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RESEARCH ARTICLE

Experimental Investigations in Pipe Bending Methods: A Literature Review.

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Abstract

This paper intended to explore the aspects of pipe bending for composites material. In current industries such as oil and gas, petro-chemical, and aerospace needs very high quality bended pipes without any defects. There are many different methods for pipe bending. The pipes and tubes can bend in one of several methods depending on what requirement is to use the bend pipes and tubes. So the comparison between pipe bending methods needs to be an identified. In pipe bending process several defects occurs such as Ovality, wrinkling, and wall thinning and thickening. Purpose of this study is to comparing the available methods and finding out the suitable outcomes for the given circumstances.

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Introduction:-

Pipe bending process is a process of straight section of pipe is formed to create curvatures or bend virtually at any angle. Bending is an important step in the process of manufacturing industrial pipes and tubes, which serve a vital role in transportation of materials. In the bending operation the pipes and tubes may be internally or externally supported to preserve the cross section of the pipe. In pipe bending operations there is a flexibility in the shape of the pipe, the pipe does not need to be supported, however there will be some deformation in the both the cross section of the pipe and the wall thickness in different areas of the bend. Pipe bending methods are varied and offer different advantages and disadvantages depending on the function of the bend and the type of material being bent. Some use mechanical force and some use heat treatment for bending. Fig-1 shows the bended pipe. There are many pipe bending methods available such as press bending, rotary draw bending, mandrel bending, three roll bending, bending springs, and heat induction. Press bending is a simple method in which pipe is hold at two external points and the ram in the shape of the bend advances on the central axis and deforms the pipes. This type of bending is suitable for light gauge product.

Fig-1 bended pipes

Rotary draw bending process (RDB) is precisely bend the pipes using tooling or "die sets" which have a constant center line radius.RDB is suitable in fluid handling lines, aviation and aerospace products. Mandrel bending is consists of a mandrel which is inserted into the pipe during the bending process to support the shape of the wall when bending. Three roller bender are consist 2 fixed rollers and one moving roller and the pipe is passed forward and backward through the rollers which is change the bend radius of the pipe. Three roller bending are used when large radii bends are required. Bending springs inserted into a pipe to support the pipe walls during manual bending. They have diameters only slightly less than the internal diameter of the pipe to be bent. They are typically used for bending 15-25 mm soft copper pipe. Induction bending uses heating coil to locally heat material by induction. The result in a narrow heat bends in a shape to be bent. Induction bending is used in oil and gas industries, petrochemical industries, and offshore. Among the several materials are used for the bending experiments such as carbon steels, alloy steels, stainless steels, aluminum, titanium, and reinforced thermoplastic materials. The RTP composite consist a wide variety of advantages including lightweight, high specific strength, and stiffness, and corrosion resistance over conventional materials like metals and alloys.

Related Studies on Pipe Bending Method:-

XunzhongGuo et al. (2015) [1] investigated thick walled large diameter bending pipe with straight section, push bending process of material P11 alloy steel pipe by Finite element simulation and forming experiment. They proposed the stress, strain, and temperature fields in the hot pipe bending process by numerical simulation and local induction bending experiments.

V. Sklenicka et al. (2015) [2] investigated the creep behavior of thick walled P92 steel pipe bent (90°) using local induction heating at 600 and 650°C. They studied uniaxial tension creep test to provide detailed information on the creep behavior. They showed that, the irrespective of the bend position, hot bending of the pipe decrease the creep resistance compared to the unbent pipe. There were similar creep rupture strength at intrados and extrados, even the extrados region of bend offered higher creep resistance and longer time to fracture.

Masaki Mitsuya and takashisakanoue (2015) [3] investigated the failure of induction bend pipes. They focused on the opening mode of the induction bend which represent the deformation outside the bend. They proposed an evaluation method which can predict the displacement at rupture based on finite element analysis. They determine stress-strain relationship by inverse calibration method. They studied the input condition which is essential to simulate the displacement at rupture by parametrically.

Wang Xun et al. (2014) [4] investigated the medium frequency induction heating process for large diameter pipe bending. They optimized three values including Ovality, wall-thickness reduction, and the forming load. The Ovality decreases with increasing of the temperature difference between inner and outer wall and Ovality increase with the increasing of thermal deformation width. Thickness reduction ratio reach minimum when the temperature difference between inner and outer wall is large and thermal deformation width is short. The forming load decreased with the increasing of the temperature of the outer wall and increased with increasing the width of thermal deformation zone.

Hiroshi Yatabe et al. (2014) [5] investigated the significance of the mechanical properties and geometry imperfection by analytically in order to propose the appropriate design for the high grade induction bend pipes. They conducted parametric studies by using FEA and the relationship between the bending moment and bending angle were calculated. They conclude that, when the bending moment applied to the bended pipe in the early stage of the deformation the bending angle linearly increases in proportion to the bending moment. And in the next stage the bending moment decrease with an increase in the bending angle.

S. NanthaGopan et al. (2014) [6] presented the induction pipe bending process with the use of mandrel and minimize the difficulties faced during the bending process. They designed a new mandrel and compared with the existing mandrel. They used ANSYS WORKBENCH as an analysis tool.

Hyun -Woo Lee et al. (2011) [7] investigated the effect of the design factors used in the pipe bending process. An optimum pipe bending process with minimum wall thickness reduction is designed on the basis of the analysis result. After that a reverse moment is applied to the area in which the wall thickness reduction is more than 12.5 %. An optimum design of pipe bending based on high frequency induction heating. The thickness reduction ratios at two ends of the bent region increase with D/t ratio. Therefore reverse moment is applied to obtain a uniform thickness reduction ratio.

G.J. Coolie and I. Black (2010) [8] investigated the true temperature distribution along, around, and through thick walled super duplex stainless steel pipe when it was subjected to induction bending and induction heating. They conducted two types of experiments. The first was a length of thick wall super duplex pipe fitted with thermocouples and fed through an induction coil. And the second experiment was with the same pipe subjected to the induction bending.

LI Xue-tong et al. (2006) [9] investigated the FEM simulation of large diameter pipe bending using local induction heating. They shows the simulation results of thinning and thickening ratio of pipe wall, the ovality of the cross section of pipe before and after unloading, and the spring-back angle after unloading of pipe steel X70. They shows that while increase in bending angle, the Ovality firstly increases and then decreases at the end of bent pipe, and the spring-back angle increase with increase in bending angle.

Zhong Hu (2000) [10] investigated the stresses and strains of the bending of a large scale pipe under loading and unloading condition using local induction heating. They presented an elasto plastic model for the calculation of spring-back angle. They conducted computer simulation by FEM software that was developed based on ANSYS. Experiments carried out with pipe materials of 20, 10CrMo910 and 12Cr1MoV steel.

J.Q.Li and Z. Hu (1999) [11] studied the computer simulation of pipe bending processes with small bending radius using local induction heating. For investigating of the process parameter of pipe bending they took mild steel as a pipe material. They shows the result such as thinning and thickening ratio of pipe wall thickness, the bending force and reverse moment, and the ovality of cross section of the pipe.

WANG ZUTANG and HU ZHONG (1990) [12] investigated a theory and technique for the bending of inductively heated pipes to a small bend radius. They calculated the stress and strain states under various loading conditions and for different bend radii. They compare the experimental and analytical result of pipe bending. They showed that the thinning of pipe wall is not exceeding than 12.5% and the bending radius is generally greater than 3.5 times outer diameter of the pipe.

Jun Fang et al. (2015) [13] developing the three dimensional finite element model of high strength stainless steel tube in rotary draw bending. They proposed the law of the tangential stress and strain distributions, wall thickness variations, cross section deformation, and spring-back angle. For the different bending angles the wall thinning ratio is more than the wall thickening ratio and it is also less than 12.5%.

T.Wen (2014) [14] proposed a new concept of rotary draw bending die called Multiple Diameter Bending-Die, on which tubes with different outer diameters can be bent by adjusting the thickness of pads and then changing the shape of the die groove. They also studied the deformation of tubes with different outer diameters, wall thickness, and bending angles when bent on the Multiple Diameter Bending-Die by experimental and numerical methods.

A.V. Kale and H. T. Thorat (2014) [15] investigated the design, development, fabrication and the use of equipment of rotary compression bending which produced the pipe bends with better quality. They also proposed the Ovality control process in the pipe bending by the rotary compression bending. They proposed four bending condition with four different thickness (1.2 mm, 1.25 mm, 1.5 mm, 2 mm). The ovality at the center of the bent pipe decrease with increase in wall thickness and the pre-compression of pipe.

YANG He et al. (2012) [16] investigated the analysis of bending characteristics and multiple defects, advances on exploring the common issues in tube bending are summarized regarding wrinkling at the intrados, wall thinning at the extrados, spring-back phenomenon, cross-section deformation.

Yu-Li TIAN et al. (2011) [17] investigated the bending behavior of large diameter thin walled CP-Ti tube in rotary draw bending and identify primary defects such as wrinkling, wrinkling tendency, cross-sectional distortion, and good forming.

E. Daxin et al. (2010) [18] investigated the wall thinning and stress distribution in rotary draw bending analytically based on the ideal rigid-plastic materials model. The tangential bending stress is decrease with the increase of R/d ratio. The analytical result indicates that the tangential bending stress decreases as t/d ratio increases.

Yuli Liu et al. (2010) [19] They investigated the influence laws of the clearance on wrinkling on thin walled rectangular aluminum alloy tube by the simulation of rotary draw bending process. The wrinkling wave number decreases with the increase of the tube mandrel clearance, the increase of the tube wiper die clearance, and the increase of the tube bending die clearance.

ZHAO Gang-yao et al. (2010) [20] investigated the cross-sectional distortion behavior of thin walled rectangular aluminum alloy tube in rotary draw bending process by using Finite element numerical simulation method. Stress appears on the larger circumferential zone after the bending angle reaches the 30° and the sagging phenomenon is produced in this zone. The maximum cross sectional distortion is obtained with the bending angle of 50° between the bending reference plane and a certain section in the symmetrical plane of the bent rectangular aluminum tube.

Yong Bai et al. (2015) [21] investigated the ovalization instability of RTP pipe under pure bending. The winding fiber with 54.7 deg. in reinforced layer has contributed the bending stiffness. And the wall thickness and diameter of the pipe have large influences on the bending capacity of the reinforced thermoplastic pipe. When the diameter of the pipe and wall thickness increases the bending moment and critical curvature also increase.

Kuang Yu et al. (2015) [22] investigated the flexural behavior of RTP pipes which are made from Polyethylene and fiber reinforced Polyethylene plies. They also investigated the effect of material non linearity of PE on spoolability. If the diameter to thickness ratio of the RTP pipe is small the failure of cover is critical and with larger diameter to thickness ratio the buckling of the pipe is more critical.

Muhammad A. Ashraf et al. (2014) [23] investigated the buckling effect on the composite pipes. They studied the effect of different diameter to thickness ratio and different angle ply combinations on the mechanical behavior of the RTP pipes. The buckling failure of the RTP pipes under excessive rotational deformation is caused by the flattening of the cross section which results in a kink in the pipe wall.

Conclusion:-

It is necessary to optimize the process parameters of bending and important influence factors for system stability. The common issues in pipe bending are regarding wrinkling instability at the intrados, wall thinning (cracking) at the extrados, spring-back phenomenon, and cross-section deformation, forming limit and process/tooling design or optimization. In the pipe bending the thinning of pipe wall is not exceeding 12.5% and the bending radius is generally greater than 3.5 times outer diameter of the pipe. The stresses and strains of the bending of a large scale pipe under loading and unloading condition using local induction heating mostly presented by an elasto plastic model. The tangential bending stress decreases with the increase of R/d. Increase in bending angle, the Ovality firstly increase and then decrease at the end of bend pipe. In rotary draw bending deformation of tubes bent on MDB-Die was affected by forming parameters such as relative wall thickness t/d, bending radius r/d, bending angle. The Ovality at the center of the bent pipe decrease with increase in wall thickness. The failure mechanism of an RTP subjected to bending is strongly dependent on its D/t ratios. It is found that the buckling of the pipe wall becomes a critical mode of failure in RTPs.

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