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Monte Carlo Simulations of Crack Propagation at Tee Joint along Pipe

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Abstract:- In this study, we use monte-carlo simulation method to understand and assess the phenomenon. With variable distance from source of crack propagating trajectories are generated. A model is made to explore simple and/or complex case considering a general raw material of known characteristics. Crack path is pen optimized. The basic mechanisms are initiation, propagation and arrest. Although it takes more than hundreds of runs to get the results but optimization show potential to put up with the model. Initial crack growth paths for equal tension to bend ratio in two dimensions from the source may be validated with other approaches, afterwards, dynamically.

Keywords:- Monte Carlo, Crack, Simulation, Propagation, Optimization, Health

I. INTRODUCTION

Crack path tracking is a major concern in many industrial situations. There are huge pipeline systems in every process industry to transport material from one location to other location. Many other materials formed and accumulated as waste in real life are needed to be transported from living place to abandon place. Hazardous fluids are security risk for human life. The pipeline transportation of these kinds of materials and any other useful products made by process industry make the economic factor grow up as well as standardize the life of common peoples effecting their development in socio-economic life style and providing healthy and safe environment. But when there is an explosion in pipe or burst of transportation system or failure of any kind in process industry during running time due to some crack in pipe wall which has been there for long, any one can imagine the worst situation which may take place due to these accidents. Many researchers have noted the importance of this area and have done a lot of work to estimate the crack path, its growth and its happening using many different techniques. In medical sciences, human body has a structure to be taken care of. It has veins, bones and blood flow, air, water, gas, solid food, and after processing the waste comprising all many materials with associated hazards and dangers of fatigue, fractures and cracks.

Initial work has been done. In this study we want to use dynamic monte-carlo approach to address the problem. It was hard to predict crack path formed at first but confidence was gained after many numerical experiments. A general random number struggle is followed at first instance. This model is planned to base on dynamic approach. Recently, [1] models fatigue crack propagation using dual boundary element method and Gaussian Monte Carlo method. Their work is plenty but they are not reporting crack paths along any side to track down it for future and to arrest it. They say that monte-carlo method predicted better for small cracks at critical location and for big cracks at unimportant locations. They also show that it is better than their other stress analysis approach for some parameters.

Reference [2] tests method variability in slow crack growth properties of sealing glasses by using constant stress rate testing in ~2% and 95% relative humidity. They say that the crack velocity is very sensitive to small changes in relative humidity at low relative humidity. They find that biaxial and uni-axial stress states produce similar parameters. They report that propagation of errors solutions parametric study for confidence intervals on crack growth parameters is comparable to those estimated from Monte Carlo simulation. From stress and velocity figures their approach may be used to predict the arrest for the material they used. Their findings are appealing to work for macro level cracks. Reference [3] reports a novel microstructure grain boundary character based integrated modeling approach of inter granular stress corrosion crack propagation in polycrystalline materials. Their predicted crack-propagation behavior is in reasonable agreement with the electron back-scattered diffraction based experimentally determined relationship. A model for inter-granular stress corrosion crack propagation in polycrystalline materials is also proposed [4]. It overcomes several limitations of the currently available model in the literature for this purpose related to crack direction. Markov Chain theory and Monte Carlo simulations are combined to predict the maximum crack lengths for different grain boundary character distributions. The fundamental Markov Chain theory requires that the summation of the probabilities from any transition point is one. This can be adapted easily for a single crack that does not branch into two cracks in any triple junction. Reference [5] presents probabilistic model to predict the formation and propagation of crack networks in thermal fatigue based on a random distribution of sites where cracks initiate and on the shielding phenomenon corresponding to the relaxed stress field created around cracks. Reference [6] estimates, using Monte Carlo simulation, the statistical properties of inter-granular crack trajectories in polycrystalline materials. Their probabilistic model proposed is able to produce synthetic crack trajectories that replicate the important statistical properties of the simulated cracks. Macro-level is a next step for their study.

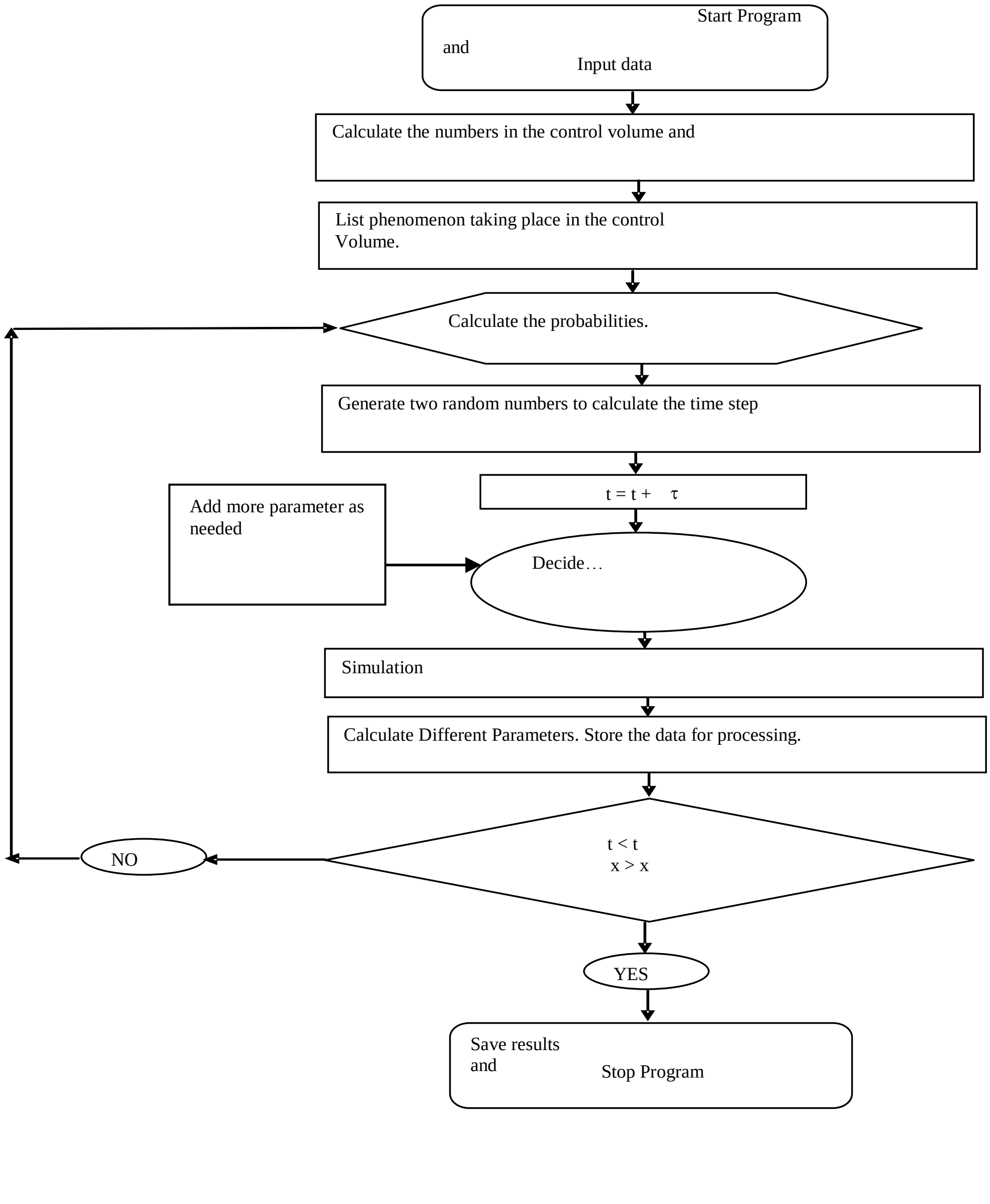

Fig. 1: The schematic diagram of the Monte Carlo method

In this work, to use monte-carlo simulation and modeling method to understand and assess the phenomenon dynamically is schemed. The basic mechanism is initiation, propagation and arrest. With variable distance from source of crack propagating trajectories are generated. Model to predict simple or complex case considering a general material of known characteristics is of concern. Crack path is to be optimized. Although it may take hundreds runs to get the results if validation with actual situation is planned but present estimations show potential to put up with the theoretical model. Initial crack growth paths for equal tension to bend ratio in two dimensions from the source are a part of the validation scheme. Moreover, different parametric studies may also be done using the same model introducing the relative formulae e.g. fatigue using Young's modulus and creep using crack growth prediction. Ductile tearing, combined effect of fatigue, creep, and ductile tearing, crack orientation, initial crack depth, and crack growth under fatigue may also be investigated using the same model with relative modifications. Initially, flow is not considered that is fluid is at rest. Characteristics of fluid may influence on the crack in many ways.

II. NUMERICAL MODEL

The Gillespie's algorithm for dynamic Monte Carlo simulation is shown in previous figure. In this method, a control volume (V), is defined at time zero. The time step is related to the inverse of total stochastic rates and the natural logarithmic of r2 according to the equation (1) [8].

$$\tau = \frac{1}{\sum_{v=1}^{\mu} R_v} \ln\left(\frac{1}{r_2}\right) \tag{1}$$

Probabilities assumption may be set varied from 0 to 1 depending upon experience. The initiation is from particle scratch on the inner surface of pipe. The monte-carlo method is just one of many methods for analyzing uncertainty propagation, where the goal is to determine how random variation, lack of knowledge, or error affects the sensitivity, performance, or reliability of the system that is being modeled. monte-carlo simulation is categorized as a sampling method because the inputs are randomly generated from probability distributions to simulate the process of sampling from an actual population. So, it is tried to choose a distribution for the inputs that most closely matches data which is already available, or best represents the current state of knowledge. Fluid and the pipe material are adjacent to each other. With particle dynamic it may show good agreement. Fluid in the pipe will have effects on crack growth which may be studied separately introducing fluid density, flow rate, pressure and temperature etc. Figure 1 describes the model which is preliminary used with fluid at rest with no reaction. Reactive fluid may have reaction with pipe material and reaction conversions may be involved. High temperature and huge pressure may be another initiation step.

III. RESULTS

Monte-carlo simulation method is applied to hit the problem to understand and assess it. With variable distance from source of crack propagating trajectories are generated. Crack path is optimized following basic mechanisms of initiation, propagation and arrest. Although it takes more than thousands of runs to get the results but predictions show potential to put up with the model. Initial crack growth paths for equal tension to bend ratio in two dimensions from the source are validated with other approaches.

Figure 2 shows the base geometry used as a system defining a control volume of specified area to study crack propagation. Initiation position of crack is shown. Tensions and loads applied are also mentioned. Along pipe in the direction of flow the tension and bend ratio is considered as one for numerical experimental simulations.

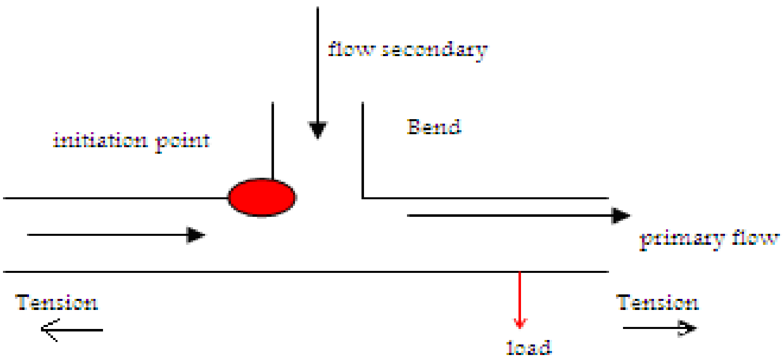

Fig. 2: Base geometry, Tensions and load are applied, along pipe in direction of flow at tension to bend ratio equal to one.

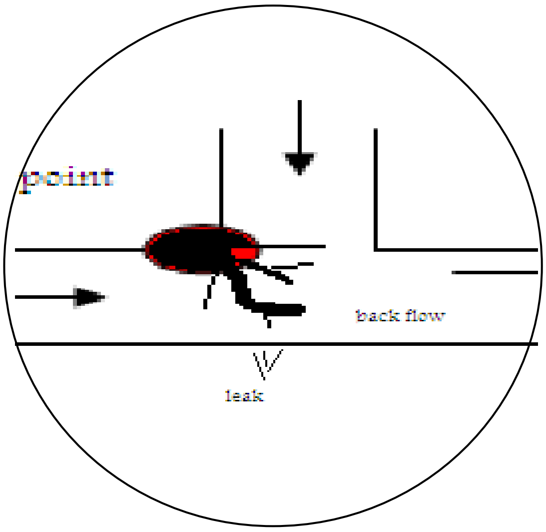

Fig. 3: Magnified Crack generated producing back flow and leaks

Directions are also shown. Initiation point is degenerated due to load and tension depending upon material characteristics whenever is shown. After time passing, fluid flowing and inner outer environmental temperature and pressure the crack follows the natural way of propagating through the material finding the weak ways where the inner bonds of construction of material are weak. Some time the fluid contained enhances this phenomenon struggling into cracks. Figure 3 shows the magnified area of crack place. Many small, large with different lengths and different widths may be seen. These propagation habits of cracks are dependant on materiel characteristics and the tension generated and load applied or deployed by outer structure. Different fluid behaviors are produced due to these small crack formations in the materials. Leaks may be started and for hazardous fluids it is very important to tap and stop these at exact and appropriate time before any mishandling or mistake or warning of life danger at plant. These modeling approaches should be done before hand for all type of materials installed and used for construction at plant and factory of any type. Figure 4 shows crack propagation path. Crack growth dynamic histories are also drawn and it is seen that initially crack breaks fast then its propagation becomes almost constant until fracture. Numerical experiments are optimized and the scale up for industrial application at design factor 1.10 is shown. Scale up crack in actual conditions is always faster than expected and more robust fracture may occur than as calculated and simulated.

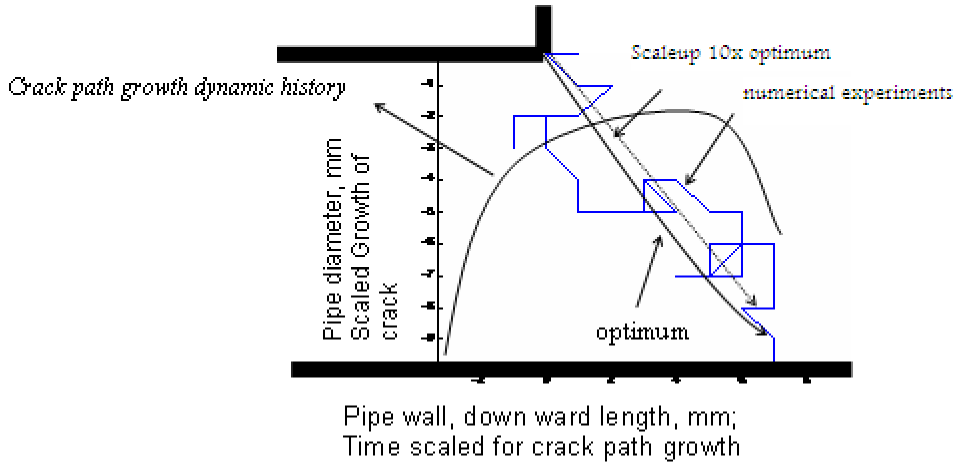

Fig. 4: Crack propagation path, pen Optimized line, Crack dynamic history graph, with numerical experiments shown, Crack Path with numerical experiments is optimized. Crack path growth dynamic history starts at no crack; it is growing constant till the fracture

IV. CONCLUSIONS AND RECOMMENDATIONS

Materials should be selected for their use depending upon the inner fluid and outer construction plant design. The development in design strongly depends upon material selection. Leak points should be mentioned

at plant lines and security inspections should be more regularly for these mentioned and marked points. Environmental conditions should be recorded regularly at plant place for any future accident investigations.
Moreover, different parametric studies may also be done using the same model introducing the relative formulae e.g. fatigue using Young's modulus and creep using crack growth prediction. Ductile tearing, combined effect of fatigue, creep, and ductile tearing, crack orientation, initial crack depth, and crack growth under fatigue may also be investigated using the same model with relative modifications. Similar layout scale down medical studies may be done for bone fatigue and fracture.

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