Computational Study of Erosion Corrosion on Elbow Pipe 90º made from low carbon steel

Hassan Gh Lama. Mohamed Etouhami Swei. Hweda Muftah Sharif. Abdurraouf Fadel

Abstract

In this paper, a computational study is performed to investigate the influence of hot steam from a boiler at the site of Meleta Oil and Gas Company on elbow pipe 90° made from low carbon steel. It is common that erosion corrosion occurs frequently in pipelines used for conveying liquids and it is considered to be one of the major problems that occur in pipes. An ANSYS (16.0) program was used to analyze all the data which have been collected from Mellita oil and gas company. This program has become the powerful engineering programs for analyzing the data. Data has been developed to obtain the best results to evaluate the speed of erosion corrosion of the used elbow. The ANSYS program (16.0), was used to simulate the elbow. The company's data which was used for the simulation are the velocity, steam pressure and constant temperature, as well as the introduction of hypothetical data, the first was lower and the second was higher than the company's data, to study the comparison of all the data and to compare them in order to obtain the best results for reducing erosion corrosion. The best results were obtained by reducing the velocity and the steam pressure, but this is difficult to change, so the recommendations have been made for changing the material of elbow pipe to increase the operating life and reducing erosion corrosion of the elbow pipe.

الملخص

في هذا البحث، تم إجراء دراسة للتحقق من تأثير البخار الساخن من المرجل في موقع شركة مليته للنفط والغاز على أنبوب الكوع 90^{0} درجة المصنوع من الصلب منخفض الكربون، ومن الشائع أن تآكل الحت يحدث بشكل متكرر في خطوط الأنابيب المستخدمة في نقل السوائل ويعتبر من المشاكل الرئيسية التي تحدث في الأنابيب.

تم استخدام برنامج انسسز (16.0) لتحليل كافة البيانات التي تم جمعها من شركة مليته للنفط والغاز، أصبح هذا البرنامج من البرامج الهندسية القوية لتحليل البيانات، تم تغيير البيانات للحصول على أفضل النتائج لتقييم سرعة تآكل الكوع المستخدم، تم استخدام برنامج انسسز (16.0) لمحاكاة الكوع الانبوب، بيانات الشركة التي تم استخدامها في المحاكاة هي السرعة وضغط البخار ودرجة الحرارة الثابتة، بالإضافة إلى إدخال البيانات الافتراضية، الأول كان أقل والثاني أعلى من بيانات الشركة، لدراسة مقارنة جميع البيانات ومقارنتها من أجل الحصول على أفضل النتائج لتقليل تآكل الحت. تم الحصول على أفضل النتائج من خلال تقليل السرعة وضغط البخار، ولكن من الصعب تغيير ذلك، لذلك تم تقديم التوصيات لتغيير مادة أنبوب الكوع لزيادة عمر التشغيل وتقليل تآكل الحث لأنبوب الكوع. تم استخدم برنامج آنسز (16.0) لتحليل جميع البينات، إن هذا البرنامج أصبح من أكثر البرامج الهندسية المستخدمة في تحليل البيانات حيث تم وضع هذه البينات للحصول على افضل النتائج لمعرفة سرعة التآكل الحثي للكوع المستخدم.

1- Introduction

In the pipeline system, erosion failure is one of main forms for elbow pipe failures, since in the steam gathering and transferring process, natural steam condensate and corrosive substances are often in the elbow pipe, by fluid effect, it is very easy for right-angle elbow pipe to be eroded by fluid velocity to cause failure [1]. Experiment is the traditional method to research erosion failure of elbow pipe, however, due to its shortcomings of long cycle of operation and high cost, numerical method is often adopted for its qualitative analysis [2,3,4]. The study utilizes CFD Software for numerical simulation. Compared with other fluid numerical simulation software's, CFX has a certain amount of advantages of precise numerical calculation, quick computational solution and abundant physical models [5,6].

Elbow pipe is used for transfer the fluid. This transfer fluid plays big role in the productivity; therefore, it is desirable that design of elbow pipe should be optimum as possible. To obtained a good design, it is essential to know the flow distribution pattern throw the elbow pipe, so that, prediction can be made regarding to flow distribution which can be used as reference for the design of elbow pipe [7,8]. In this research a study of the elbow pipe is carried to achieve a solution which can be used as reference for design, and the CFD (Computer Fluid Dynamics) analysis of erosion in elbow pipe was used to determine the flow, velocity, pressure and heat effects on elbow pipe. Since the elbow pipe configuration is encountered in piping systems in power plants and process industries [9]. It is often important to predict the flow field and temperature field in the area of the mixing region in order to properly design the junction.

The analyzations of the elbow pipe in laminar as well as turbulent flow in different parameters have been carried out. The comprising of these parameters with the data obtained from Meleta Gas Company were done, to notified the difference in flow distribution and its affects, so the design of elbow pipe can be made with respect of flow in elbow pipe.

Therefore, the analyses have been done through ANSYS (16) software, for this purpose, we have used the ANSYS software to make the CFD (i.e. Computer Fluid Dynamics analysis of elbow pipe). Nowadays ANSYS become the world's leading engineering software in this field, and their solutions are very much reliable than other.

2- The objectives of this study

The main objectives of this study as follows:

1. The simulation of CFD for elbow pipe.
2. To study the erosion-corrosion in elbow pipe.
3. To analyze the velocity, pressure, through laminar flow.

Tables (1,2) shows the physical properties if the steam and elbow pipes.

Table (1). Physical properties of the steam and the elbow pipe.

Physical properties	Steam
Temperature	168 ℃ - 441 K
Pressure	0.35 Pa - 0.75 Pa – 0.9 Pa
Velocity	0.25m/s - 0.5 m/s – 1m/s
Density kg/m^3	0.5542
Specific heat J kg^{-1} C^{-1}	2014
Thermal conductivity Wm^{-1} C^{-1}	0.0261
Thermal coefficient	0.9137

Table (2) Physical properties of the elbow pipe material

Material	Carbon Steel
Density kg/m^3	8030
Specific heat J kg^{-1} C^{-1}	502.48
Thermal conductivity Wm^{-1} C^{-1}	16.27

2-2- Geometry

The geometry of elbow pipe 90º as illustrate in figure (1) and its dimension in table (3)

Table (3) Dimensions of elbow pipe

Internal diameter	100mm
Thickness	20mm
Length X and Y	500mm
Ø angel	90º

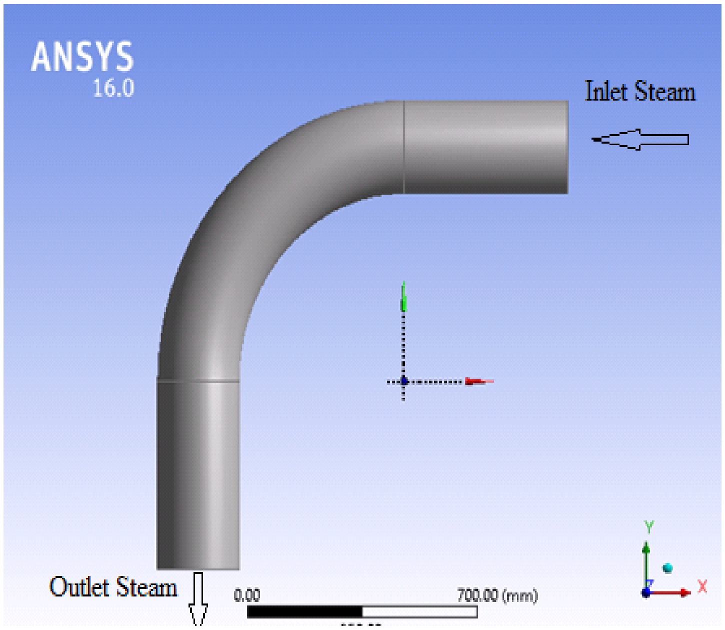

Fig. (1). Shows the geometry of elbow pipe 90º

3- Numerical Simulation

CFD is applied to simulate the flow of fluid in the elbow pipe angle and the data which have been collected from the site is set as boundary condition. It is specific that steam is set as continuous fluid and liquid phase as discrete fluid. Mass flow rates and volume fractions of steam is set as inlet boundary conditions, while static pressure of average cross section is as outlet boundary condition. Steady-state Simulation and finite volume method are adopted to implement numerical simulation for flow in the comprehensively developed steam and liquid-phase flow pipes in order to get velocity field contour and velocity vector diagram of flowing medium, volume fraction contour of downstream section in liquid-phase elbow as well as pressure contour and shear stress contour of pipe wall. The streamline is composed of different fluid particles, which gives the direction of motion of different flow particles at the same time. The volume fraction of the section can reflect the proportional relation of material at certain time.

3.1. Mesh

In the mesh generation, the flow domain is discretized into small number of elements. The size of the mesh is selected after grid independence test. In this research grid size is varied until the constant or almost equal result does not obtained. Although with fine mesh more accurate solutions are obtained then course size mesh but long computing time and more power is consumed.

After the geometry drawing the surface of the elbow have been divided in to mesh, the nudes (8196) and the elements (20406), as shown in figure (2).

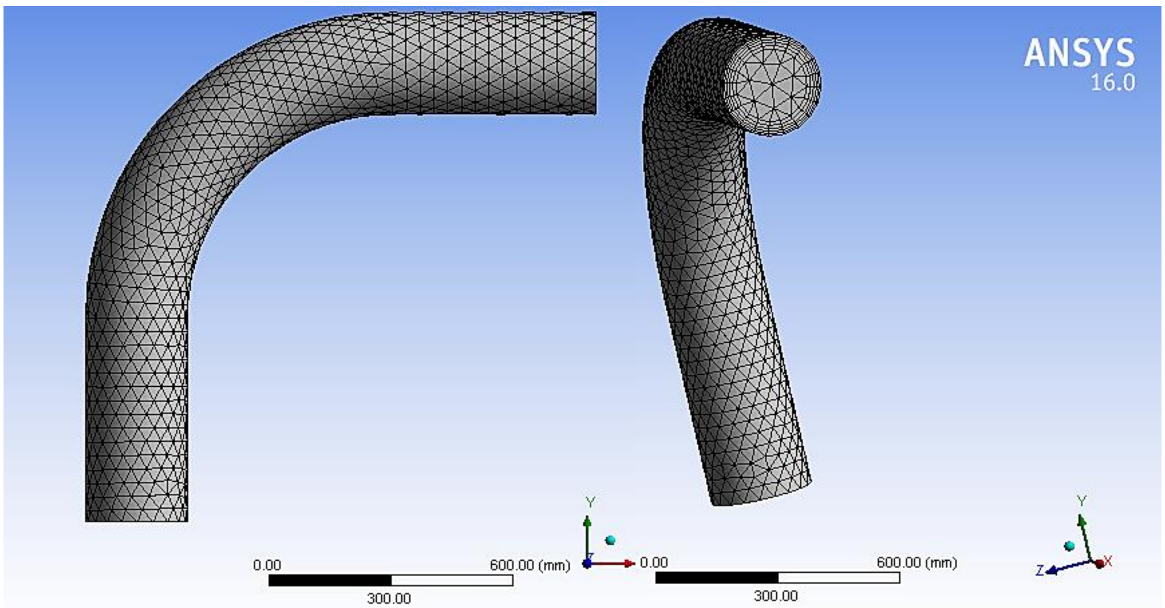

Fig. (2). Shows the Mesh for the elbow pipe 90º

3.2. Velocity

Velocity of the fluid through the elbow pipe is one of the most significant parameters due to erosion-corrosion in elbow pipe. The effect of velocity for erosion wear of elbow pipe is analyzed at three different velocities parameters (0.25 m/s, 0.5 m/s and 1 m/s), and pressures (0.9 Pa, 0.75 Pa and 0.35 Pa). The erosion rate is increases with increasing the velocity and depends upon the intensity of increased velocity by assuming the constant others parameters like impact angle, steam concentration, target material. It is observed that the erosion rate is gradually increases with increasing the velocity of flowing from (0.5m/s and 1m/s). Whereas steep erosion rate observed by increasing velocity. Figure (3) shows the effect of three different velocities parameters 1 m/s, 0.5 m/s and 0.25m/s.

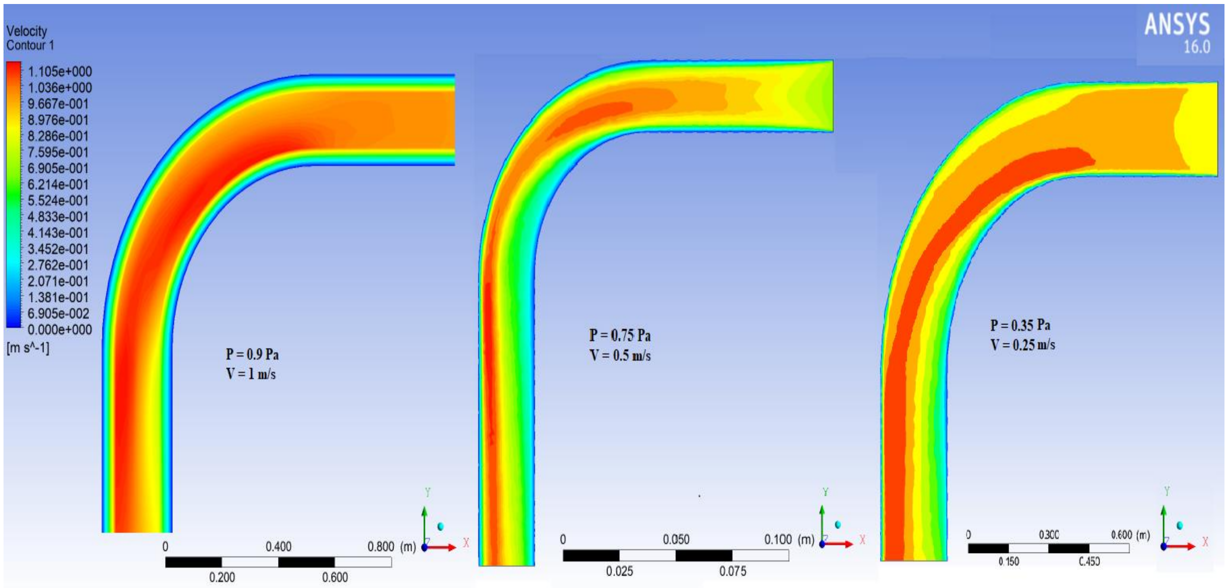

Fig. (3). Show the differences of the velocity of steam inside the elbow pipe.

Figure (4) shows the steam line direction and their concentrations at the bend angle. The steam line is composed of different fluid particles, which gives the direction of motion of the fluid at the same time. The volume fraction of the section can reflect the proportional relation of the material at a certain time. Steam line diagrams of elbow pipe section are shown in figure (4).

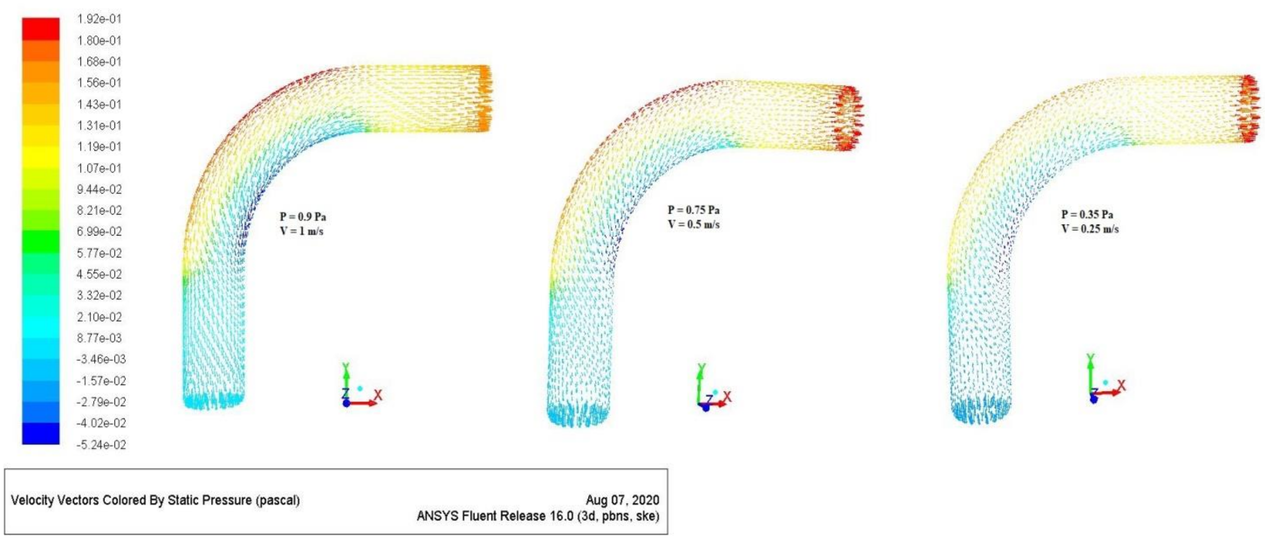

Fig. (4). Show the differences of the steam line velocity contour inside the elbow pipe

It is observed from the results that velocity at inlet and outlet of the elbow section changes in transverse direction from inner wall to outer wall. Transverse recirculation of the flow takes place due to the centrifugal effect along the curvature of the bend, due to this effect steam strikes at outer wall of the bend and lead to erosion at the impingement section as shown in figure (5).

The recirculation in transverse plan is mainly depends upon the intensity of the velocity of flowing in elbow pipe, and that means low velocity lead to low recirculation and high velocity lead to high recirculation.

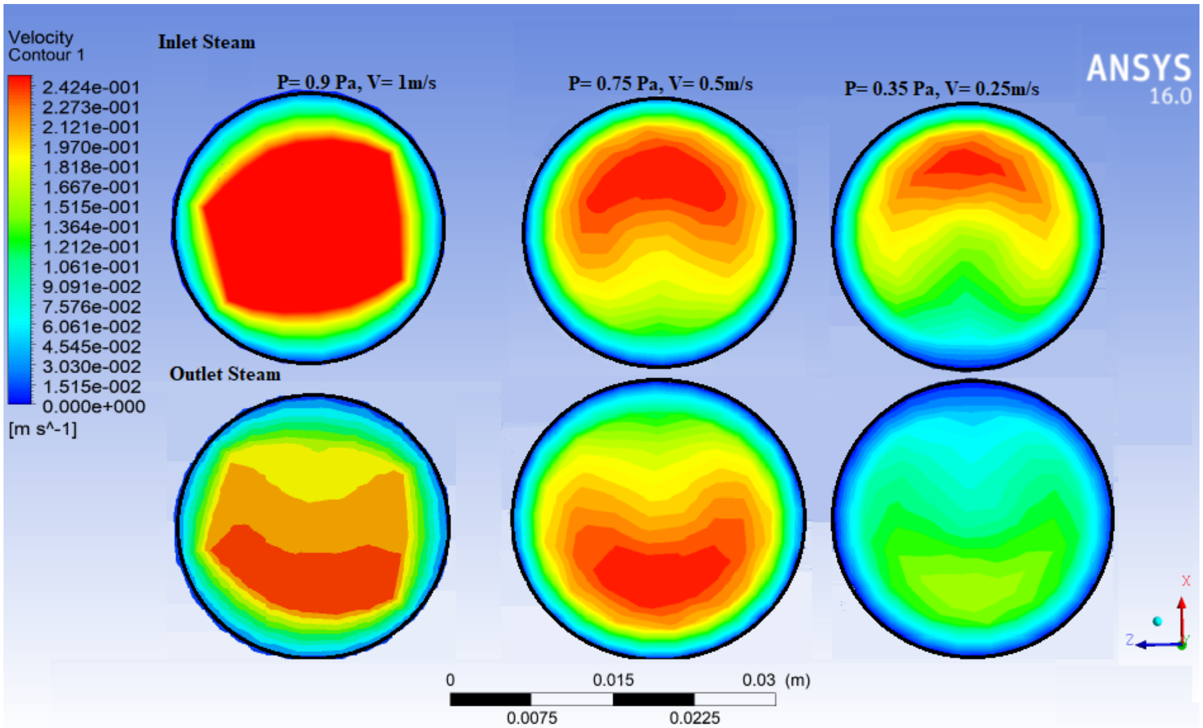

Fig (5). Illustrate the distributions of the velocity at the inlet and outlet of elbow pipe with particles concentration.

3-3- Pressure

Pressure of the fluid through the elbow pipe also is the most active parameter due to erosion-corrosion in elbow pipe. The effect of the Pressure on erosion wear of elbow pipe is analyzed at three different Pressures parameters (0.9 Pa, 0.75 Pa and 0.35 Pa). Pressure is 0.75 Pa. both velocity and pressure are influenced the erosion in the bend of the elbow pipe, as shown in figures (6,7).

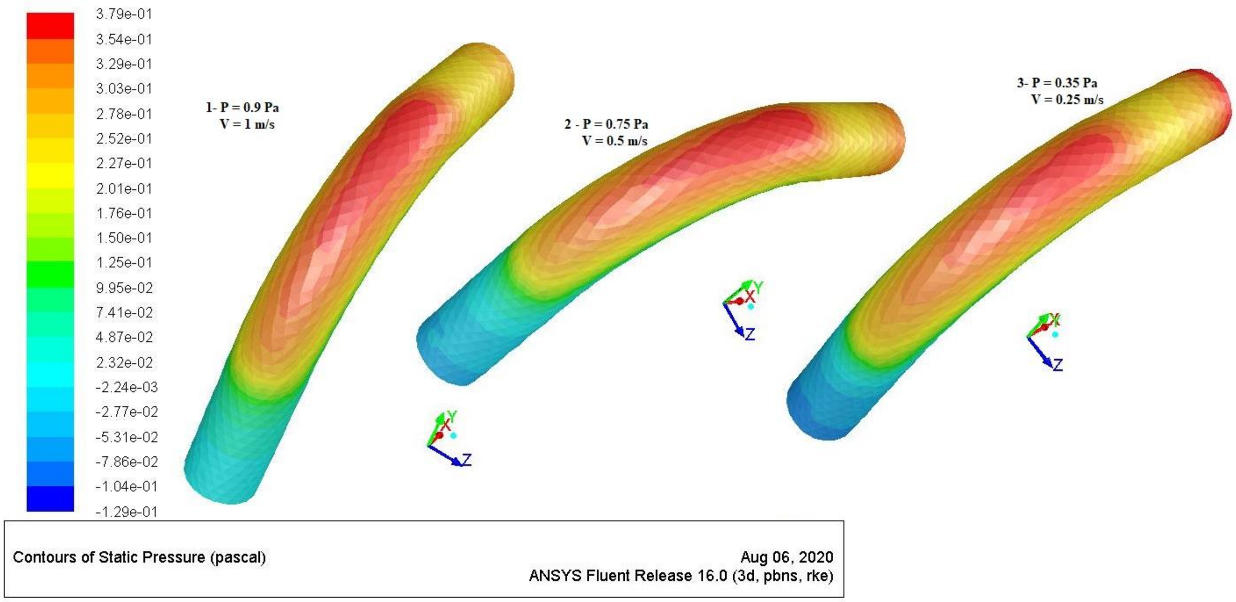

Fig (6). Shows the presuure concentrating in elbow pipe.

Figure (7) shows the concentration of pressure conture in the bend elbow pipe from inside.

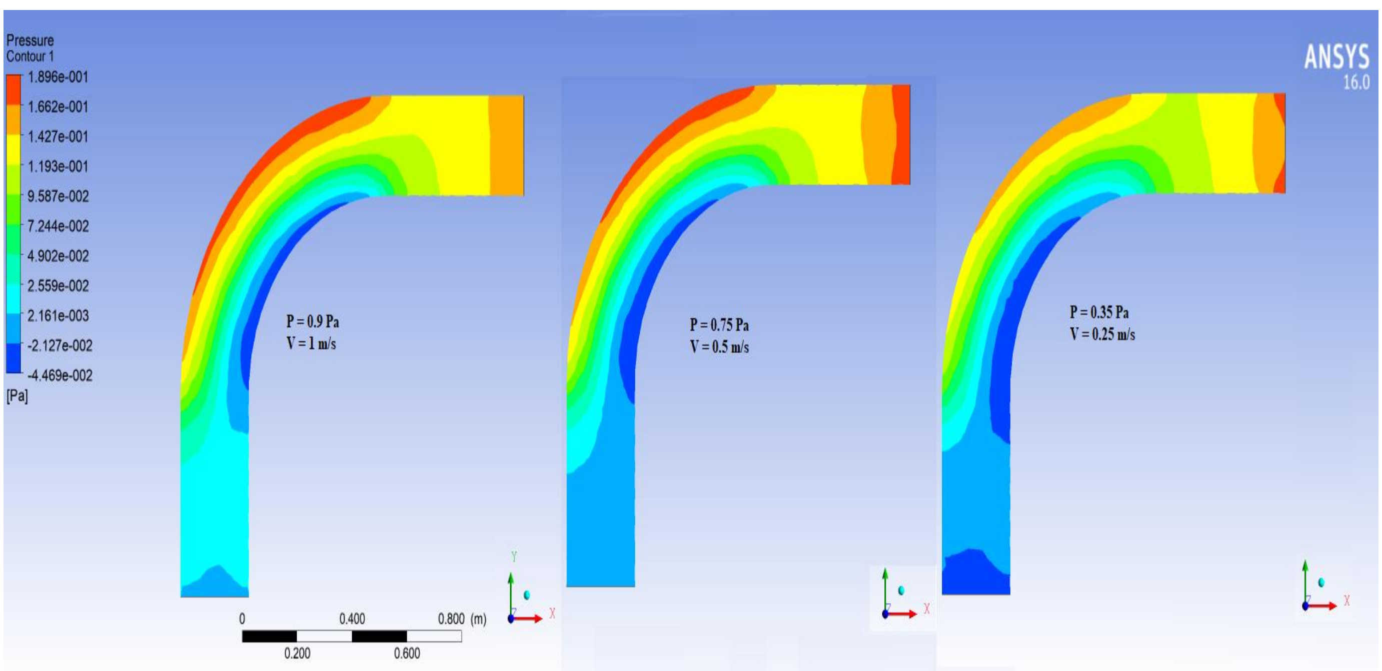

Fig (7). Shows concentrating steam presuure inside the elbow pipe.

3-4- Erosion

The contours for erosion were occurred at the elbow wall in bend side at different velocities and pressures parameters. The erosion made the elbow very weak, all the parameters were affected and lead to erosion corrosion, as shown in figure (8).

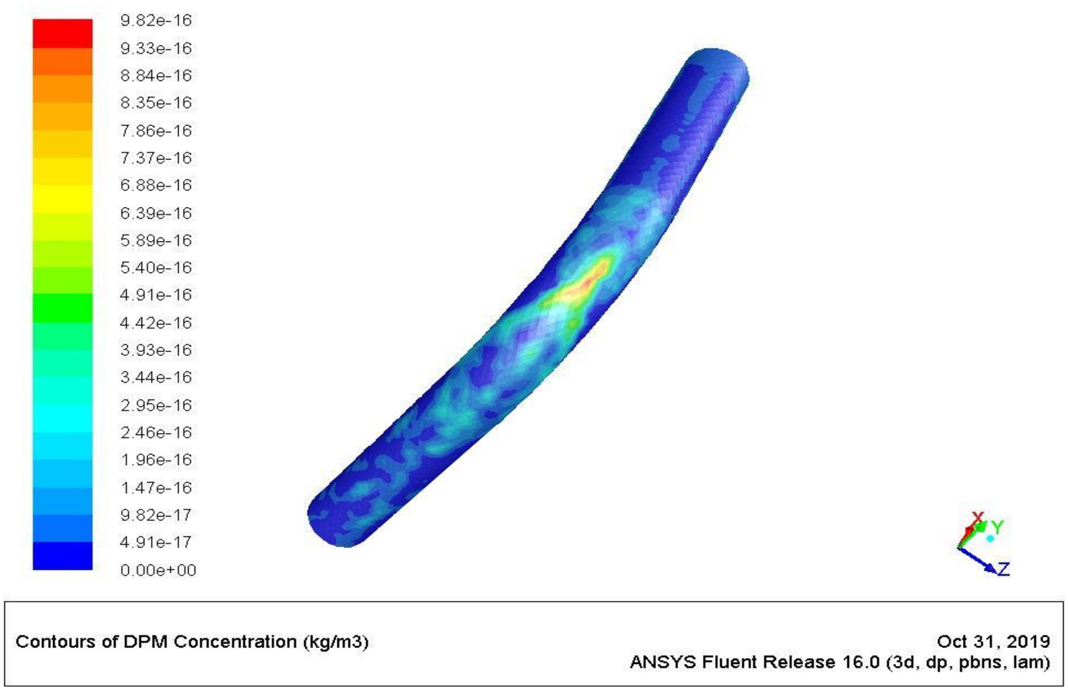

Fig (8). Shows erosion is located in the bend of the elbow pipe.

Figure (9) shows the erosion in different parameters, and it observed that the higher velocity and higher pressure are leads to more erosion.

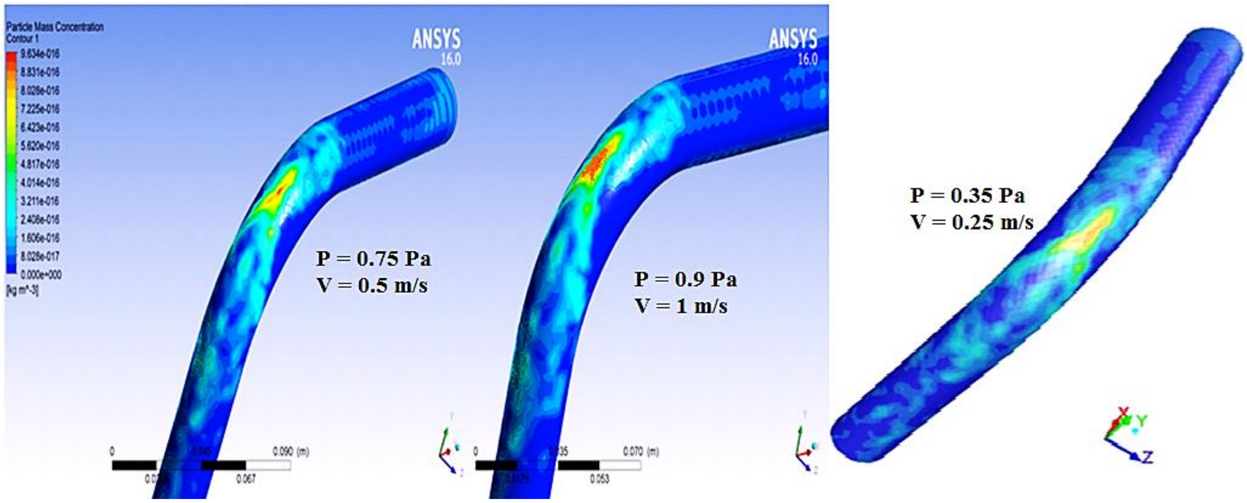

Fig (9). Shows particle mass concentration of erosion corrosion.

Results and discussion

The erosion effect is studied through simulation process by using ANSYS (16). The simulation studied the effect of hot steam on the 90° of carbon steel elbow in the pipeline. The result of this simulation is investigated and analyzed and the rate of erosion is correlated with the hot steam mass flow rate. The results show that mass flow rate of hot steam will give the significant effect on the erosion rate. The erosion rate will increase exponentially when the hot steam mass flow rate increases line in Pipeline. Figure (3) shows the distribution of streamlines in pipeline, where the color of the streamline indicates the velocity magnitude. From Figure 3 the maximum flow velocity (1 m/s) and the minimum flow velocity (0.25 m/s) are concentrated in the elbow section. From Figure 3, the location of maximum flow velocity and minimum flow velocity is close to the intrados surface. The velocity of hot steam increases and then decreases near the intrados surface **P**ressure, Friction Speed Characteristics, Intensity. Figure (6) shows the pressure distribution contour of the pipeline. Although the pressure in the inlet of the pipe is set to a constant (0.90 MPa), the pressure on the extrados surface (0.35 MPa), the pressure on the extrados surface is higher than that on the intrados surface.

The hot steam at high speed hit the wall of the tube, especially in the elbow section with high velocity, which caused the serious erosion area on the extrados of elbow. The corrosion current density of iron is concentrated in the junction of the straight section and elbow and the intersection of the straight section and the intrados surface of elbow.

4- Conclusions

A new erosion corrosion model was developed based on previous work. A commercial Computation Fluid Dynamics (CFD) was used for analyzing the erosion-corrosion in elbow pipe, and are illustrate below: -

1. The erosion which occurred in elbow pipe is greatly influenced by velocity and pressure.
2. Erosion rate varies increases with increase in velocity.

3. Patterns appeared at low velocities.
4. The u-shape Distorted pattern appeared on the outer wall of elbow high velocities.
5. The low-velocity region forms at outer wall of elbow.
6. The low velocity region occurs around circumference of elbow wall, this happens due to stimulation of the drag forces near the wall region.

5- Recommendation

It's not possible to change the parameters of velocity and the pressure, but it may recommend to replacing the material of the elbow pipe from carbon steel by:-

1- Using heat resistance alloy steel.
2- Replacing it by ceramic.
3- Replacing it by high heat resistance polymers.
4- Using appropriate composite materials.

6- References

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