Study of Common Problems Associated With Rotary Tube Bending

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Abstract- *In the recent trend in every field, industries are looking for material with high strength and less weight for the component which is satisfied by thin wall tubes. Hence nowadays applications of thin wall tube bending process is increasing in high end industries also. But thin walled tube bending operation has got some limitations because of commonly occurring defects like springback, wrinkling, wall thinning, ovality (cross section deformation). Defect like springback reduces accuracy of bent component and makes it difficult to fit that component at desired locations, wrinkling and ovality hampers the aesthetic factors of component, excessive wall thinning reduces strength of bent at extrados and after some critical point it may lead to rupture. [1]*
This paper summarises various techniques investigated by different researchers to prevent or minimise the occurrence of above mentioned defects with the help of geometrical and physical parameters. [3]

Keywords- Spring-back, wrinkling, wall thinning, Ovality.

I. INTRODUCTION

Thin walled tube bending is very complex process with multifactor coupling effect. For any bending process, upon bending deformation, the complex uneven tension and compressionstress distributions are induced at the extrados and intrados of bending tube respectively. Intensity of this phenomena increases in a components having larger tube diameter and to be bent at very smaller bending radius and after some critical extent it leads to occurrence of multiple defects or instabilities such as wrinkling, over thinning (cracking), cross-section distortion and spring-back, etc.[1]
However, by having proper knowledge of contact conditions between tube and die we can get control over the above mentioned defects up to large extent. Proper clearance at interface of tube with bending die, wiper die, pressure die, clamp die etc. should be maintained to tackle the tight boundary conditions which cause above defects. [3]

II. LITERATURE REVIEW

Yang He et al. [1] had tried to predict wrinkling using Analytical method, Implicit FE method, Eigenvalue analysis, Explicit FE method and compared all these methods on the basis of their advantages & limitations.

LeventSo¨zen et al. [2] had performed simulation using FE code LS-DYNA to predict spring-back and stated different parameters affecting spring-back

LI Heng et al. [3] had stated appropriate tube-die contact conditions to restrain the wrinkling and introduced modified Yoshida Buckling Test (YBT) to reveal behavior of thin wall tubes under normal constraints in (TWTB).

A.V Kale et al. [4] had computed percentage Ovality at different discrete places along the length of pipe and analyzed variation of ovality with respect to bend angle according to which he made comment on the relationship between Wall thickness and Ovality

SHI Kaipeng et al. [5] had investigated different significant factors affecting wall thinning

Rohit agarwal et al. [6] had tried to predict cross section distortion and thickness change using analytical model FEA.

YANG He et al. [7] had investigated different problems or failures in tube bending and stated effective controlling of these failures or instabilities.

B Lynn Ferguson et al. [8] had predicted the wall thinning of heavy pipe and percentage of ovality relevant to the amount of wall thinning, using the ABAQUS / STANDARDS FE software

B. Engel et al. [9] had tried to overcome wall thinning using geometrical models, advanced model, FE simulation and compared all these using a different bending factor, wall thickness and material properties.

III. COMMON PROBLEMS ASSOCIATED WITH TUBE BENDING

1. Spring-back: -

Spring-back is an inevitable phenomenon in bending operations. For the geometrical accuracy in manufacturing.Spring-back should be predicted and a required compensation should be applied to the operation. Spring-back is defined as undesirable change in product shape which takes place upon removal of the constraints after forming. This dimensional change is seen during the unloading by the effect of elastic recovery of the material. In other words, springback describes the shape change after release of tooling.

Spring-back has direct effect on the properties that are geometry related as well as preciseness of shape due to which performance of sealing tubes and connection of tubes is determined.It was found in the studies of YANG et al. that the spring back angle and bending angle share a linear relationship. Also the diameter and relative bending radius have an effect on spring-back. YANG et al. also found that the total spring-back angle was found to be smaller by considering mandrel retracting than not considering it. [1-3]

LeventSo¨zen et al. made a point from his studies that bend

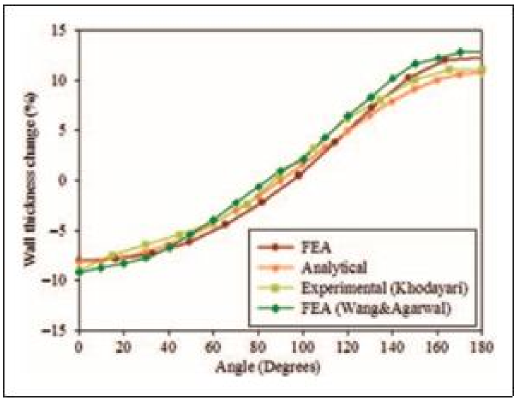

Fig 1.Wall thickness change [2]

angle is most significant parameter that determine the amount of elastic strain. Fig 1. Shows graph describing the effect of bend angle and wall thickness change. It is clearly seen that increasing the bend angle causes higher spring-back angle.
Also diameter of the tube found to be most influential variable among other parameters showed in Fig. 2. Springback simulations were performed on different bending angles and it was found that magnitude of spring-back increases linearly with increasing bend angle. LeventSo¨zen et al. also found that most effective parameter was Tube diameter and spring-back linearly decreases with increasing diameter. He made point that increasing tube thickness reduces the spring-back since more tube thickness opposes elastic recovery.It has been found through his studies that amount of area that elastically deformed increases by increasing the bend radius and it causes an increase in spring back.LeventSo¨zen et al. found relation between spring-back and friction that states spring-back increases n-on linearly with increase in coefficient of spring-back. [3]

2. Wrinkling:-

In any tube bending operation intrados (inner arc) experiences double compressive stresses and after some critical extent the wrinkling instability may occur. Wrinkling ultimately reduces the tube’s strength stiffness and fatigue strength

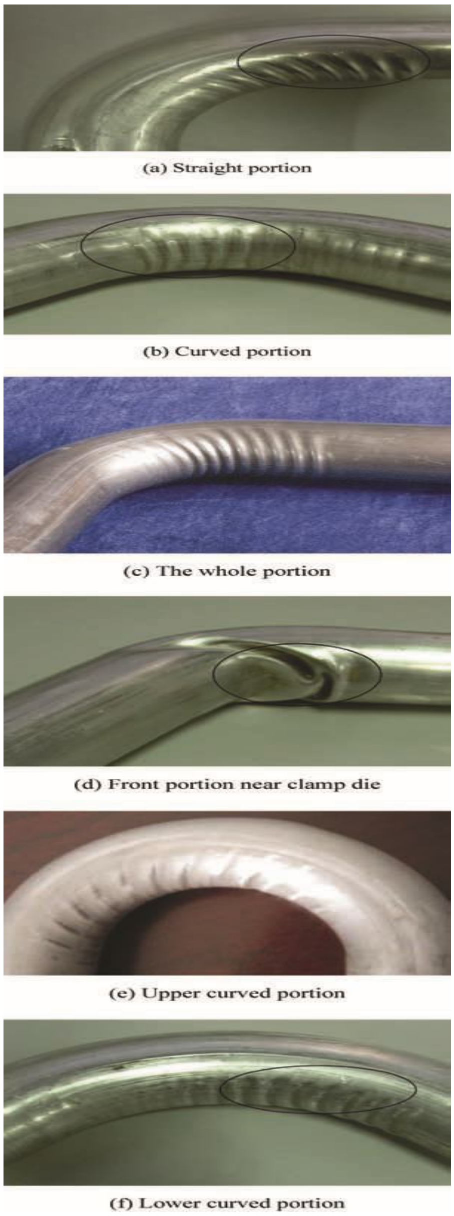

Fig 3. Wrinkle occurred in NC bending process [3]

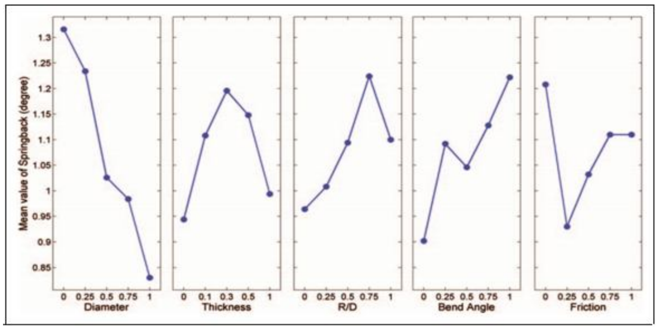

Figure2. Maineffectsplotforspring-back. [2]

Wrinkling growth and initiation is highly affected by various factors like geometrical dimensions (i.e. large diameter and small bend radius), material properties, loading patterns, contact condition, stress states. To understand wrinkling mechanism thoroughly we cannot be relying on an analytical theory and experimental approach only. By using minimum energy principle combined with analytical and finite element [FE] method, energy based wrinkling prediction model is developed to capture the critical wrinkling zone.

From various studies, it was observed that friction and clearance between tube and tooling and mandrel performs very crucial role in avoiding wrinkling and “Stepped mandrel retraction” method was proposed to avoid the wrinkling for bending having smaller bending radii. Modified Yoshida buckling test is used to study initiation and growth of wrinkling in this walled NC tube bending [3]

When bending operation involves complex boundary conditions such as multi dies constraints, the perturbation of clearance between work pieces and dies and contact conditions changing in time and space.

Experimental Setup:-

Fig shows Experimental setup of thin wall tube bending (TWTB).

Bending setup comprises of bending die, pressure die, clamp die, wiper die and mandrel. Tube interfaces with all five dies. The clearance value of all those interface depends on groove dimensions of dies and tooling setup.

The tube is held against the bend die with the help of clamp die at the leading end of the bender. The pressure die deforms the tube into desired shape. Large clearance between pressure die and tube can cause wrinkling at intrados. The clearance between tube and mandrel shank directly induces the wrinkling. This happens when pressure die is clamped against wiper die. Wrinkle is prone to happen when the wiper die is placed far behind the tangent point or at a non- zero rake angle. To support the tube from inside and to prevent the collapse of tube, mandrel is inserted inside the tube. The wiper die is used to fit the gap between back tangents of tube and bend die to prevent possible wrinkling. Fig 3 shows various areas where occurrence of wrinkling is most often.[4-5]

3. Ovaling:-

In this process point B at same position but

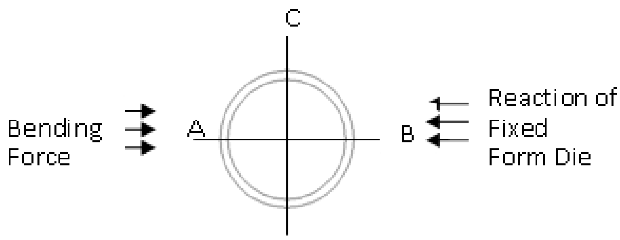

Fig.5 Pipe fixed in form die before bending [6]

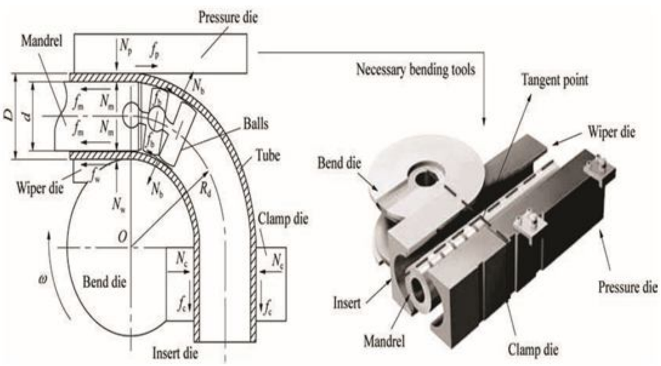

Fig.4 Thin-walled tube numerical control (NC) bending with multiple contact conditions.[3]

Pt. A shifted toward the center due to compression at the pipe. As there is no support provided at point C and D therefore this points are shifted vertically outward. To form an elliptical cross-section having major and minor axes resulting in oval cross section at the bend.

In this method restrict outward movement of point C and D by using top and bottom support.

If the top compression plate is kept touching with the pipe diameter and pipe is bent ovally reduce to half of its value. [6]

4. Wall thinning:-

During the bending process the inner and the outer fibers are subjected to compressive stress and tensile stress respectively. Because of this thinning of tube wall at outer sections (extrados) and thickening of the tube at inner section (intrados) occurs. [7]

According to YANG He et al. there are many tube bending and welded tube bending from the tube fabrication respect. In the view of bending difficulty, it is easy bending with large bending radius and tough bending with small bending radius. In the bending process, there is uneven tension and compression stress distribution are induced at the outer section and inner section of bending tube respectively, and it causes the defect or instability like over thinning.

The wall thinning at the extrados and wall thickening at the intrados as well as certain cross section deformation (Even distortion) are inevitable deformation phenomena. The pressure resistance of bent tube is directly affected by the wall thinning, while the section flattening affect the flow resistance within the transmission medium. Because of this the reliability of tubular components reduces so the wall thinning and the section distortion should be avoided.

There are many scholars have undertaken the extensive research to obtain the theories and methods for prediction and controlling the wall thinning and cross section deformation in tube bending , which gives the bending accuracy greatly.

According to the geometrical characteristics and the plastic deformation theory, some practical formulae were deduced to solve these common tube bending problems including stress-strain distribution in the bend. From the many assumptions and simplification, the accuracy and practical application are limited. From the stress formulae the wall thinning change of tubes under axial force and internal pressure were developed. In the experiment the grid method is effective method to measure strain distribution and metal flow states of the bending tube.

Li H, Yang H et al, were numerically investigated the wall thinning of the aluminum alloy and stainless tubes based on the Abaqus platform. Also, Hu Z, Li J Q was conducted FE simulation on pipe bending process with large diameter using local heating to calculate the wall thinning. For improving the bending quality and forming limit the above achievements on wall thinning and section flattening of bending tube provide theoretical guidance. These both phenomena cannot avoidwrinkling instability, while they can be controlled

According to B Lynn Ferguson, the distortion of the cross section and reduce the amount of wall thinning along the outer radius of the bend can be minimize by applying lateral pressure and axial push to the outside of a pipe during bending.[8]

B. Engel et al. showed that the material properties have an influence on neutral axis shifting and wall thickness distribution. In the steel alloy the neutral axis of the tube moves more towards the inner arc of the tube than in stainless steel tubes. [9]

IV. CONCLUSION

Currently thin Walled tube bending has found its application in many high end industries such as aerospace, shipping, automobile and so on because of its light weight and high strength. With increasing applications the demand for high efficiency and precision production as also increased.
In this paper, we have discussed various techniques to minimize the tube occurrence of common defects associated with tube bending such as spring-back ,wrinkling, wall thinning ,ovality, with repect to geometrical and mechanical variables from result of the study following conclusion be drawn,

1. Magnitude of spring-back is directly proportional to magnitude of bend angle, coefficient of friction, as well as amount of area deformed elastically due to increase in bend radius. Spring-back reduces with increasing tube diameter, increasing tube thickness.

2. Wrinkling can be effectively restricted by keeping smaller clearance at tube-wiper die interface, tube-mandrel interface, tube bend die interface. All the effects taken to avoid the wrinkling, led to increased wall thinning and cross section deformation.

3. From this study it is observed that percentage ovality at the centre of the bent pipe decreases with increase in wall thickness and pre-compression of the pipe. Ovality can be restrained by restricting the outward movement of top and bottom sides of tubeby using supports.

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