Experimental analysis of T-pipe joints forming

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Abstract

The solutions for different liquid, sand, gases transportations are very different. Many of them concern applications of different advanced polymer technologies but for high pressure pipe ducts steel materials are commonly applied. This paper presents results of numerical calculations and experimental verification of T-pipe joints forming process. FEM analyses were conducted for the chosen process technological parameters and tools designs. The kinematics of metal flow in the area of the formed flanges was analyzed. Distributions of stresses, strains and damage criterion during forming were determined. Calculated values of forces and moments acting on tools and workpieces allow for designing of tools geometry for experimental verification of the proposed forming process. Worked out numerical calculations of T-pipe joints forming show practical possibility of this process application. Regarding the existing solutions for this type of parts manufacturing it should be interesting to develop special device for this activity dedicated to the hydraulic press or for handy operated devices for smaller pipe diameters.

Keywords: FEM, design optimization, cold forming

Introduction

There are various solutions for transportation of different liquid, sand and gases. A lot of them concern applications of different advanced polymer technologies but for high pressure pipe ducts steel materials are commonly applied. For this reason, it is of great importance to preserve good sealing of the designed pipelines. Different welding technologies are normally used for connections making but especially difficult case among them is T-pipe joints (tee) forming and welding with another pipe structures. In many cases connections made with T-pipe joints are performed by drilling the wholes inside one pipe and its welding into another. A flanging technology is applied for increasing mechanical characteristics and durability of these connections. This solution is favorable for pressure distribution and makes the welding processes easier for making and verifying – Fig. 1. In comparison with a traditional solution, this one is also less material consuming and it can be also applied in existing installations using portable devices for drilling and tee making. Typical applications areas include food processing, pharmaceutical, pulp and paper industry, stainless steel piping systems, water treatment, shipbuilding and conventional and nuclear submarines [1]. The proposed solution for bigger pipe installations must be equipped with special machine for tee making. This aggregate consists of drilling section for elliptic hole making and a special flanging head. Combining rotations and axial movement of this element results in flanges (collars) creation. It is possible to reduce smaller pipes tee making by means of portable tools as this process does not require application of bigger values of forces and torques. For the planned new devices for T-pipe joints development, the observations of this problematic and numerical verification of material flow and technological parameters are fundamental. Tools geometry and load parameters knowledge combined with final parts dimensions accuracy [2-4].are the most significant for new solution designing.

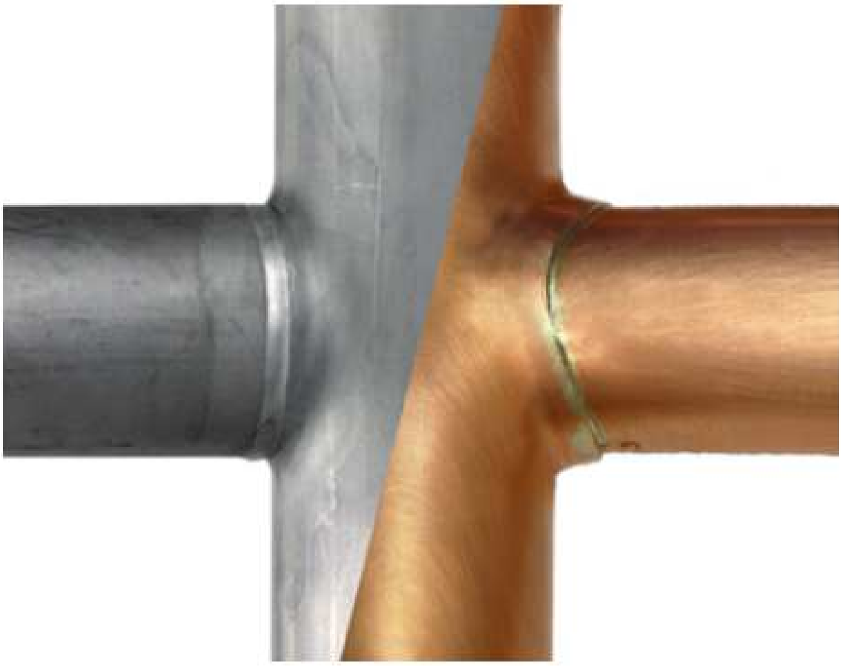

Fig. 1.The example of traditional (left) and formed by flanging T-pipe joint (right) [1]

Numerical modeling

Deform 3D software was used for numerical calculations of the proposed scope of flanging processes. Pipes with external diameter Ø150 and created collars with diameters Ø50 and were applied in numerical models. Weldable fine-grain structural steel for pressure vessels P355NH was used [2] as the material model. For the calculations needs in the cold metal forming conditions all tools and workpieces have the same initial temperature T = 20°C.The constant friction model was assumed for all cases with friction factor m = 0.25, as the processes are completed with good lubrication. Some calculations were realized with workpiece mounted inside the jaws with a diameter corresponding to the pipe dimensions. After verification of state of stress and strain, the workpiece were limited to the halfpipes fixed by boundary conditions at the external edges. For the proper circular collar shape forming the initial holes inside the pipes was designed as elliptic calculating geometrically created collar. For example, the collar Ø50 mm formed into the pipe Ø150 mm required initial elliptic whole 30 x 37 mm. Fig. 2 presents the examples of worked out models of the analyzed cases. The first model consists of formed pipe with initial elliptic whole, outer pipe as mounting for workpiece and two bars – tools which flange the collar. In the second, developed model physical fixation is replaced by boundary conditions with fixed edges (red nodes in Fig 2). The box with fine mesh was used for time calculation optimization in later realized simulation These modifications enable faster simulations.. All these changes were made after verifications of state of stress with the first model without any changes.

Feed rates and tools configurations

Feed rates f written in mm of working tools movement per rotation were crucial for the analyzed cases technological values. This parameter is strictly combined with dimensional accuracy and effective time of the realized collar tee connections. It was assumed, analyzing accessible solution [1], to apply solution with two rotating and axially moving tools. The forming tools – bars have the same diameter Ø10 mm and specially rounded ends. According to the chosen option, the feed rates applied in calculations were 0.5; 1.0 and 2.0 mm per one rotation. Tools – bars forming angle α were regarded as another very important technological parameter in this forming process The values for this parameter were taken initially within the range of α = (35÷60)°. Finally, this parameter was changeable during whole process starting from the biggest values α = 60° during necking and reaching value α = 0° at the final sizing stage of collar flanging. Final strain distribution is also changed by the forming angle choice. Bigger values of strain with significant part of redundant strains were obtained due to smaller inclination angle and feed rates.

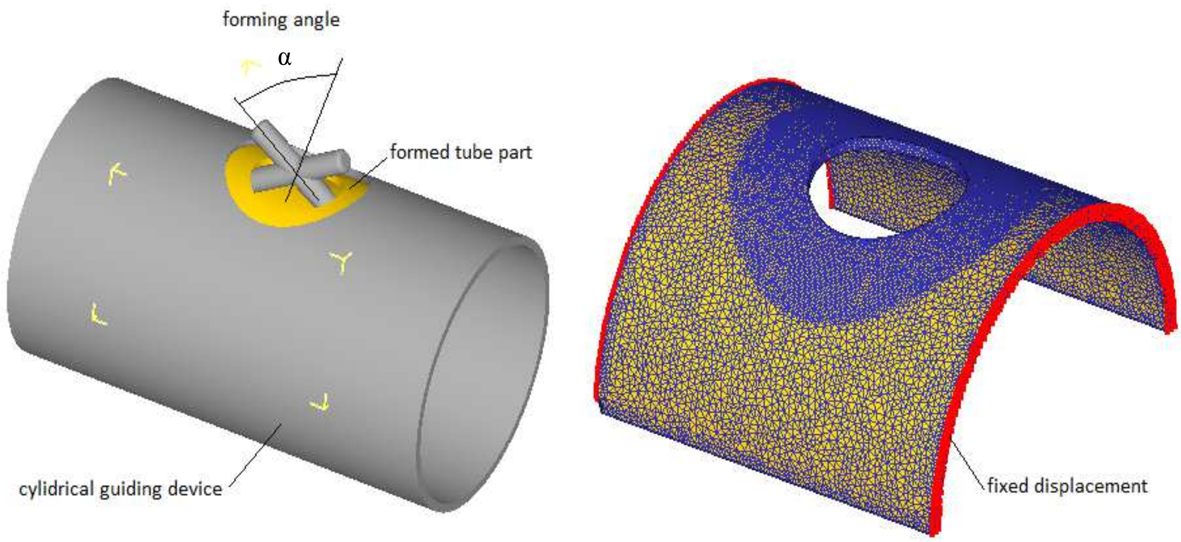

Fig.2. Worked out numerical models for calculations with physical pipe stabilization (left) and with boundary conditions with fixed displacement (right)

During numerical simulations realized with the presented assumptions and technological parameters it was possible to verify distributions of stress and strain during collars flanging. In Fig. 3 and Fig.4 the results of calculations for Ø50 collar forming into Ø150 mm pipe are presented. As it is shown in Fig. 3 the distribution of effective stress is really local and maximum values of this parameter exceed 1000MPa [5]. In zones of contact between tools and workpiece material is moved towards the direction of axial movement of tools. Presented in Fig. 4 effective strain distributions show real range of material deformation during flanging process. Values of this parameter are slightly different according to number of moving tools but the distributions are depended on different feed rates applications Bigger values of feed rate f = 1 and 2 mm per rotation provide to obtaining effective strain values reaching 12÷14. Normally this information is important considering fine grain material structures into plastically formed zones. However this observation must be verified in experimental tests in real flanging collars device [6-8]. After short verification of numerical calculations results, it was decided to design a handy operated device for smaller T-pipe forming up to 150 mm tube diameters with 50 mm flanges. Due to choosing two working bars head (caused by symmetry of loads), it was also decided to apply changeable forming angle values during forming.

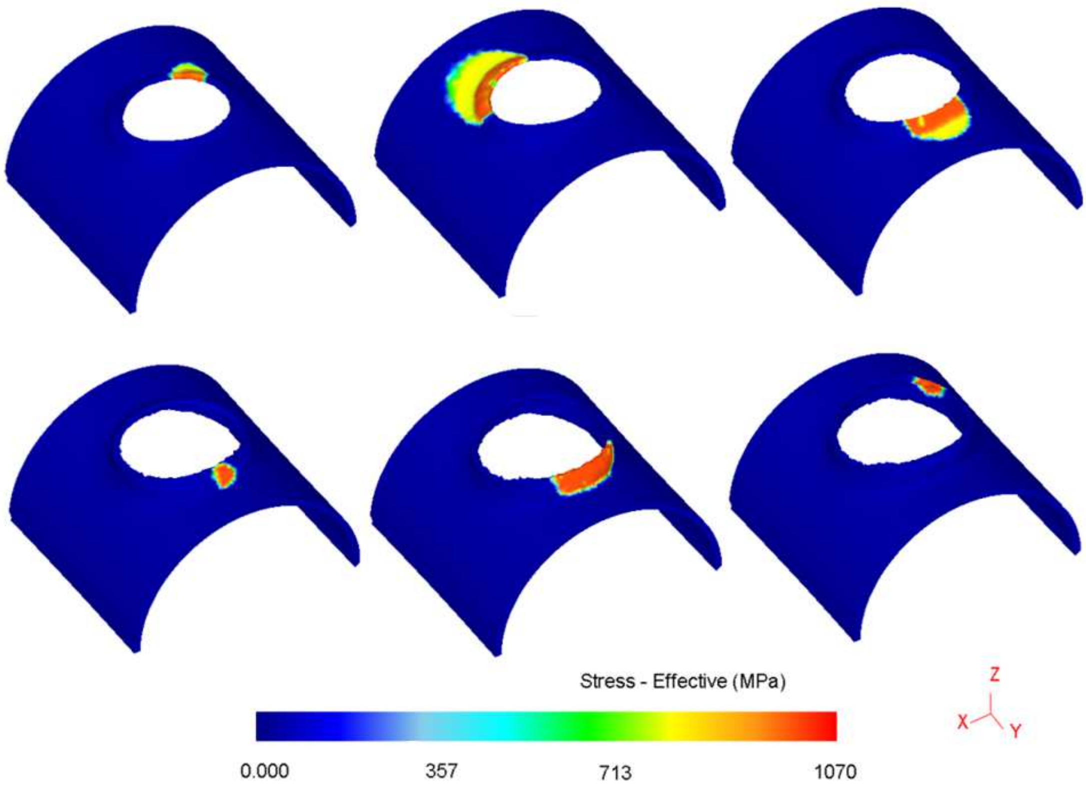

Fig.3. Progression of shape and distribution of effective stress during Ø50 collar forming into Ø150 mm pipe

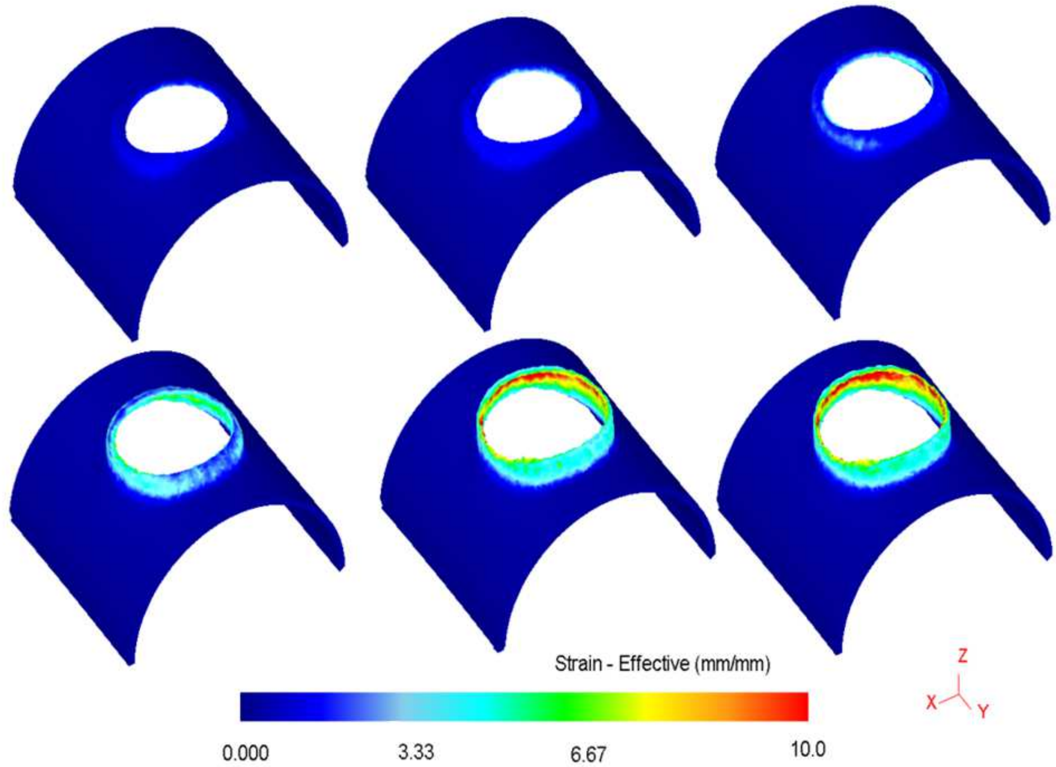

Fig.4. Progression of shape and distribution of effective strain during Ø50 collar forming into Ø150 mm pipe

Virtual model and real device for T-pipes flanges forming are presented in Fig. 5. Additionally, for verification of different forming angle α influence on the process course and final flange accuracy, three different working head with two working rounded edges were prepared – Fig. 6.

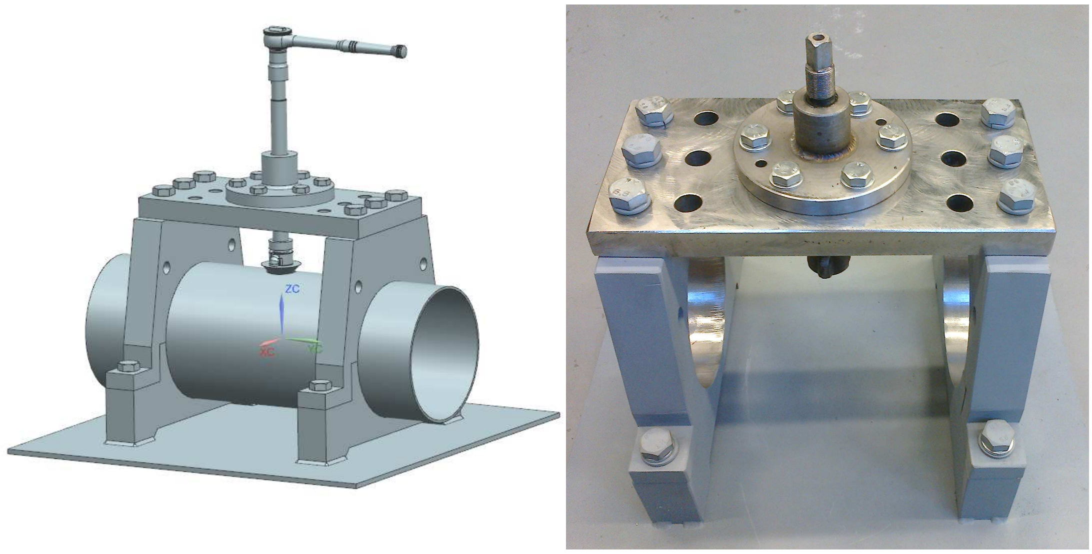

Fig. 5. Designed virtual model and worked out device for T-pipe forming

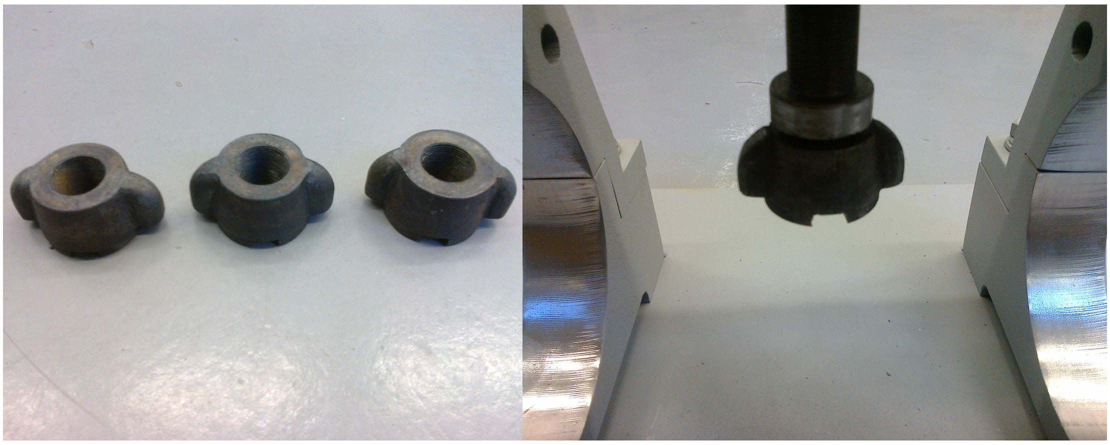

Fig. 6. Three different working heads with two working rounded edges and tools mounted on towing screw into the workspace

Designed for experimental tests three working heads have initial forming angle value α equal 65°; 50° and 35°. Finally in all cases this angle decreases up to 0° for effective flange internal diameter sizing. Results of 50 mm flange forming on 150 mm diameter tubes are presented in Fig. 7. Presented flanges were formed with feed rate f = 1 mm per rotation. Obtained after this experiment the assumed shape of collars shows the influence of working tools geometry on final wall thickness distribution at formed area and torque values. In all analysed zones of collar forming there are no significant decreases of wall thickness. This information is very important for the future scope of usage of T-pipe joint in welding of high pressure pipe ducts with very elevated mechanical characteristics. The differences between calculated and obtained in experiment distributions of collar wall thickness are not significant. The application of the pipe with initial wall thickness 4.00 mm results in minimal calculated value 3.48 mm and measured in experiment 3.56 mm. During the process observation it was stated that the friction conditions are very important for this values distribution. The application of old pipes with rusted inner surface in experiments results in bigger wall thinning during flange forming. The application of parts from carbon steel with analogical dimensions and process conditions results in final collar wall thickness equal 3.16 mm. Presented result were obtained using working head with initial value of forming angle α = 50°.

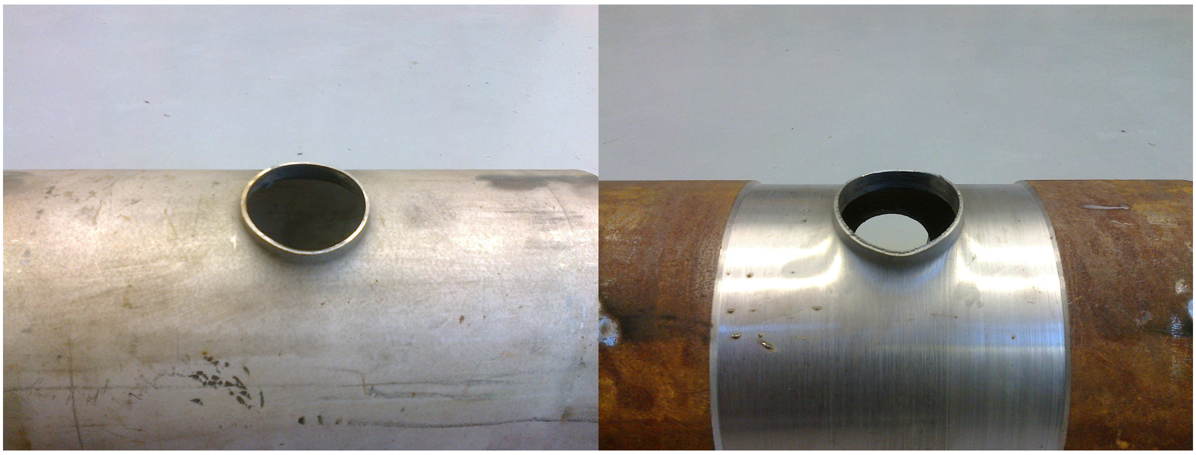

Fig.7. Flanges of 50 mm formed on 150 mm diameter tubes (new inox steel tube – left and used carbon steel tube - right)

Obtained during experimental tests maximum values of torques during flange forming depending on working head forming angles and types of tubes are presented in Tab 1. Assumed maximum values for handy – operated device was 300 Nm. This value was not exceed in whole experiment range for new tubes. During tests with presented in Fig. 7 (right side) used carbon steel tube measured maximum value of torque equal 380 Nm. It results mentioned above the biggest reduction of wall thickness. However for bigger tube diameters or wallthickness new device with servomotor is designed and it will be realized in practise.

Tab.1 Measured torques values during flange forming

Initial α angle, °	65°	50°	35°
Inox steel tube torque, Nm	240	250	270
Carbon steel tube torque, Nm	200	210	240

Conclusions

Worked out numerical calculations of T-pipe joints forming show practical possibility of this process application. Regarding the existing solutions for this type of parts manufacturing it should be interesting to develop special device for this activity dedicated to the hydraulic press. Some results concerning especially feed rate f and inclination angle α and initial elliptic hole dimensions will be very useful for this process recognizing. The observed significant torque values reduction depending on applied feed rates is very useful for handy operated worked out portable device. In this case, the crucial limitation is pipe fixation during collar forming in existing installation. The device body stiffness is also very important because it will decide about whole dimensions accuracy and tools positions stability. Another very important factor are friction conditions determining parts wall thickness distributions important for certification procedures of these T-joints. Finally, all these issues will decide on the scope of the proposed solution applicability and safety rules for users. Presently realized works at this field concern designing and working out stationary device for flanging of tubes up to 400 mm diameters.

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