Water Hammer in Engineering Application: A Review

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Abstract: *In many industrial applications, water hammer causes damage to pipes, valves, flanges, etc. In boilers, when valves becomes damaged large quantities of steam begin blowing out, which could lead to a serious accident .Also it causes bending and bursting of pipes. It creates vibrations in steam line and also creates noise. Therefore research on water hammer and its effects has become a major area of concern for many researchers. It is necessary to study water hammer in steam power plants to avoid damage and huge maintenance cost leading to long life of the power plant. It plays a vital role in the human safety of thermal power plant. Researchers have focused on study, causes and effects of water hammer on steam power plant. Water hammer is caused by several of condition in flow of sub cooled water and sudden condensation of steam. This paper discusses the various conditions in which water hammer get induced and various parameter that affects the water hammer impact i.e. pressure, temperature, force, opening time of valve, turbulence flow, steam conditions etc. This paper also gives a brief idea about water hammer theory and practice. Geometrical model and graphical representation of impact of water hammer was studied in this review.*
Keywords: *Pipe, Pressure, Water hammer, Strain, Energy dissipation, Temperature*

I. Introduction

Water hammer is caused by fluid in motion is forced to stop or change direction suddenly. Water hammer occurs a momentary abrupt pressure change over 10 Mpa occurred inside piping. It is commonly observed phenomenon. It has multiple adverse effects on system like bending of pipe, damage of equipment, bursting of pipes, etc. Because of these damages large quantity of steam or hot condensate being blowing out which could lead to a serious accident. To overcome these issues there is need to study water hammer. Hammering sound caused in pipe containing water when live steam is passed through it. Water hammer analysis is a fundamental part of the design process of piping system for power plant or water hammer network. Many researches work on causes of water hammer in various industrial application. Their work has been reported by performing exhaustic literature and industrial survey as well as general articles and patients.

II. Lterature Review

Barna et al. [1] experimentally studied in PMK-2 facility to create water hammer along with a setup which was capable to measure water hammer. Also they studied condense induced water hammer theoretically and numerically by WAHA3. They found that experimental values and theoretical values were quiet similar. They measured CIWH in a wide range of steam pressure with cold water temperature and mass flow rate measured very accurately. AgnieszkaMalesinska [2] investigated forces and displacement induced by water hammer also he create mathematical model in matlab software and they used that model for determination of dynamic forces. He carried out this whole process in two steps. In Step1he calculate hydrodynamic reaction forces. In Step 2 he confirmed the assumption of vibration motion generation. Raise et al.[3] investigated numerical analysis, energy dissipation and turbulent kinetic energy production due to water hammer. They used 2D governing equation for their study. They conclude that under α and β decrease the pressure damping decrease as well as sudden rise at wall shear stress and dissipation function increase. Dissipation in unsteady turbulent pipe flows due to water hammer problems had been numerically investigated. For both steady and unsteady turbulent pipe flow numerical and experiment result were observed. Singh et al.[4] investigated actual life incident of water hammer and they recreate that water hammer by using steam, water interaction. They used energy balance equation for variables flow process. Condition of water hammer was reacted in an engineering loop. Further it was carried out thermal hydraulic experiments. It was qualified and locates the incident impact of water hammer. Datta et al.[5]investigated DCC and they found that DCC leads to condensation induced water hammer. They found that maximum pressure peak magnitude due to condensate induce water hammer at 116.6 bar for Δp=10 bar. Also they observed that duration of valve opening affects the location of peak pressure occurance.They conclude that dry saturated steam was necessary condition for occurrence of condensation induced water hammer within test section. Effects of various inlet conditions on the occurrence were investigated and presence of dry saturated steam was necessary condition of water hammer. Sang-Gyun et

al.[6]investigated that conducted field test and numerical analysis of water hammer on the pump raising pipe line system with an air chamber. They found that experimental result and numerical calculation. They conclude that simulated result were influenced by discharge coefficient and wave speed. They found that period of water hammer increased by increasing volume of vessel. The field test and numerical analysis on the water hammer have been carried out in pump line system with an air chamber. Moon-Hyun et al.[7] performed experimental and analytical studies an condensation induced water hammer in horizontal circular pipe. They used seventeen experimental data for procedure of condensate induced water hammer. Also they compare CIWH model with two sets of CIWH data. They develop KAIST-CIWH computer. Like D,P,TR,inand L/D are determined by using computer code.
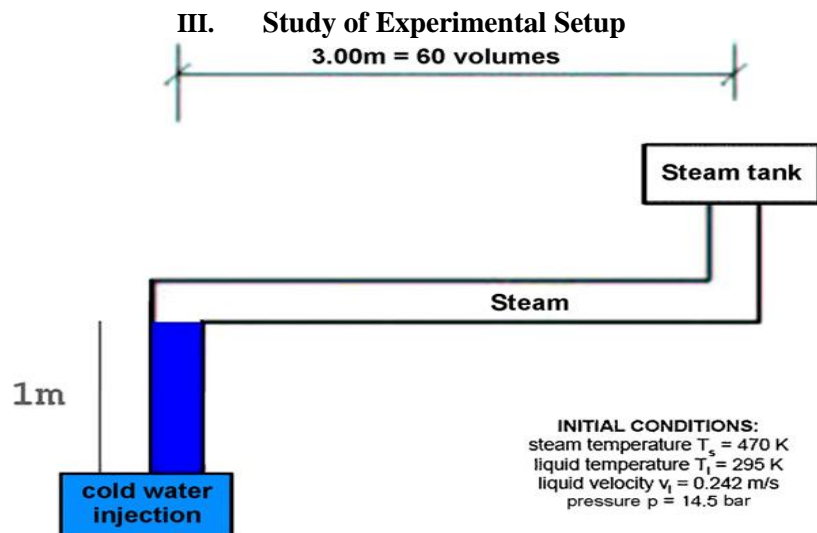
III.   Study of Experimental Setup

Fig.1 The Geometrical model with the initial conditions of the WAHA experiment[1]

Fig.1 represent geometrical model having initial inputs T=470K, P=14.5bar, Tw=295K, V=0.242m/s, horizontal pipe have 3m length and 7.3m diameter. The development of well-equipped test section with advanced instrumentation, which contain mesh sensor, needle probes, fast pressure transducer this instrument help to measure water hammer. In this setup liquid slug was formed because of which water hammer was created. In this model, when the steam was passed through the water, the mixture of steam with water was created. This steam having the large velocity so the water get travels with high intensity of flow of velocity. The bubbles were created in the system of pipe in which they were bombarded on each other and sudden impact was created was known as water hammer. The value of this water hammer was measured as water hammer force and was calculated by partial differential equation.
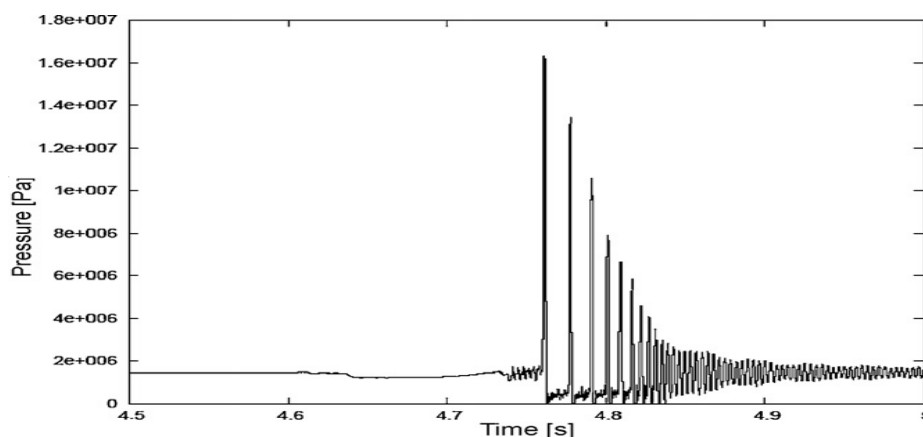

Fig.2 Variation of pressure with respect to time [1]

Fig.2 shows pressure variation peaks obtain by water hammer. By getting maximum value we can calculate major impact of water hammer. They conclude that experimentally and theoretically calculated value was good

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in agreement. More the pressure was obtained, greater impact of water hammer were developed. It gives experimental proof about the phenomenon of water hammer.

IV.   Result And Discussion

AUTHOR	MODEL NAME FOR WATER HAMMER	SOFTWARE AND EQUATION	RESULT
Barna et al. [1]	WAHA3	Two phase flow six first order partial differential equation.	It is used to measure water hammer impact in single and two phase flow.
AgnieszkaMalesinska [2]	Pressure gauge and Dynamometer	Matlab software	It gives the reaction forces and vibration motion by water hammer.
Raise et al.[3]	Standard Test Rig of Water Hammer	2-Dimensional governing equation	Water hammer in Steady and unsteady turbulent pipe flow is to be achieved.
Singh et al.[4]	Integrated Test Loop	Energy Balance Equation	Exact impact of water hammer gets located.
Datta et al.[5]	RELAP	Mod 3.4 simulation	Dry saturated steam is necessary for CIWH
Sang-Gyun et al.[6]	Booster pumping station and layout	Motion and Continuity equation	Water hammer is increased by increasing the volume of vessel.
Moon-Hyun et al.[7]	CIWH Test section and Data Acquisitions system	Governing Equation	Developed KAIST-CIWH computer code

Water hammer is generally induced by sudden closing and opening of valves. In pumping, the impact of water hammer was largely affected to the system. Water hammer was generated in little time with maximum velocity and force. This hammering effect was measured by various equation and software. With the help of values of water hammer, it will gives a benchmark or ranges of pipe, pump and valves for damage free and improvement in the life of power plant system.
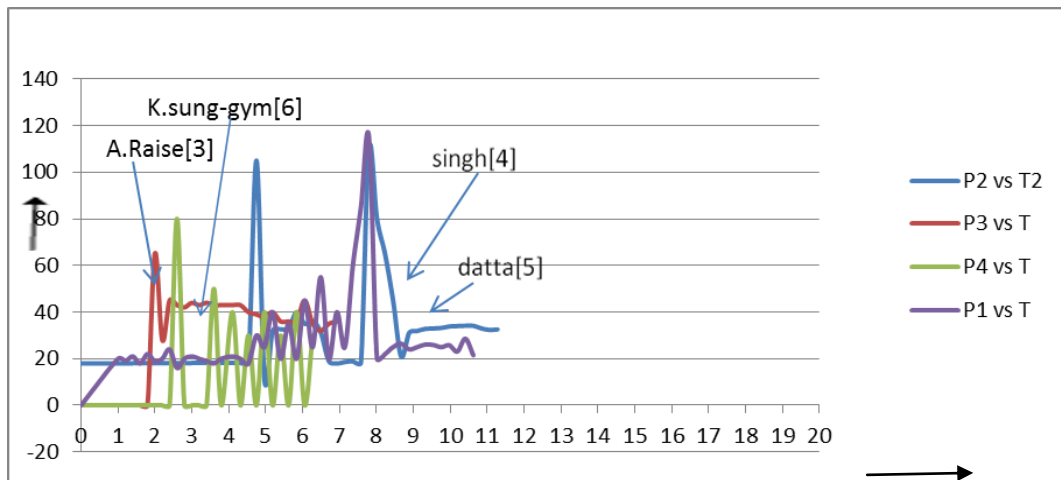

Fig. 3 Graphical Representation of Water Hammer Effect

Above graph represent pressure fluctuations by water hammer effect with respect to time .It represents various values of pressure obtained by various researchers. It shows impact of water hammer at various conditions.

V.   Conclusion

In the present work research papers by different researchers related to water hammer phenomenon has been studied and reviewed. Theoretical, experimental as well as numerical analysis of water hammer is analysed for calculation of impact of water hammer. The various equations for calculating the impact of water hammer are governing equation, energy balance equation, mass momentum equation, two dimensional equations.

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