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"Finite Element Stress Analysis and Stress Intensity Factor of T-Joint Pipe Intersection Subjected with Moments"

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Abstract- *This paper reports stress analysis of two pipes intersection using finite element method. The equal combinations of dimensions of run pipe and the branch pipe are used to investigate the stresses in pipe at the intersection. The stress intensity factors are determined for various angular locations at intersection.*
Keywords*— Stress analysis, Finite element method, Pipe T-joint.*

I. Introduction

The pipes are important and very sensitive component in the process plant and piping system. The pipes are subjected to various types of load, in different cases and application. These loads are responsible for increase in the stresses and decrease the life span of pipes. The loads may be internal pressure, external pressure, forces moments or other loads.

Stress analysis of the T-joint pipe is given carried out for the different conditions of loading. The Finite Element Method is used to find out the stresses at the junction of branch pipe and run pipe of equal diameter. The T-joint pipe is subjected to internal pressure with one end is constrained and moment applied at free end of the pipe.

In the study, the magnitude of stress intensity of T-joint pipe under the loading condition is analyzed using ANSYS. The stress intensity is obtained for 15^o, 30^o, 45^o up to 180^o angular locations at the intersection junction and stress intensity factor is also calculated. The stresses are induced in the T-joint pipes are different at different location and it depends on the nature and design of the pipe. The maximum stresses are induced at the junction or where the joint is formed. Hence stress intensity decreases away from the junction and increases towards the junction.

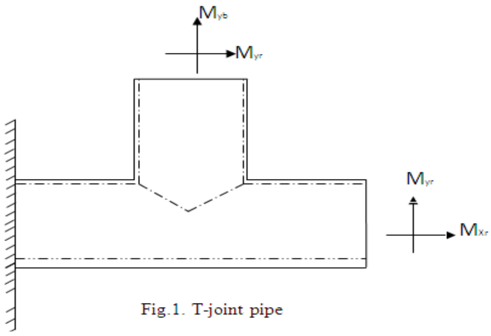

Fig.1. T-joint pipe

It is evident from the geometry of T-joint pipe shown in fig.1; there is change in geometry at the intersecting junction which leads to stress concentration effect at the intersecting junction. Due to this, probability of failure increases at this location. In this work an effort is made to study the stress intensity at intersecting junction of run and branch pipe. T pipe joint is considered for stress analysis. The loading under internal pressure and moments is considered.

Stress Analysis of Plain Pipe and T-Joint Pipe with Equal Diameter

To study the stress intensity factor, a simple problem of plain pipe and T-joint pipe are considered. The case is useful for verification of FE results with previous experimental results. The specifications of pipe considered are as fallows.

- Outer diameter (D_O) = 70mm
- Inner diameter (D_I) = 60mm
- Length of main pipe (L) = 300 mm
- Length of branch pipe (L) = 150 mm

- Modulus of Elasticity (E) = 200×10^3 N/mm²
- Poisson's Ratio (μ) = 0.3
- Pressure(P_i) = 1 N/mm² (Mpa)

A simple pipe having outer diameter of 70 mm and inner diameter of 60mm with the length of 300mm is modeled. The FE model is shown in Fig no.2.

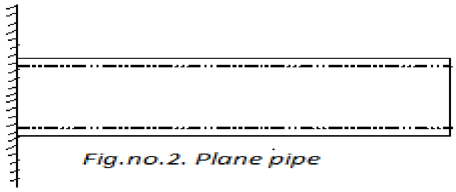

Fig.no.2. Plane pipe

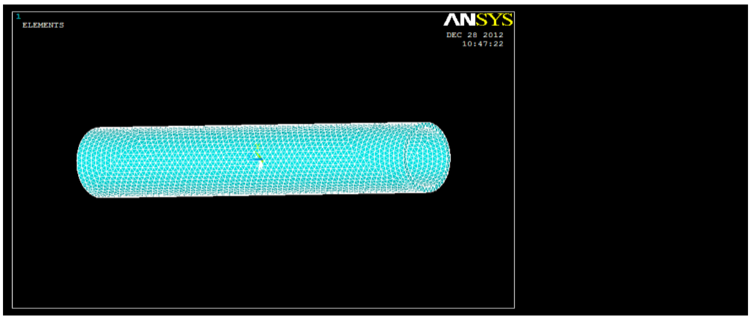

Fig .3 Mesh generation of plane pipe

Fig. 3 shows the mesh generation of plane pipe. The nodes and the element are used to apply the boundary condition and show the results of stresses on the nodes.

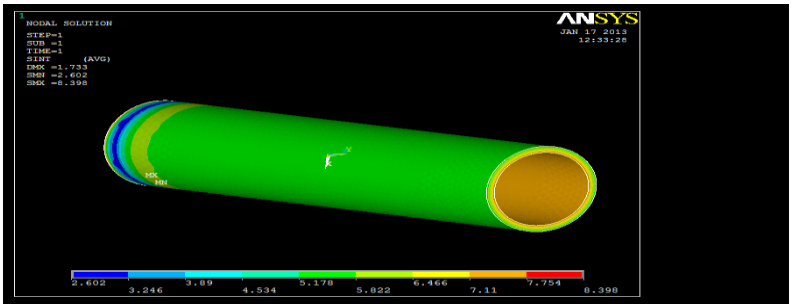

Fig.no.4 Stress intensity of plane pipe

The stress intensity of the entire node is shown in the fig.no.4 at angular location (degree). The Stress Intensity of Plane pipe is shown in table no.1 under loading condition.

Table No. 1 Stress Intensity of plane Pipe

PLANE PIPE													
Angular location (Degree)	0	15	30	45	60	75	90	105	120	135	150	165	180
Stress intensity	7.52	7.57	7.54	7.57	7.58	7.53	7.53	7.57	7.56	7.57	7.54	7.53	7.52

Fe Solution of T-Joint Pipe with Equal Diameter Branch Pipe

The T-joint pipe with equal diameter branch pipe is model by considering 3D element. For FE analysis the T-joint pipe is used with 20 node brick element. The stress intensity is obtained in both branch and run pipe as shown in fig.no.4.

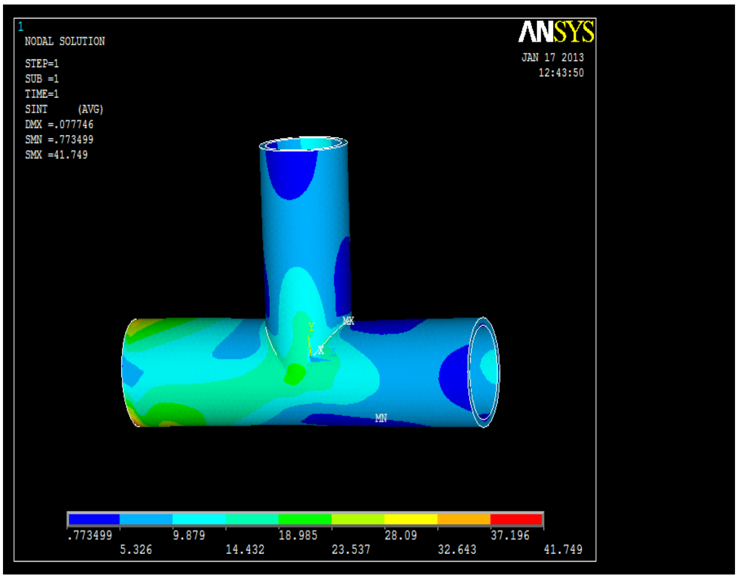

Fig.5. Stress intensity of T-joint pipe

The stress intensity factor is calculated as follows.

$$\text{The intensity factor (SIF)} = \frac{\text{Stress intensity of t-joint pipe}}{\text{Stress intensity of plain pipe}}$$

The SIF is calculated to run pipe under the specific applied moment condition shown in table 2.

Table: 2 FE results of stress intensity factor of run pipe with moment about X-axis.

STRESS INTENSITY FACTOR													
Angular location (Degrees)	0	15	30	45	60	75	90	105	120	135	150	165	180
Run pipe	1.21	1.58	0.66	2.55	3.28	5.44	5.6	4.95	3.43	2.55	0.66	1.58	1.22

The SIF is calculated to run pipe under the specific applied moment condition shown in table 3.

Table: 3 FE results of stress intensity factor of branch pipe with moment about X-axis.

STRESS INTESITY FACTOR													
ANGULAR LOCATIONTION (DEGREE)													
Angular location (Degrees)	0	15	30	45	60	75	90	105	120	135	150	165	180
Branch pipe	1.14	2.03	1.13	1.44	3.25	3.3	2.8	2.95	2.19	1.45	1.11	2.04	1.06

II. The Comparision Of Stress Intensity Factor

The SIF is calculated for run pipe and compared with previous experimental results under the specific applied moment condition and shown in table 4

Table: 4 Comparison of FE and previous experimental results of stress intensity factor, M_{xr} (run pipe).

(Note: Experimental result are previously find out by the researcher by D.G .MOFFAT, M.G. KIRKWOOD and G.R.T. CARMICHAEL)

STRESS INTENSITY FACTOR													
ANGULAR LOCATION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Run pipe	1.21	1.58	0.66	2.55	3.28	5.44	5.6	4.95	3.43	2.55	0.66	1.58	1.22
Experimental	1.7	1.85	1.9	1.85	3.1	5.1	4.1	5.4	3.1	1.7	1.8	1.85	1.6

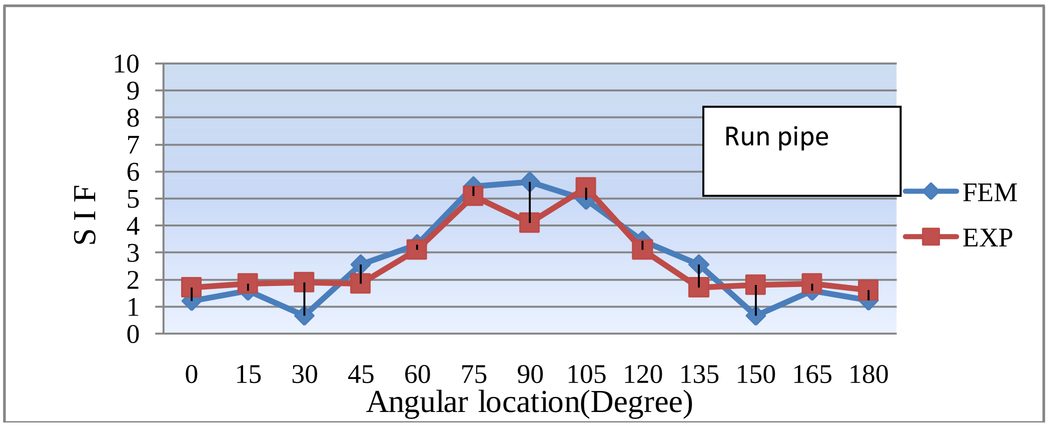

Fig. No. 6 Intersection stresses-run pipe moment (run pipe), Mxr

The graph shown in fig.no.6 gives the comparison of stress intensity factor in between experimental and FE results at various angular locations (degree).

The SIF is calculated for branch pipe and compared with previous experimental results under the specific applied moment condition and shown in table 5.

Table: 5. Comparison of FE and previous experimental results of stress intensity factor, M_{xr} (branch pipe).

STRESS INTESITY FACTOR													
ANGULAR LOCATIONTION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Branch pipe	1.14	2.03	1.13	1.44	3.25	3.3	2.8	2.95	2.19	1.45	1.11	2.04	1.06
Experimental	0.2	0.45	1	2.1	3.6	4.7	4.1	4.6	3.35	1.85	0.9	0.4	0.2

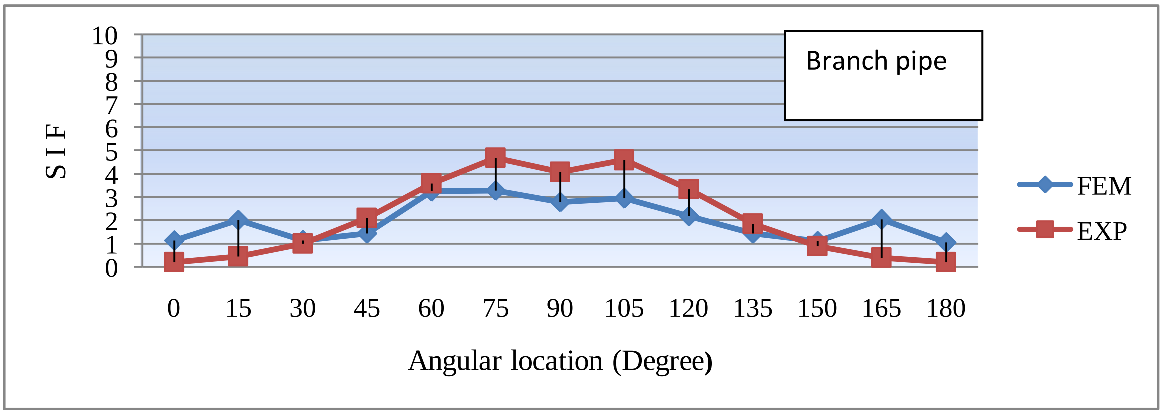

Fig No. 7 Intersection stresses-run pipe moment (branch pipe), M_{xr}

The graph shown in fig.7 gives the comparison of stress intensity factor, it is observed that the stress intensity factor increases from 0 to 90 angular location (degree) and decreases from 90 to180 angular locations (Degree).

The SIF is calculated to run pipe and compared with previous experimental results under the specific applied moment condition and shown in table 6.

Table: 6 Comparison of FE and previous experimental results of stress intensity factor, M_{yr} (run pipe).

STRESS INTENSITY FACTOR													
ANGULAR POSITION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Run pipe	1.21	1.58	0.66	2.55	3.28	5.44	5.6	4.95	3.43	2.55	0.66	1.58	1.22
Experimental	0.78	0.45	0.8	2.1	2.65	2.6	1.2	2.65	2.55	2.05	1	0.45	0.8

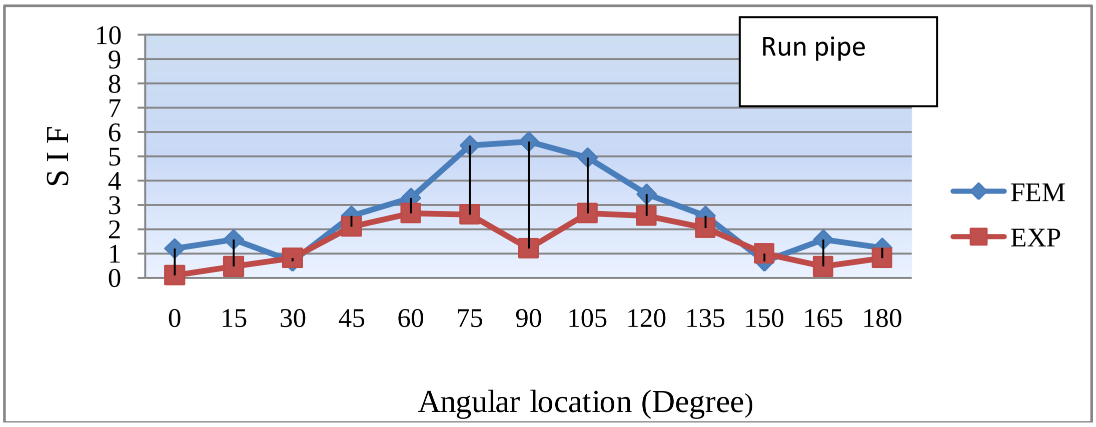

Fig No. 8. Intersection stresses-run pipe moment (run pipe),M_{yr}

From fig.8 it is observed that, the stress intensity factor is maximum in between 60 to 120 angular locations (degree).The SIF is calculated to branch pipe and compared with previous experimental results under the specific applied moment condition and shown in table 7.

Table: 7. Comparison of FE and previously experimental results of stress intensity factor,M_{yr} (branch pipe).

STRESS INTESITY FACTOR													
ANGULAR LOCATION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Branch pipe	1.14	2.03	1.13	1.44	3.25	3.3	2.8	2.95	2.19	1.45	1.11	2.04	1.06
Experimental	0.1	0.35	0.65	0.87	0.6	0.68	1.08	0.68	0.46	0.8	0.56	0.24	0.1

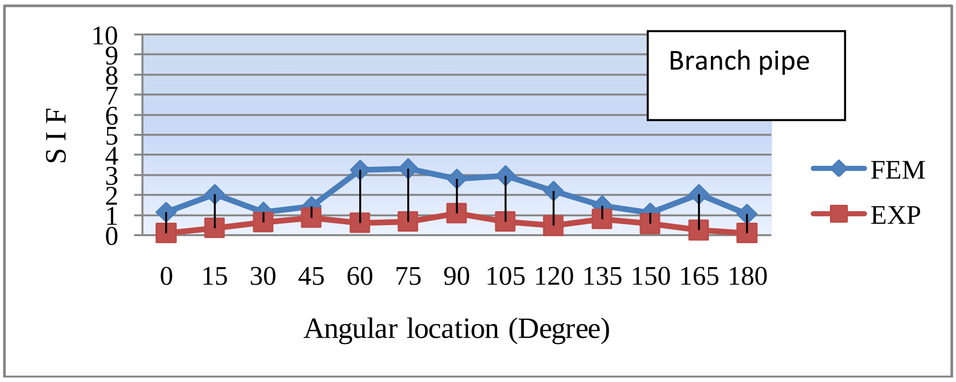

Fig No.9 Intersection stresses-run pipe moment (branch pipe),M_{yr}

From the fig.9, it is observed that, the stress intensity factor increases from 0 to 90 angular locations (degree) and later it decreases from 0 to 180 angular locations (degree).

The SIF is calculated to run pipe and compared with previous experimental results under the specific applied moment condition and shown in table 8.

Table: 8 Comparison of FE and previous experimental results of stress intensity factor, Mxb. (run pipe).

STRESS INTENSITY FACTOR													
ANGULAR LOCATION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Run pipe	1.21	1.58	0.66	2.55	3.28	5.44	5.6	4.95	3.43	2.55	0.66	1.58	1.22
Experimental	1.4	0.73	2.5	3.4	5.8	7.6	2.5	2.4	2.35	1.6	0.95	0.5	0.4

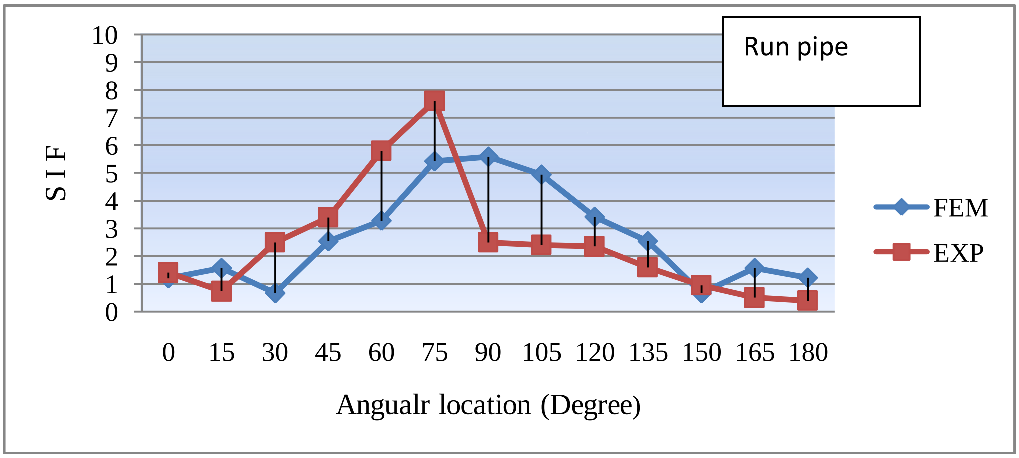

Fig No. 10 Intersection stresses-run pipe moment (run pipe),M_{xb}

The graph shown in fig.10 gives the comparison of experimental and FE results, it is observed the stress intensity factor increases from 0 to 90 angular locations (degree) and later it decreases from 0 to 180 angular locations degree.The SIF is calculated to branch pipe and compared with previous experimental results under the specific applied moment condition and shown in table 9.

Table: 9 Comparison of FE and previously experimental results of stress intensity factor,M_{xb} (branch pipe).

STRESS INTENSITY FACTOR													
ANGULAR LOCATION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Branch pipe	1.14	2.03	1.13	1.44	3.25	3.3	2.8	2.95	2.19	1.45	1.11	2.04	1.06
Experimental	0.7	1.1	1.56	2.2	4.2	6.1	5.6	3.35	1.65	0.4	0.6	0.8	1

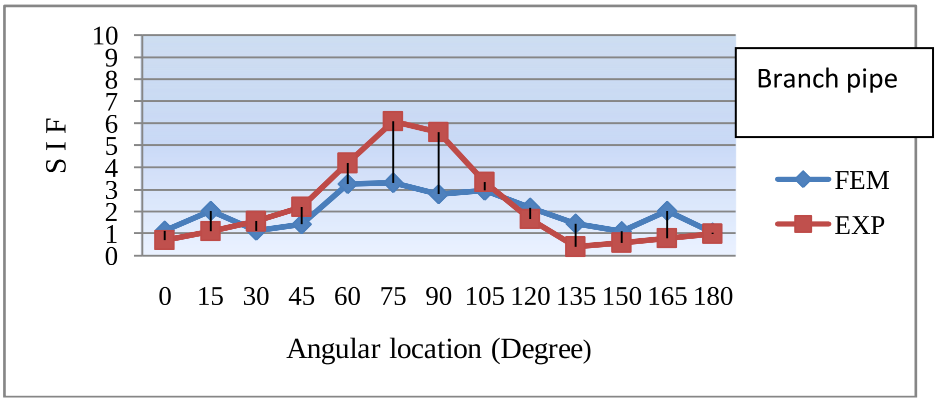

Fig No. 11 Intersection stresses-run pipe moment (branch pipe),M_{xb}

The fig.11 shown the comparison of experimental and FE results, in this case the SIF is increases in between 60 to 105 angular locations (degree).The SIF is calculated to run pipe and compared with previous experimental results under the specific applied moment condition and shown in table 10.

Table: 10 Comparison of FE and previously experimental results of stress intensity factor,M_{yb} (run pipe).

STRESS INTENSITY FACTOR													
ANGULAR LOCATION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Run pipe	1.21	1.58	0.66	2.55	3.28	5.44	5.6	4.95	3.43	2.55	0.66	1.58	1.22
Experimental	0.48	0.6	1	1.7	5	6.9	3.7	4.9	3.1	1.2	0.55	0.2	0.1

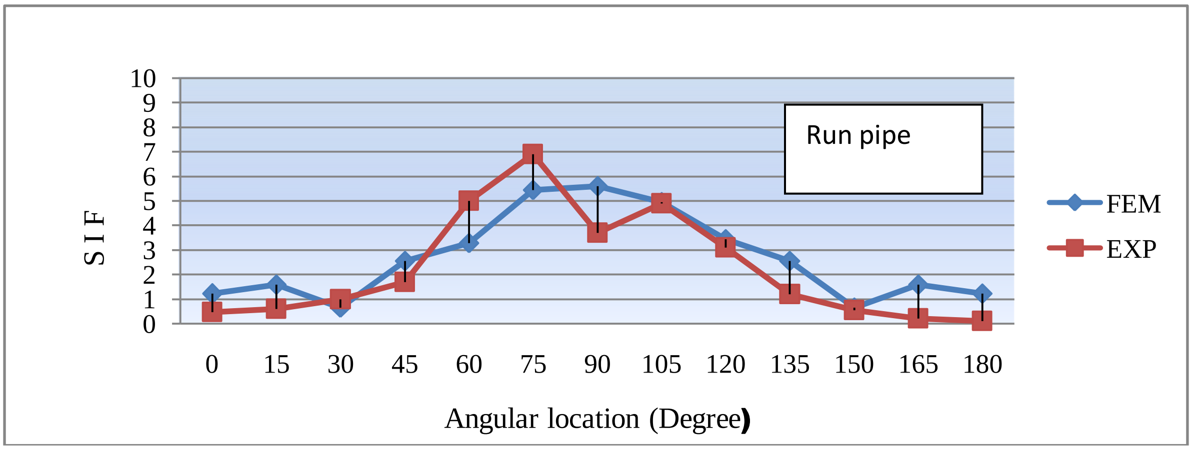

Fig No. 12 Intersection stresses-branch pipe moment (run pipe),M_{yb}

The graph shown in fig.12 gives the comparison of experimental and FE results, in this case the SIF concentration is more in between 60 angular locations (degree) to 105 angular locations (degree).The SIF is calculated to branch pipe and compared with previous experimental result under the specific applied moment condition and shown in table 11.

Table: 11 Comparison of FE and previously experimental result of stress intensity factor, Myb (branch pipe).

STRESS INTENSITY FACTOR													
ANGULAR POSITION (DEGREE)													
	0	15	30	45	60	75	90	105	120	135	150	165	180
Branch pipe	1.14	2.03	1.13	1.44	3.25	3.3	2.8	2.95	2.19	1.45	1.11	2.04	1.06
Experimental	1.32	1.5	2.05	2.95	4.2	4.9	4.5	4.8	3.8	2.2	1.7	1.6	1.59

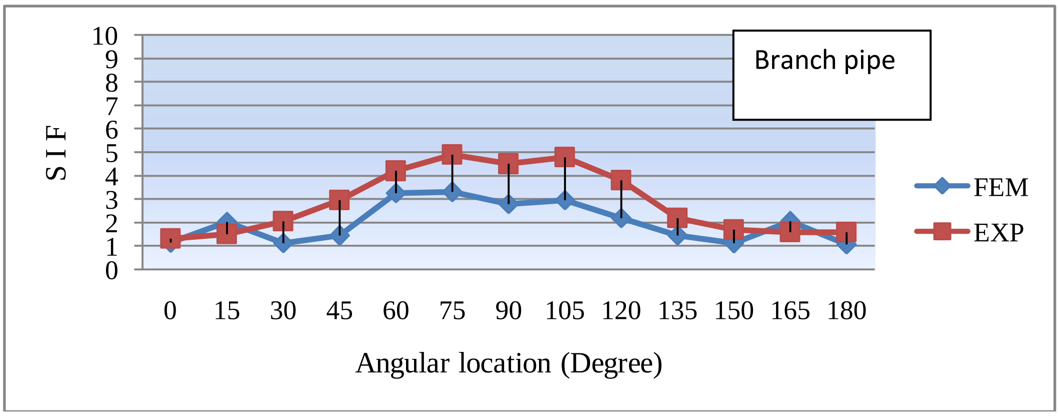

Fig No. 13 Intersection stresses-branch pipe moment (branch pipe),M_{yb}

The graph shown in fig.13 gives the comparison of experimental and FE results, it is observed that stress intensity factor increases from 0 to 90 angular location (degree) and later decreases from 90 to 180 degree.

III. Discussion And Conclusion

Though the detailed results are presented in earlier chapter, here the detailed discussion is presented as follows.

- The experimental work of D.G. Moffat, M. G. Kirkwood, G.D.T. Carmichael gives the experimental results of T-joint pipe with equal diameter branch pipe by applying internal pressure and moments about the axis. In the present work the F.E results are compared with experimental results for the various angular location of intersecting junction of the pipe for 0^0, 15^0, and 45^0 up to 180^0 of intersection junction.
- The T-joint pipe is subjected to internal pressure and moments about the axis, the results are obtained and compared separately with branch pipe and run pipe with the experimental result, in the 4 to table 11 showed the good agreement in between the experimental and F.E results.

- From the fig.8, 10, 12, it is observed that, the stress intensity factor of run pipe increases from 0^0 to 90^0 angular location and decreases from 90^0 to 180^0 angular location. There is greater variation in between the F.E and experimental result from 60^0 to 120^0 angular location.
- From fig. 6, 7, 13, it is observed that the magnitude of stress intensity factor is having good agreement in between F.E and experimental result. But at angular location 15^0, 90^0, 165^0 the agreement is poor.
- From the fig. 9,10,11,12, it is observed that the SIF of F.E result is having poor agreement with experimental results in between angular location of 60^0 to 120^0 and it is observed that at the angular location of 15^0&165^0 the experimental results shows the closeness.
- It is observed that from fig. 6. To 13, there is less variation in between the F.E and experimental results of branch pipe but there is greater variation in between the F.E and experimental results of run pipe.

  The SIF is calculated for T-joint pipe for various condition of load and can be used by designers to estimate the maximum stress at the intersection junction of T-joint.

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