Determination of length of attached straight pipes for different angle of elbows

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Abstract - When elbows are subjected to external loads, they undergo deformation both within and outside their plane due to their curved geometry showing a shell-type behavior. This makes them more flexible than straight pipes which comes at a cost of higher stresses and strains. The collapse moment of elbows is an important criterion to decide the failure of it. This research investigates the determination of sufficient length of straight pipes so that length of attached straight pipes does not affect the value of collapse moment of different angle elbows. The angle of elbows considered are of 30º to 180º with interval of 30º. The result shows that with the increase in the length of straight pipe collapse moments has been decreased initially. Then the collapse moment is nearly steady when the attached length is over five times the outer diameter of the elbow for in-plane closing, in-plane opening and out-of-plane bending moment.
Index Terms – Finite Element Analysis (FEA), Collapse moment, Elbows, Angle, Bending Moment

I. INTRODUCTION

The piping system, which consists of both straight and curved pipes (elbows), is essential for the conveyance of fluids under high pressure that are chemically active. Particularly, elbows are given great importance since they provide 5–20 times more flexibility than straight pipes of the same size and material. When subjected to the same loading configuration of straight pipes, such as pressure, bending moments, self-weight, and fluid weight, the elbow section is more prone to stress development than a straight pipe. This makes elbows critical element of piping arrangement. The elbows can of any angle between 0º to 180º. Many detailed studied have been carried out on the parameters of elbows affecting the collapse moment. Here, a few relevant studies are discussed.

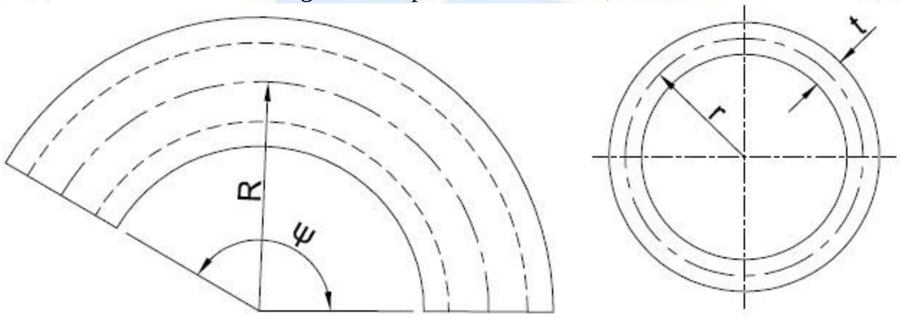

Fig.1 Schematic diagram of elbows

Fig.2 3D model of 120 degree elbow

II. Literature survey

Shalaby and Younan [1-2] analysed elbows using unique elbow element and carried out non-linear FE analysis. They discovered that for closing bending moment values of the maximum moment and the collapse moment obtained using graphical TES method were comparable. Further they found that in both in-plane moment cases, yielding began near the interior of the elbow crown **[3-4]. Yu and Matzen [5]** used FE analysis to determine the length of an attached straight pipe by taking end effects into account for 90 degree elbows. The results showed that the pipe's length needed to be at least ten times the pipe bend's mean radius. **Kim and Oh [6]** studied 90º elbow with attached straight pipe of five times the diameter of pipe elbow. **Kim et al. [7]** studied 30º to 90º elbows with straight pipe of five times the diameter. **Li et al. [8]** determines collapse moment for 30º to 180º elbows with straight pipe straight pipe of five times the diameter.
From literature, it is identified that attached straight pipes does affect the collapse moment values and in literature, the value of length of attached straight pipes has not been determined for in-plane closing, in-plane opening and out-of-plane bending moment. Therefore, this paper aims at determining the sufficient length of attached straight pipes under different bending moment.

III. Modelling and Analysis of elbows

Different angled elbows are analyzed for investigating the value of length of straight pipes should be attached so that it does not affect the collapse moment values under in-plane and out-of-plane moments.

(1) 3D modelling of elbows

The modelling of elbows have been carried out using commercial 3D software. The parameters required for modeling are mean radius of elbows (r), thickness of elbows (t), bend radius of elbows (R) and angle of elbows (ψ). The schematic diagram of elbow is shown in Fig.1 with modeling parameters. The values of r = 168.28 mm, t = 3.14 mm, R = 298 mm and ψ = 30º, 60º, 90º, 120º, 150º and 180º. The 3D model of 120 degree elbow is shown in Fig. 2.

(2) Material of pipe and elbow

Stainless Steel 304 (SS304) is selected for present analysis. The material properties required for analysis are Young's modulus (E) = 193 GPa, Yield Stress (σ) = 272 MPa and Poisson's ratio (υ) = 0.26.

(3) Analysis Procedure

The three dimensional analysis software is used for analysis purpose. After providing material properties, meshing of structure is required. The detailed meshing procedure is given in Reference **[7].** A total of 6144 elements are selected for analysis of elbows. For applying loading and boundary condition, one side of straight pipes is fixed and on other side of straight pipe moment loading is applied. After successful completion of analysis for each model, collapse moment is determined using graphical method twice elastic slope (TES). The TES method is explained in References [5-8].

IV. Results and discussions

The deformation in pipe elbows tends to decrease towards the end section, where straight pipes are connected. The deformation of the elbow cross-section propagates to some extent in the straight pipes at each end. It is necessary to determine the sufficient length of the attached straight pipes for the different angles of elbows so that effect of attached pipes on collapse moment can be neglected. In this section, all the considered angled elbows models are examined for the effect of attached straight pipes. The length of attached straight pipes is varied from 0 to 10 times the outer diameter of elbow and its variation in collapse moment under in-plane closing moment, in-plane opening moment and out-of-plane moment.

Under in-plane closing moment, it is observed that with the increase in the length of straight pipe collapse moments has been decreased initially. Then the collapse moment is nearly steady when the attached length are is over five times the outer diameter of the elbow, as shown in Fig 3. Similar variation is shown in Fig. 4-5, for elbows under in-plane opening and out-of-plane bending moment.

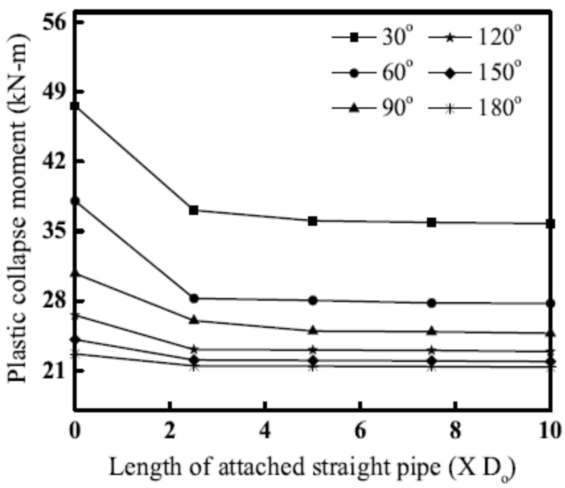

Fig.3 Variation of collapse moment with straight pipes under closing moment

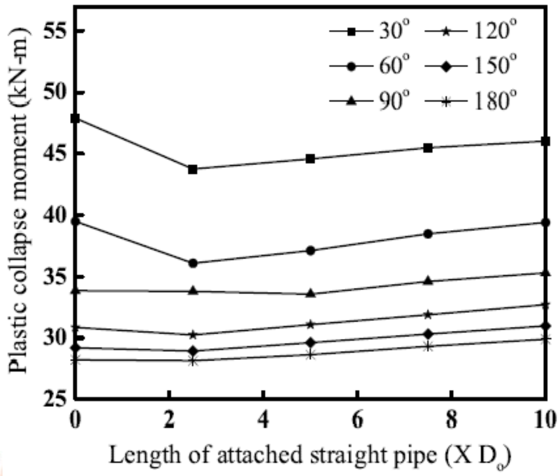

Fig.4 Variation of collapse moment with straight pipes under opening moment

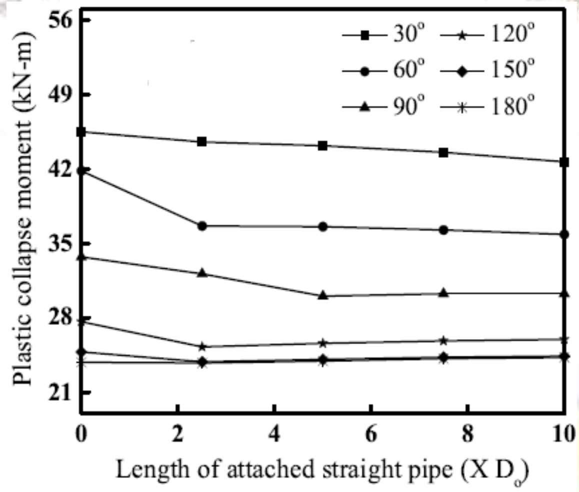

Fig.5 Variation of collapse moment with straight pipes under out-of-plane moment

V. CONCLUSIONS

A thorough 3-dimensional finite element analysis is conducted to determine the sufficient length of straight pipes for different angled elbows under in-plane closing, in-plane opening and out-of-plane bending moment. The analysis incorporated the material and geometrical non-linearity's. The result shows that with the increase in the length of straight pipe collapse moments has been decreased initially. Then the collapse moment is nearly steady when the attached length is over five times the outer diameter of the pipe bend. Therefore, the length of attached straight pipe is considered five times the outer diameter of elbows of different angle under in-plane closing, in-plane opening and out-of-plane bending moment.

VI. REFERENCES

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