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CFD ANALYSIS OF SMALL HYDRO PLANT TURBINES: CASE STUDIES

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ABSTRACT

Performance analysis of Small Hydro Turbine is an essential practice to ensure that Small Hydro Plant performance is still at an acceptable level. In addition, performance testing is required as a part of programs to improve the efficiency, output, and economic performance of small hydro plants along with Optimization which has been an important focus in recent years. This study deals with three different Small Hydro Turbines of various manufacturer or projects. Comparison between simulation results and project/manufacturer data reveals a good agreement. To the best of the author's knowledge these novel approach for CFD analysis of Small Hydro Turbines together using DSS Solidworks Flow Simulation (FloEFD) is absent in renewable energy or fluid mechanics literature due to its assessment complexity.

Keywords: CFD, turbomachines, pelton wheel, Francis turbine, kaplan turbine.

1. INTRODUCTION

Hydro power projects are classified as large, medium and small (renewable energy) hydro projects based on their sizes. Ranging from 10MW to 50 MW various countries have various size criteria to classify small hydro projects. Hydro power plants of 25MW or below capacity are classified as small hydro in India. It is further classified into pico-hydro (5kW or below), micro hydro (6kW - 100kW), mini hydro (101kW-2MW) and small hydro (2-25MW) plants.

Various potential power generation sites are found in existing water infrastructures and delivery networks. Common uses are at water supply to transmission locations, tank fill locations, residential zones with elevation changes, and at large commercial areas. Most existing water infrastructure sites have pressure reducing valves already installed; they simply need the valves replaced with energy recovery turbines. [1-50]

2. METHODOLOGY ADOPTED

The purpose of this study was to check three types of small hydro plant turbines efficiency at various heads. The experiment and analyse were carried out to find the various parameters of the turbine, as well as the overall efficiency and compare them with manufacturer or project data (not detailed due to company privacy policy). [51-60]

3. THEORY AND CALCULATION

The governing equations for fluid flow and heat transfer are the Navier-Stokes or momentum equations and the First Law of Thermodynamics or energy equation. The analyses of these 03 cases (Pelton Wheel, Francis Turbine, Kaplan Turbine) reveal that significant improvement could be obtained by applying the proper arrangements of vanes, draft tubes etc.

The Favre-averaged Navier-Stokes equations are used, where time-averaged effects of the flow turbulence on the flow parameters are considered, whereas the large-scale, time-dependent phenomena are taken into account directly. Through this procedure, extra terms known as the Reynolds stresses appear in the equations for which additional information must be provided.

To close this system of equations, DSS SOLIDWORKS Flow Simulation (FloEFD) employs transport equations for the turbulent kinetic energy and its dissipation rate, using most popular the k-ε model [61-77].

The purpose of these performance analysis of Pelton Wheel, Francis Turbine and Kaplan Turbine is to determine: power generated, velocity, pressure, various turbulence parameter distributions in runner for future work (on fatigue analysis). The governing PDEs can be written as:

Table-1. CFD analysis - governing equations.

Continuity Equation:

$$\frac{\partial \rho}{\partial t}+\frac{\partial \rho u}{\partial x}+\frac{\partial \rho v}{\partial y}+\frac{\partial \rho w}{\partial z}=0$$

X-Momentum Equation:

$$\rho\frac{\partial u}{\partial t}+\rho u\frac{\partial u}{\partial x}+\rho v\frac{\partial u}{\partial y}+\rho w\frac{\partial u}{\partial z}$$
$$=\rho g_x-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}\left[2\mu\frac{\partial u}{\partial x}\right]+\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right]+\frac{\partial}{\partial z}\left[\mu\left(\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}\right)\right]$$
$$+S_{\omega}+S_{DR}$$

Y-Momentum Equation:

$$\rho\frac{\partial v}{\partial t}+\rho u\frac{\partial v}{\partial x}+\rho v\frac{\partial v}{\partial y}+\rho w\frac{\partial v}{\partial z}$$
$$=\rho g_y-\frac{\partial p}{\partial y}+\frac{\partial}{\partial x}\left[\mu\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right]+\frac{\partial}{\partial y}\left[2\mu\frac{\partial v}{\partial y}\right]+\frac{\partial}{\partial z}\left[\mu\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)\right]$$
$$+S_{\omega}+S_{DR}$$

Z-Momentum Equation:

$$\rho\frac{\partial w}{\partial t}+\rho u\frac{\partial w}{\partial x}+\rho v\frac{\partial w}{\partial y}+\rho w\frac{\partial w}{\partial z}$$
$$=\rho g_z-\frac{\partial p}{\partial z}+\frac{\partial}{\partial x}\left[\mu\left(\frac{\partial u}{\partial z}+\frac{\partial w}{\partial x}\right)\right]+\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)\right]+\frac{\partial}{\partial z}\left[2\mu\frac{\partial w}{\partial z}\right]$$
$$+S_{\omega}+S_{DR}$$

These studies present Computational Fluid Dynamics (CFD) or performance analysis of Pelton Wheel, Francis Turbine and Kaplan Turbine for Small Hydro Projects.

4A. CASE STUDY-1: PELTON WHEEL

This study presents Computational Fluid Dynamics (CFD) analysis of Pelton Wheel using DSS Solidworks Flow Simulation (FloEFD). The purpose of performance analysis is to determine torque generated by the turbine, velocity, pressure, various turbulence parameter distributions in bucket.

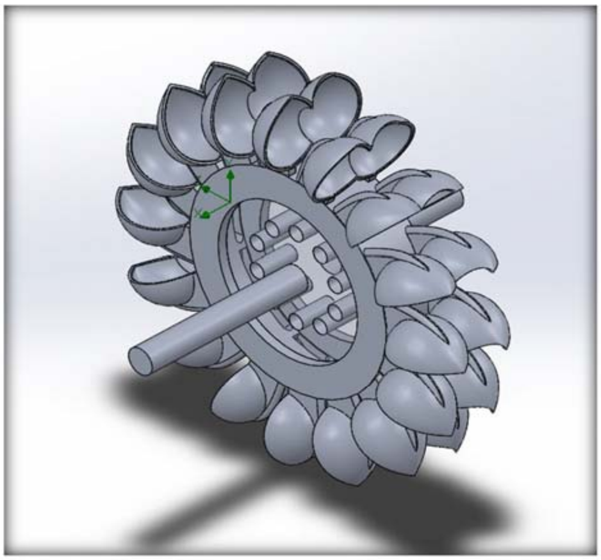

Figure-1. Pelton wheel - 3D model of runner.

The CFD analysis is carried out on model size Pelton runner reduced scale to minimize computational time, effort and cost. The operating conditions for model size runner are selected in accordance with IEC 60193 and IEC 1116 (not detailed here due to company privacy policy) as shown below.

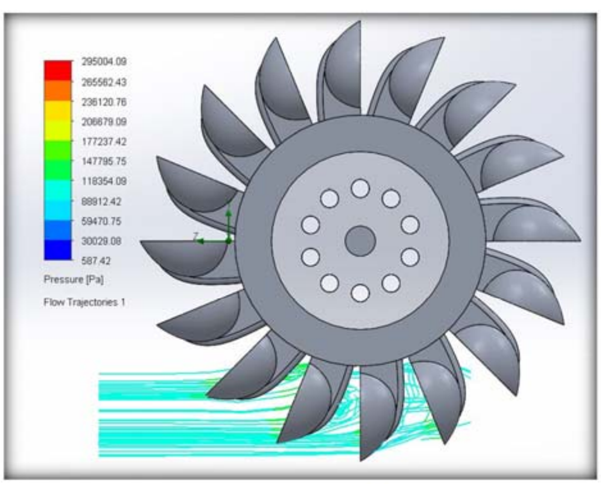

Figure-2. Pelton wheel 3D model - pressure plot.

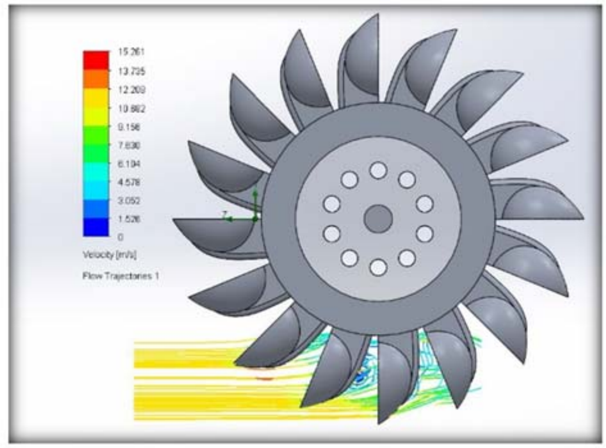

Figure-3. Pelton wheel 3D model - velocity plot.

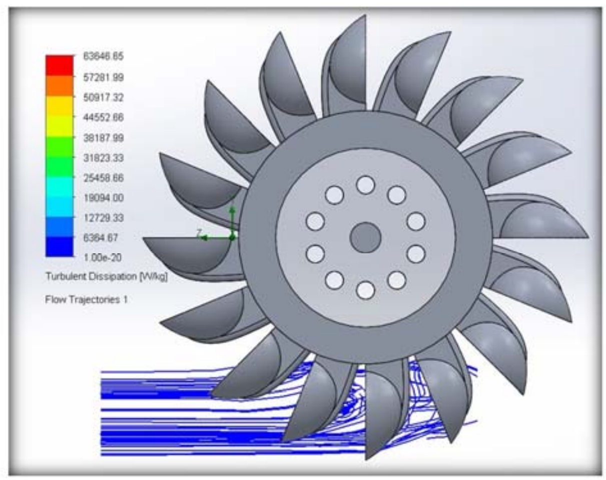

Figure-4. Pelton wheel 3D model - turbulence dissipation plot.

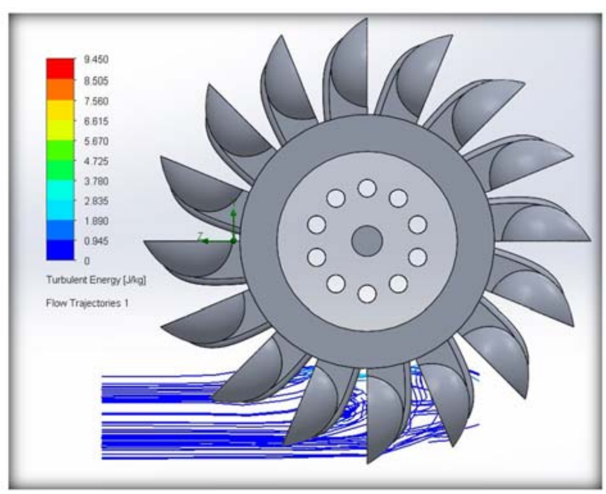

Figure-5. Pelton wheel 3D model - turbulence energy plot.

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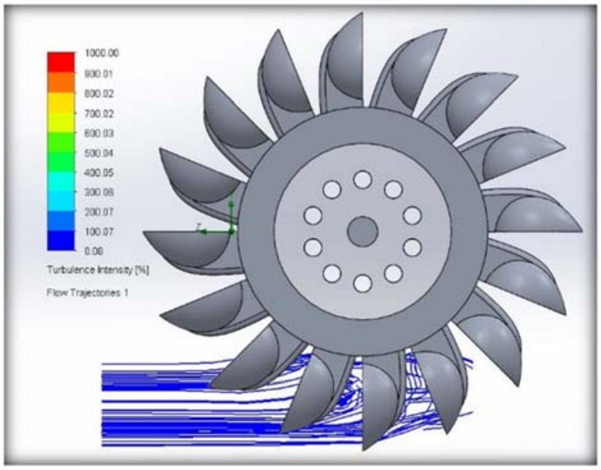

Figure-6. Pelton wheel 3D model - turbulence intensity plot.

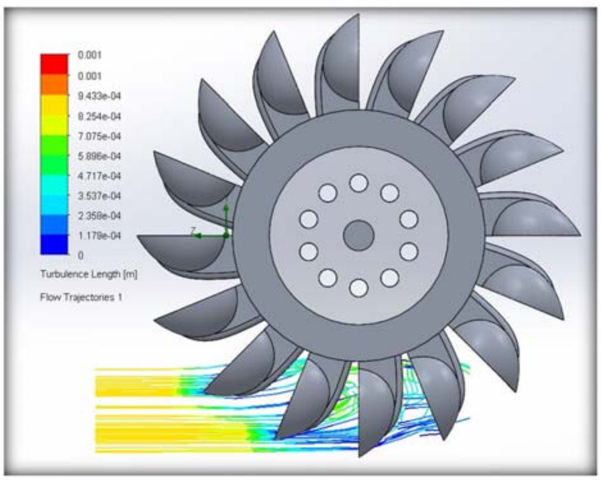

Figure-7. Pelton wheel 3D model - turbulence length plot.

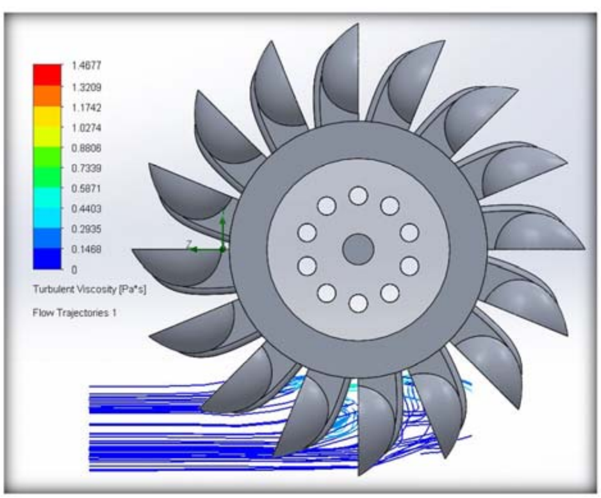

Figure-8. Pelton wheel 3D model - turbulence viscosity plot.

Table-2. Pelton wheel simulation data - min/max values of various parameters.

Parameter	Minimum	Maximum
Absolute Humidity [kg/m^3]	377.13	998.74
Density (Fluid) [kg/m^3]	377.17	998.84
Mass Fraction of Dissolved gas [ ]	1.0000e-04	1.0000e-04
Mass Fraction of Vapour [ ]	0	1.0000000
Mass Fraction of Water [ ]	0.9999	0.9999
Pressure [Pa]	587.42	295004.09
Temperature [K]	289.81	293.64
Temperature (Fluid) [K]	289.81	293.64
Velocity [m/s]	0	15.261
Velocity (X) [m/s]	-10.784	12.297
Velocity (Y) [m/s]	-12.559	8.077
Velocity (Z) [m/s]	-15.147	6.348
Volume Fraction of Vapour [ ]	0	0.9999378
Mach Number [ ]	0	5.03
Velocity RRF [m/s]	0	15.261
Velocity RRF (X) [m/s]	-10.784	12.297
Velocity RRF (Y) [m/s]	-12.559	8.077
Velocity RRF (Z) [m/s]	-15.147	6.348
Vorticity [1/s]	0.28	9203.50
Relative Pressure [Pa]	-100737.58	193679.09
Shear Stress [Pa]	0	513.48
Bottleneck Number [ ]	7.8217525e-16	1.0000000
Heat Transfer Coefficient [W/m^2/K]	0	0
ShortCut Number [ ]	1.1377939e-15	1.0000000
Surface Heat Flux [W/m^2]	0	0
Surface Heat Flux (Convective) [W/m^2]	0	0
Turbulence Intensity [%]	0.08	1000.00
Turbulence Length [m]	0	0.001
Turbulent Dissipation [W/kg]	1.00e-20	63646.65
Turbulent Energy [J/kg]	0	9.450
Turbulent Time [s]	0	0.351
Turbulent Viscosity [Pa*s]	0	1.4677
Acoustic Power [W/m^3]	0	2748.031
Acoustic Power Level [dB]	0	154.39

Various Min-Max Parameter values (table) for Pelton Wheel is shown above.

4B. CASE STUDY-2: FRANCIS TURBINE

This study presents Computational Fluid Dynamics (CFD) analysis of Francis Turbine using DSS Solidworks Flow Simulation (FloEFD). The purpose of performance analysis is to determine power generated by the turbine, velocity, pressure, various turbulence parameter distributions in vanes/blades for further work (as fatigue analysis).

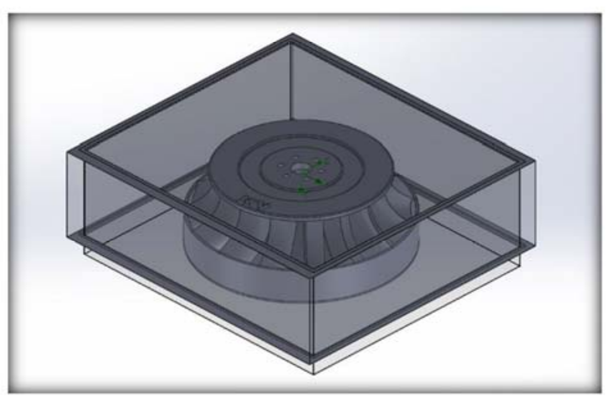

Figure-9. Francis turbine - 3D model of runner.

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The CFD analysis is carried out on model size Francis Turbine runner reduced scale to minimize computational time, effort and cost. The operating conditions for model size runner are selected in accordance with IEC 60193 and IEC 1116 (not detailed here due to company privacy policy) as shown below.

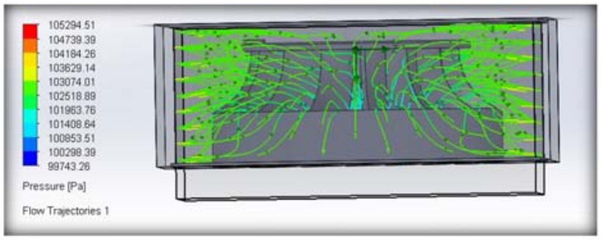

Figure-10. Francis turbine 3D model - pressure plot.

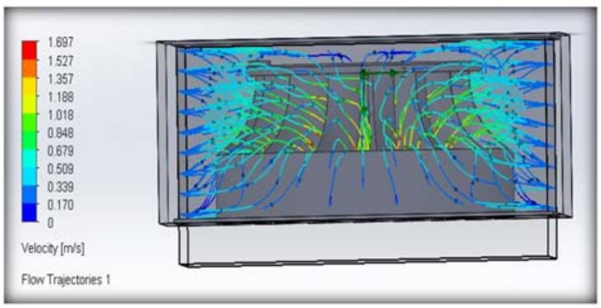

Figure-11. Francis turbine 3D model - velocity plot.

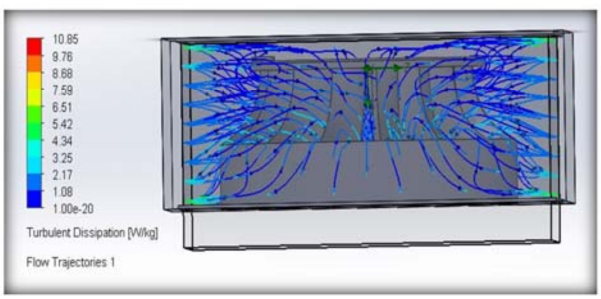

Figure-12. Francis turbine 3D model - turbulence dissipation plot.

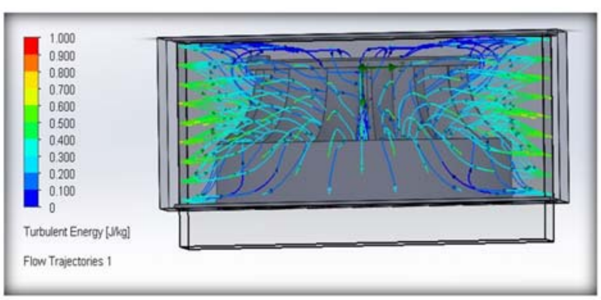

Figure-13. Francis turbine 3D model - turbulence energy plot.

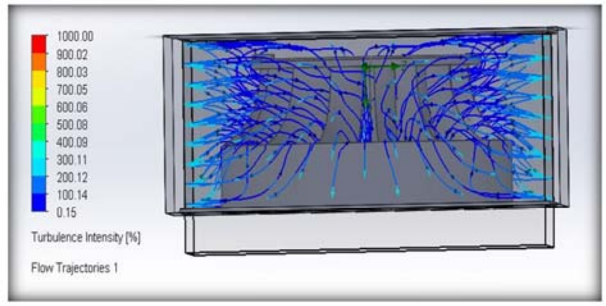

Figure-14. Francis turbine 3D model - turbulence intensity plot.

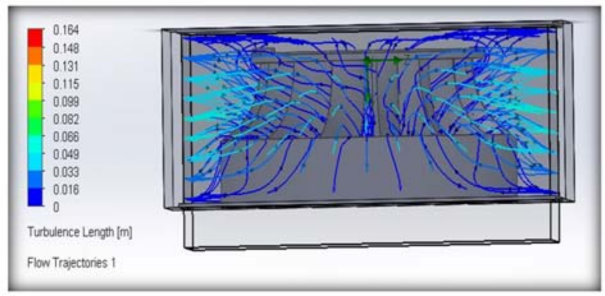

Figure-15. Francis turbine 3D model - turbulence length plot.

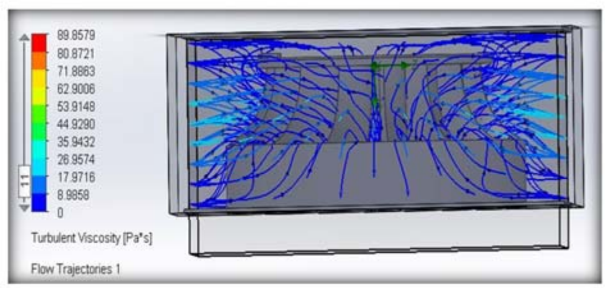

Figure-16. Francis turbine 3D model - turbulence viscosity plot.

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Table-3. Francis turbine simulation data - min/max values of various parameters.

Parameter	Minimum	Maximum
Absolute Humidity [kg/m^3]	998.32	998.32
Density (Fluid) [kg/m^3]	998.42	998.42
Mass Fraction of Dissolved gas [ ]	1.0000e-04	1.0000e-04
Mass Fraction of Vapour [ ]	0	0
Mass Fraction of Water [ ]	0.9999	0.9999
Pressure [Pa]	99743.26	105294.51
Temperature [K]	293.19	293.20
Temperature (Fluid) [K]	293.19	293.20
Velocity [m/s]	0	1.697
Velocity (X) [m/s]	-1.416	1.414
Velocity (Y) [m/s]	-0.909	1.335
Velocity (Z) [m/s]	-1.350	1.272
Volume Fraction of Vapour [ ]	0	0
Mach Number [ ]	0	1.63e-03
Velocity RRF [m/s]	0	1.697
Velocity RRF (X) [m/s]	-1.416	1.414
Velocity RRF (Y) [m/s]	-0.909	1.335
Velocity RRF (Z) [m/s]	-1.350	1.272
Vorticity [1/s]	8.35e-03	63.24
Relative Pressure [Pa]	-1581.74	3969.51
Shear Stress [Pa]	0	9.10
Bottleneck Number [ ]	5.4192219e-07	1.0000000
Heat Transfer Coefficient [W/m^2/K]	0	0
ShortCut Number [ ]	0.0000721	1.0000000
Surface Heat Flux [W/m^2]	0	0
Surface Heat Flux (Convective) [W/m^2]	-5.160e+08	3.244e+09
Turbulence Intensity [%]	0.15	1000.00
Turbulence Length [m]	0	0.164
Turbulent Dissipation [W/kg]	1.00e-20	10.85
Turbulent Energy [J/kg]	0	1.000
Turbulent Time [s]	0	1.704
Turbulent Viscosity [Pa*s]	0	89.8579
Acoustic Power [W/m^3]	0	6.714e-13
Acoustic Power Level [dB]	0	0

Various Min-Max Parameter values (table) for Francis Turbine is shown above.

4C. CASE STUDY-3: KAPLAN TURBINE

This study presents Computational Fluid Dynamics (CFD) analysis of Kaplan Turbine using DSS Solidworks Flow Simulation (FloEFD). The purpose of performance analysis is to determine torque generated by the turbine, velocity, pressure, various turbulence parameter distributions in vanes/blades for further work.

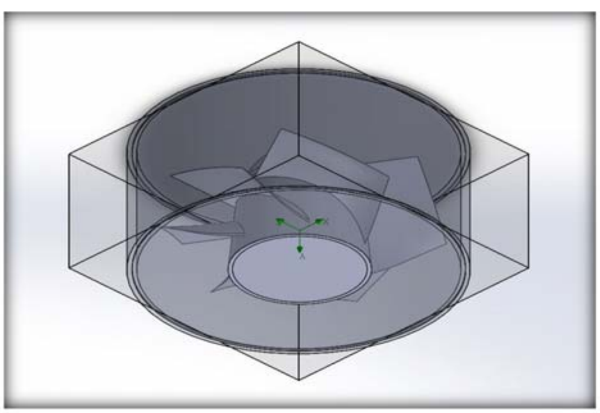

Figure-17. Kaplan turbine - 3D model of runner.

The CFD analysis is carried out on model size Kaplan Turbine runner reduced scale to minimize computational time, effort and cost. The operating conditions for model size runner are selected in accordance with IEC 60193 and IEC 1116 (not detailed here due to company privacy policy) as shown below.

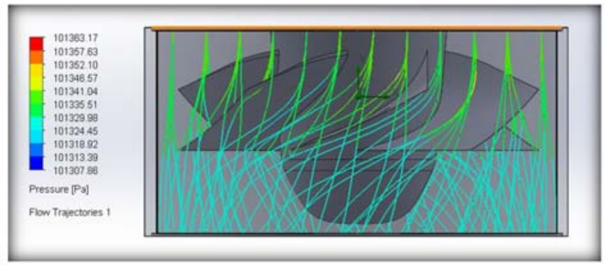

Figure-18. Kaplan turbine 3D model - pressure plot.

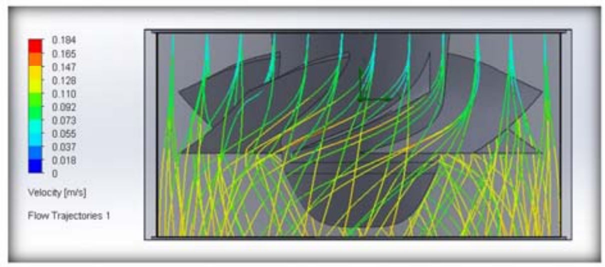

Figure-19. Kaplan turbine 3D model - velocity plot.

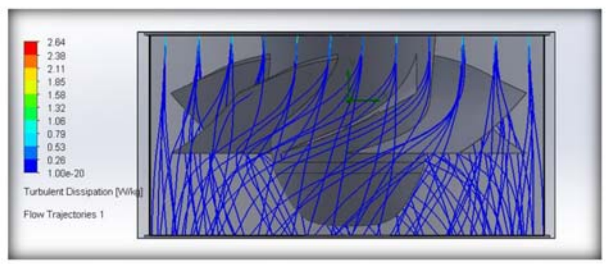

Figure-20. Kaplan turbine 3D model - turbulence dissipation plot.

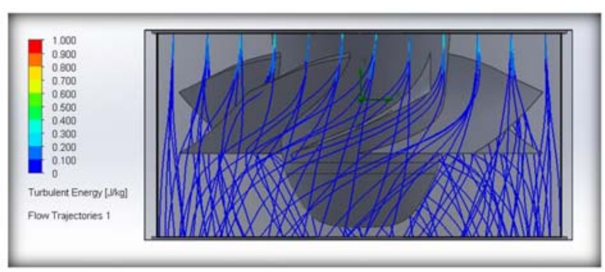

Figure-21. Kaplan turbine 3D model - turbulence energy plot.

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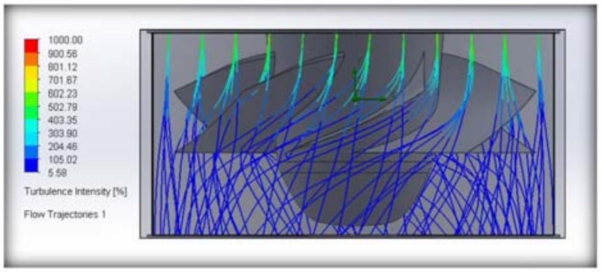

Figure-22. Kaplan turbine 3D model - turbulence intensity plot.

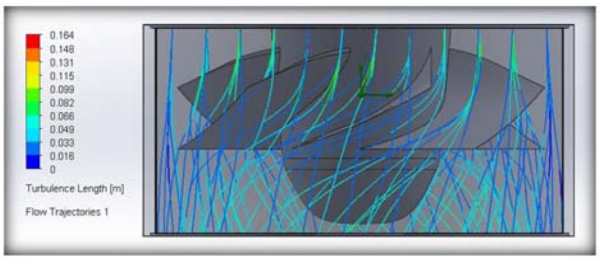

Figure-23. Kaplan turbine 3D model - turbulence length plot.

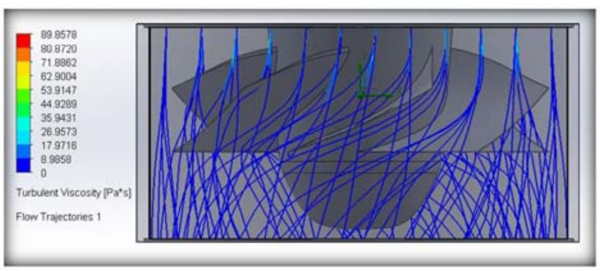

Figure-24. Kaplan turbine 3D model - turbulence viscosity plot.

Table-4. Kaplan turbine simulation data - min/max values of various parameters.

Parameter	Minimum	Maximum
Absolute Humidity [kg/m^3]	998.32	998.32
Density (Fluid) [kg/m^3]	998.42	998.42
Mass Fraction of Dissolved gas [ ]	1.0000e-04	1.0000e-04
Mass Fraction of Vapour [ ]	0	0
Mass Fraction of Water [ ]	0.9999	0.9999
Pressure [Pa]	101307.86	101363.17
Temperature [K]	293.20	293.20
Temperature (Fluid) [K]	293.20	293.20
Velocity [m/s]	0	0.184
Velocity (X) [m/s]	-0.152	0.153
Velocity (Y) [m/s]	-0.147	0.031
Velocity (Z) [m/s]	-0.167	0.172
Volume Fraction of Vapour [ ]	0	0
Mach Number [ ]	0	1.77e-04
Velocity RRF [m/s]	0	0.184
Velocity RRF (X) [m/s]	-0.152	0.153
Velocity RRF (Y) [m/s]	-0.147	0.031
Velocity RRF (Z) [m/s]	-0.167	0.172
Vorticity [1/s]	9.28e-03	1.42
Relative Pressure [Pa]	-17.14	38.17
Shear Stress [Pa]	0	0.13
Bottleneck Number [ ]	5.4580202e-08	1.0000000
Heat Transfer Coefficient [W/m^2/K]	0	0
ShortCut Number [ ]	0.0005882	1.0000000
Surface Heat Flux [W/m^2]	0	0
Surface Heat Flux (Convective) [W/m^2]	-1.696e+08	3.570e+08
Turbulence Intensity [%]	5.58	1000.00
Turbulence Length [m]	0	0.164
Turbulent Dissipation [W/kg]	1.00e-20	2.64
Turbulent Energy [J/kg]	0	1.000
Turbulent Time [s]	0	16.470
Turbulent Viscosity [Pa*s]	0	89.8578
Acoustic Power [W/m^3]	0	4.684e-13
Acoustic Power Level [dB]	0	0

Various Min-Max Parameter values (table) for Kaplan Turbine is shown above.

5. RESULT AND DISCUSSIONS

Comparison between simulation results and experimental / manufacturer data for the Pelton Wheel reveals good agreementas shown below.

Figure-25A. Pelton wheel - experimental setup.

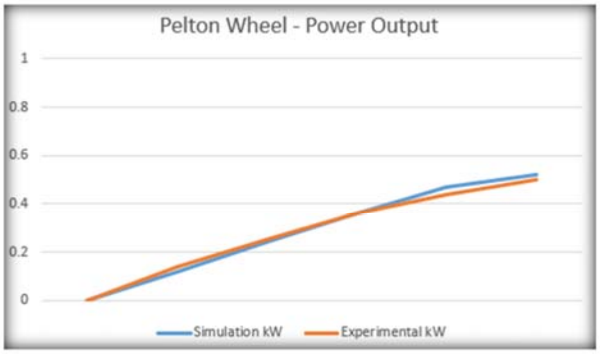

Figure-25B. Pelton wheel - output result comparison.

Comparison between simulation results and experimental / manufacturer data for the Francis Turbine reveals good agreement as shown below.

Figure-26A. Francis turbine - experimental setup.

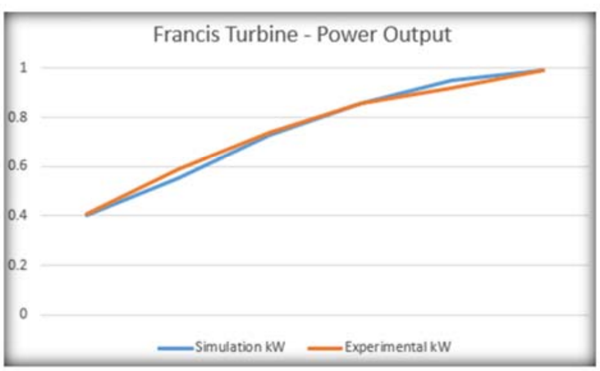

Figure-26B. Francis turbine - output result comparison.

Comparison between simulation results and experimental / manufacturer data for the Kaplan Turbine reveals good agreement as shown below.

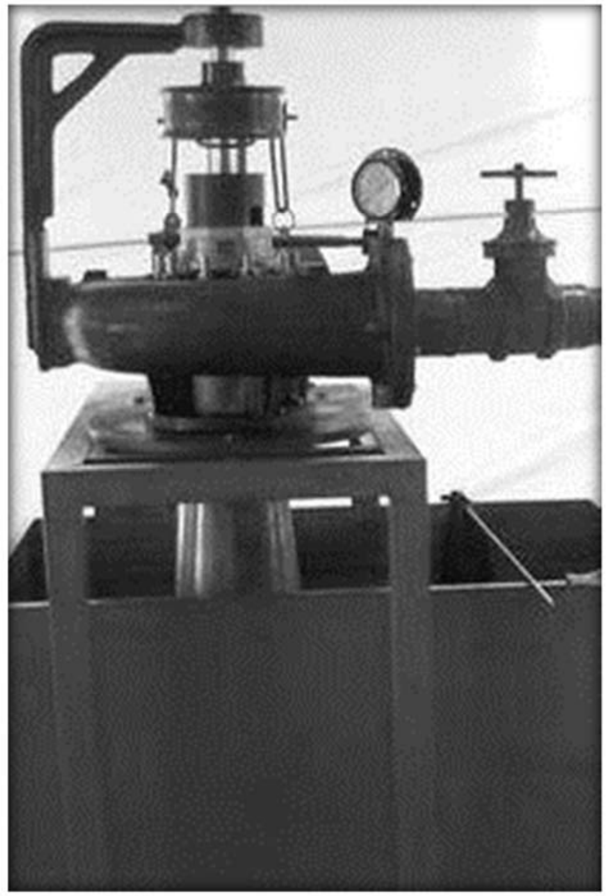

Figure-27A. Kaplan turbine - experimental setup.

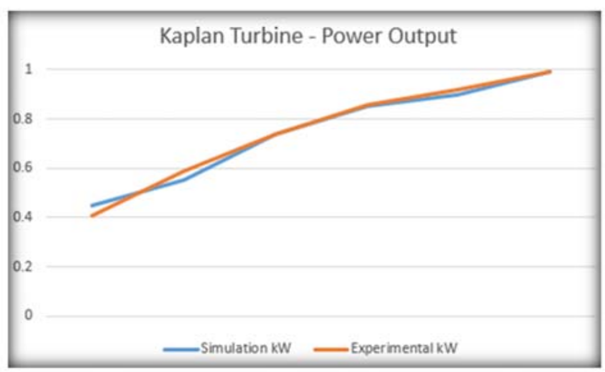

Figure-27B. Kaplan turbine - output result comparison.

6. CONCLUSIONS

Advantages of CFD models include their basis in the fundamental physics of fluid flow, a flexibility that allows the analysis of a huge range of boundary conditions, and the ability to design much more detailed geometries compared to algebraic or zone models. Disadvantages of CFD models include increased complexity, proper training of the tool user, greater computational capacity requirements of system, and a longer timeline between initiating a project and completing the necessary performance analysis.

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REFERENCES

[1] P. Adhikary, P.K.Roy, A.Mazumdar. 2013. Fuzzy Logic Based Optimum Penstock Design: Elastic Water Column Theory Approach; Journal of Engineering & Applied Sciences (JEAS). 8(7): 563-568.

[2] P. Adhikary, P.K.Roy, A.Mazumdar. 2013. Optimum selection of hydraulic turbine manufacturer for SHP: MCDA or MCDM tools; World Applied Sciences Journal (WASJ). 28(7): 914-919.

[3] P. Adhikary, P.K.Roy, A.Mazumdar. 2014. Multi-Dimensional Feasibility Analysis of Small Hydropower Project in India: A Case Study; Journal of Engineering & Applied Sciences (JEAS). 9(1): 80-84.

[4] P. Adhikary, P.K.Roy, A.Mazumdar. 2015. Selection of Small Hydropower Project Site: A Multi-Criteria Optimization Technique Approach; Journal of Engineering & Applied Sciences (JEAS). 10(8): 3280-3285.

[5] P. Adhikary, P.K.Roy, A.Mazumdar. 2015. Optimal Renewable Energy Project Selection: A Multi-Criteria Optimization Technique Approach; Global Journal of Pure and Applied Mathematics (GJPAM). 11(5): 3319-3329.

[6] P. Adhikary, P.K. Roy, A. Mazumdar. 2015. Maintenance Contractor Selection for Small Hydropower Project: A Fuzzy Multi-Criteria Optimization Technique Approach; International Review of Mechanical Engineering (I.RE.M.E.). 9(2): 174-181.

[7] P. Adhikary, P.K. Roy, A. Mazumdar. 2015. Turbine supplier selection for small hydro project: Application of multi-criteria optimization technique; International Journal of Applied Engineering Research (IJAER). 10(5): 13109-13122.

[8] P. Adhikary, P.K. Roy, A. Mazumdar. 2014. Preventive Maintenance Prioritization by Fuzzy Logic for Seamless Hydro Power Generation. Journal of the Institution of Engineers (India): Series A. 95(2): 97-104.

[9] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. C.F.D. Analysis of Micro Hydro Turbine Unit: A Case Study; Journal of Engineering & Applied Sciences (JEAS). 11(7): 4346-4352.

[10] P. Adhikary, S. Bandyopadhyay, A. Mazumdar. 2017. Application of Artificial Intelligence in Energy Efficient HVAC System Design: A Case Study; Journal of Engineering & Applied Sciences (JEAS). 12(21): 6154-6158.

[11] P. Adhikary, S. Bandyopadhyay, A. Mazumdar. 2018. C.F.D. Analysis Ofair-Cooledhvac Chiller Compressors. Journal of Engineering & Applied Sciences (JEAS). 13(23): 9222-9228.

[12] P. Adhikary, Ashok Kumarr, S. Bandyopadhyay, A. Mazumdar. 2019. Chilled Water Pump Trouble Shooting by AI: A case Study. Journal of Engineering & Applied Sciences (JEAS). 14(16): 2836-2842.

[13] P. Adhikary, P.K. Roy, A. Mazumdar. 2013. Selection of hydro-turbine blade material-Application of Fuzzy Logic (MCDA). International Journal of Engineering Research and Applications (IJERA). 3(1): 426-430.

[14] P. Adhikary, P.K. Roy, A. Mazumdar. 2012. Safe and efficient control of hydro power plant by fuzzy logic. International Journal of Engineering Science & Advanced Technology (IJESAT). 2(5): 1270-1277.

[15] P. Adhikary, P.K. Roy, A.Mazumdar. 2014. Small Hydropower Project: Standard Practices. International Journal of Engineering Science & Advanced Technology (IJESAT). 4(3): 300-306.

[16] P. Adhikary, P.K. Roy, A. Mazumdar. 2012. Selection of Penstock Material for Small Hydro Power Project-A Fuzzy Logic Approach. International journal of advanced scientific and technical research (IJAST). 6(2): 521-528.

[17] P. Adhikary, P.K. Roy, A. Mazumdar. 2012. MCDA of manpower shift scheduling for cost effective hydro power generation. International Journal of Emerging Trends in Engineering and Development (IJETED). 7(2): 116-127.

[18] P. Adhikary, P.K. Roy, A. Mazumdar. 2013. Fuzzy Logic based user friendly Pico-Hydro Power generation for decentralized rural electrification.

International Journal of Engineering Trends and Technology (IJETT). 4(4): 507-511.

[19] P. Adhikary, P.K. Roy, A. Mazumdar. 2013. Indian SHP Project Planning and Development: A Review of Decision Support System Tools; International Journal of Engineering Research & Technology (IJERT). 2(6): 1386-1391.

[20] P. Adhikary, P.K. Roy, A. Mazumdar. 2014. Renovation Modernization Uprating & Life Extension: Optimal Solution for Small Hydropower Development. International Journal of Engineering Science & Advanced Technology (IJESAT); 4(3): 300-306.

[21] P. Adhikary, P.K. Roy, A. Mazumdar. 2014. MCDA or MCDM Based Selection of Transmission Line Conductor: Small Hydropower Project Planning and Development. International Journal of Engineering Research and Applications (IJERA). 4(2): 426-430.

[22] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Small Hydro Plant Planning and Development: A Case Study on Renewable Energy Project Modelling and Simulation. International Association for Small Hydro (IASH) Journal. 5(1): 03-07.

[23] P. Adhikary, P.K. Roy, A. Mazumdar. 2015. E.S.I.A. and Environmental Audit for Small Hydropower Projects - M.C.D.M. Approach. International Association for Small Hydro (IASH) Journal. 4(1): 24-32.

[24] P. Adhikary, P.K. Roy, A. Mazumdar. 2014. Small Hydropower Site Selection using spatial - Fuzzy Expert System: A Case Study; REASON-A Technical Journal (KGEC). 13; 49-60.

[25] P. Adhikary, P.K. Roy, A. Mazumdar. 2015. Optimal Turbine Selection for Eco-Friendly Micro Hydro Project: Application of Fuzzy-MCDM. International Journal of Applied Environmental Sciences (IJAES). 10(3): 847-858.

[26] P. Adhikary, P.K. Roy, A. Mazumdar. 2015. Selection of optimal small hydropower project: Risk and uncertainty analysis using fuzzy-MCDM. International Association for Small Hydro (IASH) Journal. 4(2): 06-14.

[27] P. Adhikary, P.K.Roy, A. Mazumdar. 2016. Small Hydro Plant Planning and Development: A Case Study on Renewable Energy Project Modelling and Simulation. International Association for Small Hydro (IASH) Journal. 5(1): 03-07.

[28] P. Adhikary, P.K. Roy, A. Mazumdar. 2013. Hydraulic Transient Analysis of SHP: A MCDM Application for Optimum Penstock Design; Proc. of IWMSID 2013, International Conference, IIT Bhubaneswar.

[29] P. Adhikary, P.K. Roy, A. Mazumdar. 2013. Fuzzy Logic based blade angle control of Kaplan Turbine for a hydropower project; Proc. of ICERTSD 2013, International Conference, BESUS (IIEST) Howrah.

[30] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. C.F.D. Analysis of 12V 10W DC Micro Hydro Turbine: A Case Study; Proc. of NCETPFS 2016, National Conference, Jadavpur University, Kolkata.

[31] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. A Cup of Power in Rural Locations: A Case Study of Micro Hydropower Generation from Drinking Water; Proc. of GCRE 2016, International Conference, NIT Patna.

[32] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Turbine Selection for Small Hydropower Plant: A Multicriteria Optimization Technique Approach; Proc. of GCRE 2016, International Conference, NIT Patna.

[33] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Energy Recovery in Existing Infrastructure with Small Hydropower Plants: A Review; Proc. of GCRE 2016, International Conference, NIT Patna.

[34] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Small Hydro Project Planning Optimization: A Case Study; Proc. of NWRADES 2016, National Conference, Jadavpur University, Kolkata.

[35] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Micro Hydro Turbine Performance Analysis: A CFD Application; Proc. of NWRADES 2016, National Conference, Jadavpur University, Kolkata.

[36] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Green Cold Chain: A Step toward Energy Conservation; Proc. of NWRADES 2016, National Conference, Jadavpur University, Kolkata.

[37] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. H.V.A.C. in Modern Commercial Buildings: Application of Energy Performance Optimization;

Proc. of NWRADES 2016, National Conference, Jadavpur University, Kolkata.

[38] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Sustainable Thermal Energy Storage System (H.V.A.C.): A Case Study; Proc. of NCATE 2016, National Conference, Jadavpur University, Kolkata

[39] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Effect of Airflow Management on a Modular Cold Storage Performance: A Case Study; Proc. of FMFP 2016, International Conference, MNNIT Allahabad.

[40] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Energy Efficient Airflow Management by VRF System: A Case Study; A Case Study; Proc. of FMFP 2016, International Conference, MNNIT Allahabad.

[41] P. Adhikary, P.K.Roy, A. Mazumdar. 2016. Hydro Turbine Runner Material Selection: Application of M.C.D.A. or M.C.D.M.; Proc. of FMFP 2016, International Conference, MNNIT Allahabad.

[42] P. Adhikary, P.K. Roy, A. Mazumdar. 2016. Micro Hydropower Generation from Rural Drinking W.T.P.: C.F.D. Analysis & its Validation; Proc. of FMFP 2016, International Conference, MNNIT Allahabad.

[43] P. Adhikary. 2017. Energy consumption optimization in centrifugal pump: A case study; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB).

[44] P. Adhikary. 2017. 12V DC pico hydro for hilly rural electrification: performance analysis by C.F.D.; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB).

[45] P. Adhikary. 2017. Design and CFD analysis of centrifugal pump; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB).

[46] P. Adhikary. 2017. Hydraulic modelling of water supply network using EPANET; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB).

[47] P. Adhikary. 2017. CFD analysis of concept car for improvement of aerodynamic design; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB).

[48] P. Adhikary. 2017. Design and CFD analysis for pump impeller; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB).

[49] P. Adhikary. 2017. Stress analysis of a hydraulic loader; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB).

[50] P. Adhikary; Thermal Analysis of Halogen Flood Lamp; Proc. of 2nd Regional Science and Technology Congress 2017 (RSTC-Western Region, GoWB); 2017

[51] P. Adhikary; ANN based method to support chilled water pump multi-failure diagnostic: A case study; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata, 2018

[52] P. Adhikary. 2018. Design optimization of chilled water pump impeller using CFD: A case study; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[53] P. Adhikary. 2018. Energy optimization in centrifugal pump like systems: A case study; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[54] P. Adhikary. 2018. Thermal CFD study and improvement of domestic refrigerator evaporator: A case study; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[55] P. Adhikary. 2018. The contact analysis for ball bearing based on DSS Solidworks; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[56] P. Adhikary. 2018. Impact analysis of a cellular phone: A case study of FEA; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[57] P. Adhikary. 2018. Energy efficiency analysis of chilled water pumps: A case study of commercial building HVAC system; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[58] P. Adhikary. 2018. Performance prediction method for pump as turbine (PAT) using CFD modelling: A case study; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[59] P. Adhikary. 2018. Numerical studies on indoor air flow in air-conditioned space: A case study of CFD application; Proc. of ICMAAM 2018, International Conference, Jadavpur University, Kolkata.

[60] P. Adhikary. 2018. 12V DC pico hydro for hilly rural electrification: performance analysis by C.F.D.; Proc. of WBSSTC 2018 (GoWB).

[61] P. Adhikary. 2018. ANN based occupancy detection solution for energy efficient HVAC Control - a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[62] P. Adhikary. 2018. Modelling and analysis of Cooling Tower Pump - a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[63] P. Adhikary. 2018. Rotary Compressor performance analysis comparison using two high pressure refrigerants (R410A and R407C); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[64] P. Adhikary. 2018. Rotary Compressor performance analysis by CFD using two high pressure refrigerants (R134A and R410A); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[65] P. Adhikary. 2018. Performance analysis of HVAC Twin Screw Compressor: study with two different refrigerants (R123 and R407C); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[66] P. Adhikary. 2018. CFD analysis of low-pressure Screw Compressor using two refrigerants (HFD1234yp and R123); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[67] P. Adhikary. 2018. CFD analysis of Twin-Screw Compressor using low pressure refrigerants (HFD1234yp and R407C); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[68] P. Adhikary. 2018. High pressure Rotary Compressor CFD analysis - Performance comparison of two R gases (R134A and R407C); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[69] P. Adhikary. 2018. CFD analysis of high pressure Scroll Compressor - comparison with two refrigerants (R134A and R407C); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[70] P. Adhikary. 2018. Performance analysis by CFD of Scroll Compressor using two high pressure refrigerants (R134A and R410A); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[71] P. Adhikary. 2018. CFD analysis of HVAC Scroll Compressor performance - case study using two refrigerants (R407C and R410A); Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[72] P. Adhikary. 2018. CFD analysis of dairy cold room: a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[73] P. Adhikary. 2018. CFD analysis of a Call Centre HVAC system: a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[74] P. Adhikary. 2018. Data Centre cooling system performance analysis: a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems. (ICHVACR 2018), IEI-ISHRAE.

[75] P. Adhikary. 2018. Performance analysis of an office space HVAC system: a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

[76] P. Adhikary. 2018. Conference room AC system performance analysis: a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems (ICHVACR 2018), IEI-ISHRAE.

[77] P. Adhikary. 2018. Design and development of Arduino controlled self-balancing duct cleaning robot: a case study; Proc. of International Conference on Emerging Technologies for Sustainable and Intelligent HVAC &R Systems. (ICHVACR 2018), IEI-ISHRAE.