

[11] 11. K. Hadad, A. Hajizadeh, K. Jafarpour, and B. D. Ganapol, "Neutronic study of nanofluids application to VVER-1000," Annals of Nuclear Energy, vol. 37, no. 11, pp. 1447–1455, 2010.

[12] 12. J. Sarkar, “A critical review on convective heat transfer correlations of nanofluids,” Renewable and Sustainable Energy Reviews, vol. 15, no. 6, pp. 3271–3277, 2011.
[13] 13. M.R.NematollahiandM.Nazifi,“Enhancementofheattransfer in a typical pressurized water reactor by different mixing vanes on spacer grids,” Energy Conversion and Management, vol. 49, no. 7, pp. 1981–1988, 2008.
[14] 14. ANSYS FLUENT Workbench User’s Guide. Release 12.1. ANSYS, Inc., 2009.

