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Failure Analysis of Hydraulic Piping Systems by Computational Approach- A Survey

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***Abstract*—Hydraulic piping systems are the crucial part of any automation systems. Safe operation of systems is primarily depends on the functioning of hydraulic components incorporated in the systems. Need of high velocity and pressurized fluid resulted in failure of those systems at the junction of joints and the area where more stress likely to act, researcher have tried to solve various problems of flow viz. jamming, erosion, bursting of lines due to turbulence, vortex ,back pressure etc. To avoid the failure and to have robust design the scientist and researchers tried to optimize the design by proper understanding and analysis of hydraulic systems using modern computational and finite analysis techniques. The computational analysis and simulation of flow through pipes provides finest solution which plays an important role in the designing of the hydraulic systems. A finest and correct prediction of the burst pressure of cylindrical vessels or pipes carrying high pressurized fluid is very important in the engineering design for the power, chemical, oil and gas industry. This paper presents a detail literature survey based on modeling and analysis of flow in which various techniques had been used to predict the result by various researchers along with the case study of one of the forging press industry. The breakdown and severity of bursting problem clearly presented with the possible solution considering the problem associated with the systems. This data would be beneficial to the designers and researcher to study the techniques available and to know about the current status for the analysis and investigation of high pressure fluid flow through pipes and vessels.**

Keywords— Bursting, CFD, Hydraulic pipe, Forging Press

I. Introduction

Today's scenario of Indian industries has been changed due to advancement in automation technology that dealing to cope up the mass production with smooth working condition. In an industry most of the machines are working on hydraulic systems which uses seamless pipes for transmission of fluid through suction, delivery lines etc., Safe and convenient operation of piping networks for hydraulic systems required several different aspects to be considered, as the possibility of failure of transmission pipelines at various joints, branches, nozzles, increases due to high pressure of fluid, most of the losses are associated with the failure of pipes only. One of which is the assessment of cracked piping components. The surface crack is usually postulated at locations at which the highest stresses coincident with poorest material properties occur for base materials, weldments area. Current pipeline practices provides different scenarios for understanding the failures of hydraulic systems in which pipeline subjected to large global deformations, well within the plastic range which is very harmful to industry economically. They often operate under extremes high or low temperatures and high pressures that are becoming highly sophisticated. .

After Studying the Literature it is observed that a lot of work is undergoing in the field of Hydraulic piping system to avoid bursting of pipe. H. Li, J. Wood et al. (2013) Investigates the ratcheting and fatigue behavior of 90degree single unreinforced mitred pipe bends subjected to a cyclic in-plane for that The Basquin-Coffin Manson equation over Predicted the fatigue life while the modified equation provided a reasonable estimation. [1] Mihaela Eliza et al. (2012) Studied Fatigue limit assessment on seamless tubes in presence of in homogeneities: Small crack model vs. Full scale testing, experiments. [2] Rahman Seifi, Majid Babalhavaeji (2012) investigate on bursting pressure of Autofrettage cylinders with inclined external cracks bursting pressure increases with increasing the ratio of outer to inner radius (k). [3] I.A. Khan, P. Ahuja et al. (2011) Fracture investigations on piping system having large through-wall circumferential crack and Analysis of surface flaw that might have gone undetected in the NDT would not become through thickness during the life time of the component. [4] T. Aseer Brabin et al. (2011) used Faupel's bursting pressure formula for mild steel cylindrical vessels for predicting the burst strength of thick and thin-walled steel cylindrical vessels.[5] Erling Ostby Asle O. Hellesvi (2008) prepare model for Large-scale experimental investigation of the effect of biaxial loading on the deformation capacity of pipes with defects. [6] X.K. Suna et al. (1999) investigate the bursting problem of filament wound composite pressure vessels, The higher the strength of the composite material is, the lower the relative loading capacity of the dome is, and the relatively easier the case may burst at the dome.[7] S R Shah et. al. (2012) studied The flow analysis inside the centrifugal pump is highly complex mainly due to 3D flow structure involving turbulence, secondary flow, cavitations and unsteadiness. CFD technique has been applied by the researcher to carry out different investigation with the use of navier- stroke equation and k-ε turbulence model. [8] G. Ferrara et. al. (2006) developed CFD model based on the unsteady RANS approach for the numerical simulation of a gas explosion vented through a duct has been proposed. The satisfactory agreement between the model results and the experiments has allowed using the developed CFD code as a numerical tool able to give reliable prediction of the observed experimental trends and it has been then exploited to gain some insights into the phenomenon.[9]M. Egemen Aksoley et al. comparison of bursting pressure result with finite element method this will bring the cost decrease of the tank along with itself. The matching of the experiment and FEM results has indicated that the FEM studies can be used effectively for testing of cylinders. [10] M.A. Lynch (2000) The junctions have branch/run pipe diameter ratio equal to 0.5 and the loads are internal pressure and out-of-plane branch bending for the uncracked cases, circular interaction is relevant but that, as the crack length extends, there is a distinct trend towards linear interaction.[11] Xueguan Song et al (2014) studied numerical model is developed to investigate the fluid and dynamic characteristics of a direct-operated safety relieve valve (SRV). The CFX code has been used to employ advanced computational fluid dynamics (CFD) techniques including moving mesh capabilities, multiple domains and valve piston motion using the CFX Expression Language (CEL). And understanding of the flow and dynamic characteristics of SRVs and also studied dynamic events of the opening and closing process of a SRV mounted on a pressure vessel. [12] M. Staat (2013) experiment on large defects contributes to plastic collapse with a rapid loss of strength with increasing crack sizes. The formulae are compared with primal–dual FEM limit analyses and with burst tests further they have been checked against primal–dual finite element (FEM) limit analyses with rectangular defects in thick pipes. [13] Yi Gong et al (2010) implement finite element analysis FEA was employed to study the erosive effect of on the pipe. Also study Analysis results revealed that interaction between corrosion and erosion both led by scaling, was the main cause that accelerated its thinning and eventually resulted in its premature failure. Metallurgical structure and chemical composition of the pipe's metal matrix were inspected by metallographic microscope (MM) and photoelectric direct reading spectrometer; scanning electron microscope (SEM) and energy dispersive spectroscope (EDS) were applied to observe the microscopic morphology and micro-area composition on the ruptured surface.[14] Asnawi Lubis (2006) studied pressure reduction effect in smooth piping elbow under moment loading, increased flexibility and stress intensification are found for small value of pipe bend diameter.[15]

FEM and CFD have been frequently used in the production process with the aid of mathematical modeling to demonstrate and investigate the piping system for failure. As these are the best tool available to study behavior of flowing fluid through piping system, by means of this available technique one can easily access and analyze the hydraulic piping system to get the solutions as per requirement.

II. CASE STUDY OF FORGING INDUSTRY

Forging is a process whereby metal is shaped into required shape with application of compressive forces. At the forging station with over 2000 Ton of hammer load and over 350 bar pressure delivered by the power-pack system in an industry most of the machines are working on hydraulic system. This system has seamless pipes which used for transmission of fluid through suction, delivery lines etc. for obtaining high pressure. Transmission pipelines having various joints, branches, nozzle if this pipes has failure then most of the losses occur. Finite element analysis is used to analyze the system for failure or defects.

A. Modes of failure

A.1 Development of Cracks near the T-Joint in the piping system.

Occurrence of cracks near the welding section of two connected pipes, as show in Figure A.1 which causes oil loss and eventually affect on production system.

Fig.A.1 (Cracked near T- joint)

A.2 Due to continuous loading cracks resulted to Bursting of lines.

Bursting of a high pressure line due to continuous loading shown in Figure A.2 which causes severe loss of material and to overcome the failure cost required to company is high.

Fig. A.2(Burst pipe)

A.3 Effect of Backpressure

Figure A.3 shows nonstop penetrating of high pressure fluid on T section, Backpressure generated which affect on wall thickness of pipe beyond elastic property it result into failure at joint section.

Fig. A.3(Backpressure Region)

A.4 Due to Stress Concentration

High stress concentration area of the branch pipe as shown in Figure A.4 these is very important phenomena which have to consider while installation of the system, if stress concentration is more it results into jamming, erosion of pipe which ultimately causes failure of pipe.

Fig. A.4(Highly Stress area)

A.5 Insufficient strength of material or selection of improper material

Figure A.5 shows failure of hydraulic pipe due to poor material properties, insufficient strength of pipe which causes wastage of fluid.

Fig. A.5(Poor material condition)

B. FREQUENCY OF FAILURE

The actual data for the breakdown in hours is collected from the forging industry and plotted months against % of actual break down to predict the severity of failure due to hydraulic problem associated with the system as shown in fig. B.1 and fig. B.2. the data is taken per month as per total production time, and percent breakdown is calculated as;

% Break Down (BD) = (Total Effective Delay / Total Production Time) X 100

Figure B.1 shows yearly breakdown report of forge shop since 2012-13 it gives that breakdown period is more than budgeted due failure of pipes which causes production loss.

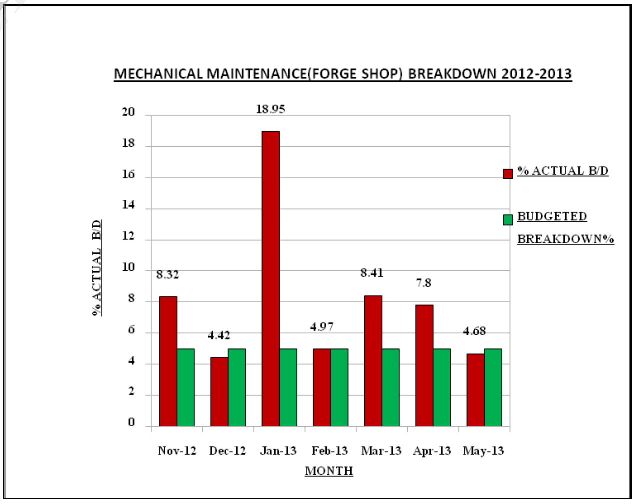

Fig. B.1 Breakdown History 2012-13

Figure B.2 shows that breakdown times are increasing rapidly; more time is required to overcome the encountered failure which frequently occur in the system.

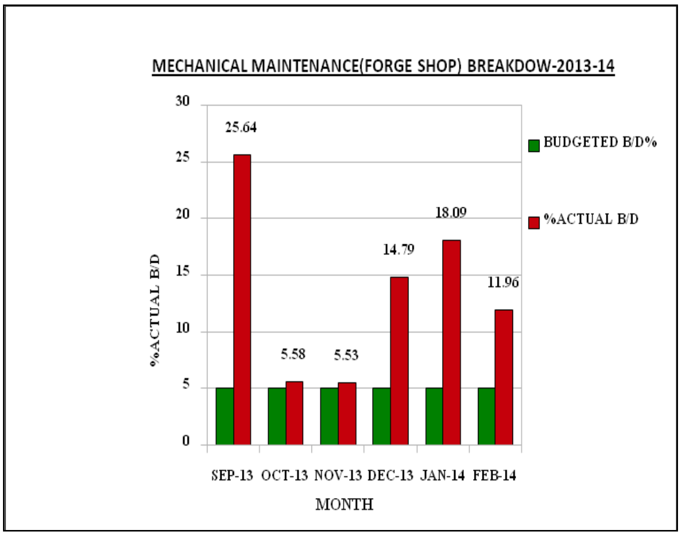

Fig. B.2 Breakdown History 2013-14

From this case study it has been observed that Mathematical Modeling is suitable to predict failure related with piping system. These failures also solve by CFD and FEM more likely with the help of mathematical model to encountered problem very easily and get better results for testing and design of hydraulic system.

Finite Element Analysis consists of a computer model of a material or design that is stressed and analyzed for specific results. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition. It also used to solve problem based on 2-D and 3-D model as per requirement.

Computational Fluid Dynamics (CFD) is the science of predicting fluid flow heat and mass transfer, chemical reactions, and related phenomena by solving numerically the set of governing mathematical equations like Conservation of mass, Conservation of momentum, Conservation of energy, Conservation of species, Effects of body forces. CFD analysis complements testing and experimentation by reducing total acquisition effort and cost required for experimentation and data acquisition. In order to analyzed the hydraulic piping system problem CFD is an excellent tool to find required result.

CONCLUSION

In this paper, a literature survey is carried out to investigate different techniques for finding out failure occur in hydraulic piping system. From the case study it has been observed that the chances of frequency of failure are going on increasing as the modes of failure occurs. Therefore intense research is necessary in type of circumstance. Making changes in production system generally can cause high costs, foreseeing this earning from this cost, the application of FEM and CFD with the it's mathematical modeling is essential in modern hydraulic system to reduce cost and increases productivity.

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