A PROPOSED METHODOLOGY FOR DESIGN AND SIMULATION OF MULTI-AXIS PIPE BINDING SYSTEM

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ABSTRACT

In this paper, we discuss the hose and accurate measurement coordinate dimension designed in Auto Cad. This paper also examines the reception gauge designed with the help of CMM report. Usually, the coordinate points while measuring pipes is done by traditional and conventional methods. These methods are time consuming and they lack precision. At par with the latest technological advancement, CMM came as a new and advanced method for measuring, the pipes coordinate points.

To calculate the coordinate points the coordinate measurement machine (CMM) is used. CMM with its several advantages like its flexibility, its unique configuration enabling a reduced setup time, its accuracy, improved productivity and its quality of reducing the influence of the operator makes it one of its kind. All the measurements of CMM are taken from a common fixed geometric measurement system, which eliminates the introduction and accumulation of errors resulting into the hand inspection gauge and technical transfer methods. Most procedures have MMT routine measurement for typical elements parts, such as holes or distances from the center.

The CMM machine captures the view of the pipe and records it automatically. When we fix any part of the pipe the CMM machine inspects that part, weather it is arranged properly or not. And if there is an error in the arrangement (pipe set up) it rectifies it. When the proper arrangement is done the CMM machine rectifies the coordinate points (of the corner of the pipe). And thus it observes the XYZ coordinate points and this is how it gives its final results. It is found that result of the CMM machine is more accurate than other machines. Further it adds to the fact that less skilled operators can be easily loaded to perform relatively complex inspection procedures. The advantages mentioned above makes CMM more productive than conventional inspection techniques.

INTRODUCTION

General anatomy of the XYZ concept used in the tube industry tells about the accuracy of the co-ordinate system and dimensions used to design the pipe or tube for better flow of oil inside the engine. The tube is constructed of a straight section, an arc segment, and another straight section and continues until it ends with a final straight. The tube is not a smooth flowing continuous curve, but a series of straight and arc segments. This methodology of XYZ points can be expanded to locate and describe a variety of other features such as clamps, brackets, or other attachments.

1.1 90°-bend pipelines are widely applied in engineering. When the local head loss coefficient is from different sources, the RID = 1 (R is curvature radius of pipe centreline; D is pipe diameter), it can be found that the local head loss coefficient will be 0.2, 0.24, 0.3, 0.35, 0.52 and 0.80. The difference between maximum and minimum values varies 4times. When RID = 5, the values are 0.13 and 0.29, of which the difference is more than 2 times. As a result, it makes the hydraulic calculation uncertain and directly affects the safety and cost of engineering construction [1].

Large bending frequency heating hydraulic pipe bender adopts the digital hydraulic servo control system. This type of bender runs smoothly and avoids the phenomenon of vibration and arc ridging in the process of bending thin-wall pipe. The hydraulic control technology for realizing large cylinder's ultra-low and constant speed could be widely used in any hydraulic equipment which needs steady and low-speeding operation [2].

There are some specific methods to calculate plastic forming process. One method is based on numerical simulation, and the other method is based on design. At present, process evaluation of tube is generally based on long-term experience of technologist; therefore the result is probably random and subjective. With the development of computer technology and plastic forming theory, numerical simulation has been applied to study tube bending process. The forming quality on the basis of theory analysis and EFA method results into forecasting of the finite elements. The Tube forming quality is affected by many factors, such as bender machine capacity, geometry dimension, tube material, surface quality and location in machine of bend die set. Plastic forming mechanism of tube bending is so complicated that it is difficult to get the numerical model between the forming quality and the complex factors [3].

1.2 The characteristics of 2D pipe drawings after investigation and analysis of plenty of 2D chemical pipe drawing shows :

(1)Generally, a pipe drawing is made up of a lot of points, line segments, arcs and pipe joints. A pipe segment expressed by a line segment usually locates in, the horizontal or perpendicular position. In this case, the line segment reflects its real shape in a certain projection view, and accumulates one point in the corresponding projection view.
(2) Projection of pipes is overlapped, in order to describe hierarchy relationship of pipes, "twofold fracture" symbol with lowercase letters a, a and b, b is dimensioned beside the fracture, which may bring difficulties to recognize and match pipe segments.
(3) There are several ways to express pipes, for examples, signal-line expression, double-line expression and axonometric drawing expression. In a word, the special expression method of chemical pipe drawing makes it difficult to reconstruct its 3D pipe model. [4].

1.3 Springback is often an important part of a forming analysis because the springback analysis determines the shape of the final, unloaded part. Springback in a stamping process is due to the elastic deformation of the part during removing off the tools. Control of springback is very important in the automotive industry because the high strength steels and aluminium alloys are increasingly used. Modern finite element (FE) codes for sheet metal forming simulation have shown that they are able to produce excellent results regarding the springback prediction. Springback can be predicted accurately by using modern finite element codes for sheet metal forming simulation, but there still remains the problem of how to apply the results to appear at a suitable die design to produce a target part shape. It is crucial to compensate for springback errors by modifying the shape of stamping tools. Tools shape modification due to springback errors, is a very complex process. There are two methods commonly used to modify die tools, the trial-and-error and FE method. [5]

In order to analyse accuracy of the concrete temperature field in the approximate method, the convective transfer heat coefficients are calculated by numerical simulation. The characteristics of the cooling water flow field and Nusselt number distribution along the pipeline are studied in this paper. The numerical results show that the flow field distribution is very complex and a secondary flow appeared in the bend position. The main velocity is decreased by the secondary flow, and the heat exchange between the concrete and the cooling water pipe is attenuated. In the bend position, Nusselt number also distributed complex bending, this implied that it should be loaded different convective coefficient on the pipe to calculate the thermal field in the approximate method. These results will help us study the temperature distribution in curing age of the concrete with the cooling water pipe in a better way [6].

1.4 Finite element analysis by ANSYS has been conducted for the cyclic bending tests with 1000f.!s and 6000f.!s strain range loading conditions respectively. The solder constitutive models, elastic-plastic, creep, and viscoplastic models are compared and the Von misesstress, plastic strain and plastic work are calculated. By correlating the experimental and numerical results, it can be concluded that the elastic-plastic constitutive model is not suitable for cyclic bending simulation for the reason that the elastic-plastic model is rate independent and the deformation is separated as elastic and plastic stages. The creep constitutive model is also inappropriate for cyclic bending simulation due to the character of the impact condition is room temperature, short duration and large deflection. The viscoplastic model is selected as the solder constitutive model for bending simulation because that the viscoplastic property includes inelastic deformation and rate effect. The simulation results of the viscoplastic model can describe the deformation behaviour of Sn2.5AgO.5Cu during actual bending condition appropriately [7].

1.5 Tube bending has been one key manufacturing technology for lightweight and high-strength components in many high-end industries. The current urgent demands for high efficiency and precision production are vitally related to the accurate prediction and effective controlling of the various failures or instabilities in tube bending. This depends on the insight into the occurring mechanisms and influences rules of different defects or instabilities. Thus, advances on the studies of these common topics in tube bending are summarized including wrinkling instability, wall thinning (cracking), springback phenomenon, cross-section deformation and process/tooling design/optimization.
2) With the increasing needs for better performance, the more complex three-dimensional spatial tubular bent components with more lightweight materials are required. These components are characterized with the thin wall thickness, large diameter, small bending radius, and the tubular materials are generally hard to-deform ones with limited ductility and high strength. Considering the facts of tough tolerance in applications and multiple constraints with nonlinear contact conditions in bending, several challenges should be overcome,

viz., the calibration and modelling of the tubular materials, the accurate prediction and control of the multiple defects or instabilities, and the robust optimization of tooling/processing parameters with multi-objective and multiple constraints[8].

1.6 Ratcheting studies is carried out on four straight pipes and four elbow specimens subjected to steady internal pressure and cyclic bending load. All the experiments are carried out under displacement control by subjecting the specimens to different levels of load-line displacement. The straight pipes have undergone significant ratchet swelling (ballooning), ovalization and consequent thinning of the cross-section during ratcheting. The ballooning in straight pipes is found to be varying from 13.4% to 19.0% with respect to the original diameter in the gauge length portion. The percentage reduction in thickness varied from8.0% to 16.3%. The pipe specimens failed either by occurrence of through-wall crack which is accompanied by simultaneous ballooning or bursting with simultaneous ballooning. In the case of elbows, the ballooning is found to be varying from 3.8% to 5.8% and the reduction in thickness is around 12e15%. All the elbows failed by occurrence of axial through wall crack accompanied by simultaneous ballooning. Crack are observed in the bent portion at crown locations in all the four elbow specimens.
In order to understand the ratcheting behaviour of pipes elbows, the applied internal pressure and cyclic bending load are represented in the form of non-dimensional parameters. In the case of straight pipes, which were subjected to the same value of internal pressure and different values of cyclic displacement, the number of cycles to the occurrence of through-wall crack depended on the applied cyclic bending load, i.e., higher the bending load, lower the number of cycles to occurrence of through-wall crack. It was also observed that higher the number of cycles to occurrence of through-wall crack, lower the percentage of ballooning. Even in the case of elbows, higher the bending load, lower the number of cycles to occurrence of through-wall crack. From the comparative study, it was generally inferred that ratcheting is more pronounced in straight pipes than in elbows [9].

The linear reduced-integration elements tend to be too flexible because they suffer from their own numerical problem called hourglassing. In coarse meshes, the zero-energy mode can propagate through the meshs, producing meaningless results. An artificial stiffness is introduced to limit the propagation of the hourglass mode. This stiffness is more effective at limiting the hourglass mode when more elements are used in the model, which means that linear reduced-integration elements can give acceptable results as long as a reasonably fine mesh is used. That’s the reason why springback results are tending towards stability with the finishing of mesh size. In quasi-static analysis, there are a few smaller meshes which control the steady time increment of the whole model. Generally speaking, applying MSF can increase the size of the stable time increment, resulting in less computation time. However, overlarge MSF may introduce excessive kinetic energy which could generate large inertia forces.

1.7 The Inertia forces should be remained insignificantly in the quasi-static process. The principle to find a proper MSF is to increase MSF until the same results have been achieved [10].
Within the frame of research a former investigated concept for a shear-force-free bending test bench has been analyzed in order to identify the potential for improving the accuracy of the trajectory of the clamping point. These investigations have led to a different synthesis approach for the guidance mechanism in combination with specific constraints. Based upon the adjusted method an optimization has been carried out that resulted in a highly improved overall precision of the shear-force-free bending movement for both bending directions [11].
This paper has presented the results of an experimental study on thin-walled steel circular hollow section (CHS) under bending. A total of sixteen specimens are fabricated and tested, with diameter-to thickness ratio ranging from 75 to 300. The influence of stiffeners on bending capacities and ductility was also studied. Based on the test observations and analyzing of experimental data, the following conclusions can be drawn [12].
The study provides knowledge on bending behaviours of thin-walled tube under different bending specifications and help efficient design and optimization of the forming parameters. It is noted that the ‘‘size effect’’ related springback and the property variations of thin-walled Al-alloy tubes are not considered in the present study. While, the bending deformation may be greatly affected by the variations of mechanical properties, which will be explored in the further study [13].
In the scope of this paper a FE model of the three roll-push-bending process has been presented. It is capable to predict the resulting bending geometry in terms of the curvature and the torsion. In particular, 3-dimensional bends have been investigated by numerical simulations throughout the entire relevant parameter space. The key process variable is the rotation angle of the feeding arm in relation to the feeding distance proceeded simultaneously. To gain a deeper understanding the process behaviour is examined using a characteristic value called the torsion adjustment coefficient which the feeding movement and the resulting torsion of the tube. The values of the torsion adjustment coefficient have been between 0.85 and 1.8 but have not shown a uniform

trend. The occurrence of the torsion highly depends on the position of the tool elements [14].

1.8 Bending angle and longitudinal distortion, were studied in the laser forming process, using experimental and finite element approaches. Then, the results of both methods were compared and good agreement was found between them. Finally, the following points were concluded:

1. In the fixed scan speed pattern, by increasing the scan speed, the distortion quantity was decreased, which means that the longitudinal distortion is inversely proportional to the scan speed values.

2. In the step scan speed pattern, by increasing the step speed, the sheet surface temperature was decreased, which causes lower strain to be obtained.

3. In the inclined linear scan speed pattern, with a rapid increase in scan speed, temperature distribution along the lines perpendicular to the laser paths decreased. Therefore, plastic strain was reduced.

4. In general, in order to control the longitudinal distortion and bending angle, an optimum fixed scan speed was found (40 mm/s) [15].

1.9 Tube bending has been one key manufacturing technology for lightweight and high-strength components in many high-end industries. The current urgent demands for high efficiency and precision production are vitally related to the accurate prediction and effective controlling of the various failures or instabilities in tube bending. This depends on the insight into the occurring mechanisms and influences rules of different defects or instabilities. Thus, advances on the studies of these common topics in tube bending are summarized including wrinkling instability, wall thinning (cracking), springback phenomenon, cross-section deformation and process/tooling design/optimization [16].

1.10 (a) Overall patterns and taking into account the flow of wall roughness on the large influence of elbow flow, numerical calculation should be close to actually build models to minimize errors. Numerical study on the flow as if the whole object and set the roughness, reasonable simulation of water flow in as far as possible ensure runner internal flow.

(b) By analyzing the results, draw the bending radial velocity distribution: speed from the near-wall to near outside walls gradually decrease; bending radial velocity distribution and pressure distribution in the opposite [17].

1.11 External pressure increases (as the water depth increases for marine pipelines), the thin wall pipe formula predicts conservatively higher hoop stress than the exact solution (thick wall pipe formula).The original thin wall pipe formula or Barlow equation D/(2t) should be used as-is, without replacing the P term with (Pi-Po) to account for the external pressure. If the external pressure to be accounted for, replace the P term with (Pi-Po) and subtract Po in the formula, which is the same as the modified thin wall pipe formula [18].

1.12 For the same **flow rate range**, pipe bend devices with crests generate the higher head pressure difference in comparison with non-crested ones, pipe bend devices with longer crests generate the higher head pressure difference in comparison with shorter ones. The coefficients of the pressure head difference with and without bypass flow and the ratio of bypass flow with main pipe flow are all ranked as: No.4> No.3 > No.2 > No.1[19].

1.13 Carbon steel showed better fatigue characteristics at bended section than at as-received pipe. Improvement of fatigue strength resulted from both refinement of ferrite grain size and the achievement of a relatively fine pearlite by both plastic deformation and rapid-heating-cooling during pipe bending applying local induction heating. Hardness increased over 20% and fatigue endurance limits of deformed section were enhanced over 10% [20].

1.14 Coordinate Measuring Machine (CMM) most common method of design, found on almost all CAD/CAM systems, is easily understood. Due to the built-in datum source, this method lends itself to Coordinate Measuring Machine (CMM) inspection and the general CMM concepts used for measuring blocks or spheres. With the advent of numerically controlled machine tools, the demand has grown for some means to support this equipment. There has been growing need to have an apparatus that can do faster first piece inspection and many times, 100% dimensional inspection. The Coordinate Measuring Machine (CMM) plays a vital role in the mechanisation of the inspection process. Some of the CMMs can even be used as layout machines before machining and for checking feature locations after machining. Coordinate measuring machines are relatively recent developments in measurement technology. Basically, they consist of a platform on which the work piece being measured is placed and moved linearly or rotated. A probe attached to a head capable of lateral and vertical movements records all measurements. Coordinate measuring machines are also called measuring machines. They are versatile in their capability to record measurement of complex profiles with high sensitivity (0.25 µm) and speed. Recently Eicher Company used manual bending to manufacture the pipe bending of its new model Eicher rotary model 5150 part no 77002369.

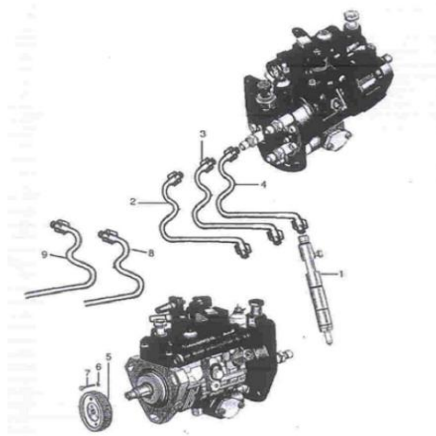

Figure 1

Table No 1: Eicher Tractor Parts Catalogue

APPLICABLE MODEL (S) : 5150 SS IND.APP.P/S O/I.B						
GROUP :ENGINE						
SUB GROUP : E-43A FUEL INJECTION SYSTEM-ROTARY TABLE: E-43A						
S.N O	ITEM CODE	ITEM	NO	LOCATION		
			OF F	FBD	ALW	BPL
1	93430560	INJECTOR ASSEMBLY	3	NA	NA	CUR
2	77002368	PIPE FUEL INJECTION ASSY.CYL:1-DELPHI	1	NA	NA	CUR
3	77002369	PIPE FUEL INJECTION ASSY.CYL:2-DELPHI	1	NA	NA	CUR
4	77002370	PIPE FUEL INJECTION ASSY.CYL:3-DELPHI	1	NA	NA	CUR
5	77002319	GEAR FIP (DELPHI)	1	NA	NA	CUR
6	93190432	74DE0844=SETSCREW DRIVING GR TO CAM SHAFT	3	NA	NA	CUR
7	93357432	00920053=WASHER SPRING O.SEAL HSG CYL.BL	3	NA	NA	CUR
8	93357405	FUEL DUCT ASSLY	1	NA	NA	CUR
9	93357417	FUEL DUCT ASSLY	1	NA	NA	CUR

PROBLEM IDENTIFICATION

2.1 The limitations of the XYZ coordinate system for tubing, fall into two general areas. The first is this system describes a three-dimensional model on a two dimensional plane. If the model is rotated at any degree out from any of the views, the entire XYZ table is voided and will need to be recalculated. While the tube shape did not change in relationship to itself, its relationship to those planes change. Therefore, the values describing tubes in terms of XYZ points, relates to whether you are looking at the whole picture or only at the tube.

The second general area of limitation is that parts cannot be bent in XYZ. XYZ data must always be converted to what is generally called "Bend Data". Discuss limitations of XYZ co-ordinate system make the design complicated and the design reading complex to understand with terms.

2.3 While studying and collecting the data it was found that there are too many defects in bending of pipes and it is not easy to rectify it in the design. Another important thing noticed is that, the design is too complicated and there is no discussion about the receiving gauge. The receiving gauge is very important because it measures the bending angle and accurate dimension with center line. The receiving gauge is a practical model and it is used to hold masterpiece of pipe for further pipe bending systems thus its importance cannot be ignored. One thing is to be kept in mind that the manufacturing of the receiving gauge is very costly. The design of the receiving gauge is very complicated because one has to set its accurate dimension with center line, bending radius and angles and we have to design the gauges according to it. We even maintain the center line of the gauges and pipe center line and thus the working is from center line to center line. Thus the whole process affects the cost and design of receiving gauge.

2.4 Defects in Tube Bending

During the bending process the tube undergoes considerable in-plane distortion. The limitations in the tube bending process are distortion of cross-section, wrinkling, variation in wall thickness, springback and fracture.

1. Variation in Wall Thickness: During the bending process the bending moment induces axial forces in the inner and outer fibers. The inner and outer fibers are subjected to compressive and tensile stresses respectively. This results in thinning of the tube wall at the outer section (extrados) and thickening of the tube wall at the inner section (intrados).

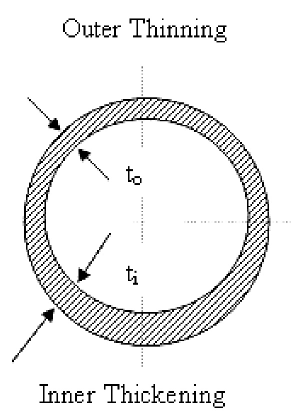

Figure 2: Variation in wall thickness of the tube

2. Bursting or Fracture: The fibers at the extrados are subjected to tensile stress. When the tensile stress induced in the tube due to the bending moment at the extrados exceeds the ultimate yield strength of the material, the tube fractures at the extrados.

3. Wrinkling: As the tube is bent, the inner surface of the tube, the intrados is subjected to compressive stress. When the tube is bent into a tight radius, it is subjected to high compressive stress in the intrados which leads to Bifurcation instability or buckling (wrinkling) of the tube. Wrinkles are wavy types of surface distortions. As tubes are used as parts in many applications where tight dimensional tolerances are desired, wrinkles are unacceptable and should be eliminated. Furthermore, wrinkles spoil the aesthetic appearance of the tube.

Figure 3: Tube wrinkling

4. Cross Section Distortion: As described above the outer fibers of the tube are subjected to tensile stress whereas inner fibers of the tube are subjected to compressive stress. There is a tendency of fibers at both the ends to move towards the neutral axis. The outer fiber of the tube tends to move towards the neutral plane to reduce the tensile elongation. This results in the cross section of the tube being no longer circular, instead becoming oval. The common practice in industry is to provide support to the tube from inside to prevent flattening or distortion of cross section; usually a filler material or mandrel is used for that.

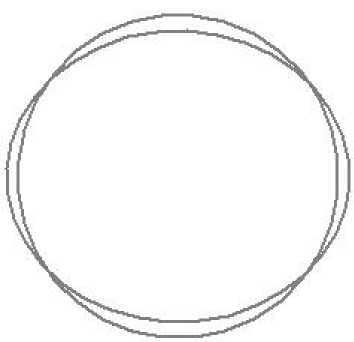

Figure 4: Cross section distortion

5. Springback: After the bending process is complete and the tooling have been withdrawn the bend tube springbacks due to the elastic nature of the tube material. This is called springback or the elastic recovery of the tube. During the bending process internal stresses are developed in the tube and upon unloading the internal stresses do not vanish. After bending the extrados is subjected to residual tensile stress and the intrados is subjected to residual compressive stress. These residual stresses produce a net internal bending moment which causes springback. The tube continues to springback until the internal bending moment drops to zero. The springback angle depends on the bend angle, tube material, tube size, mandrel, machine and tooling. In actual practice the amount of springback is calculated and the tube is over bent by that amount.

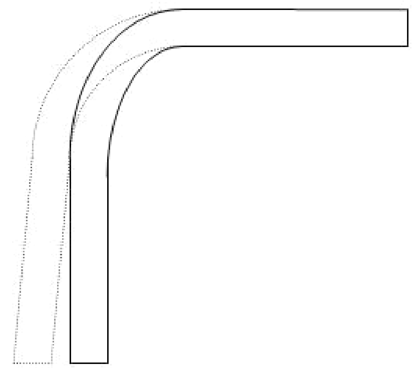

Figure 5: Springback

PROPOSED METHODLOGY

Simpler design with dimension is examining through Coordinate Measuring Machine (CMM).

We have already discussed about the problem in the problem identification. Therefore we are proposing method to overcome the defects of the pipe. We have calculated the dimensions and coordinate points of the pipe and have given the calculations and design below. This whole process is done by CMM machine.

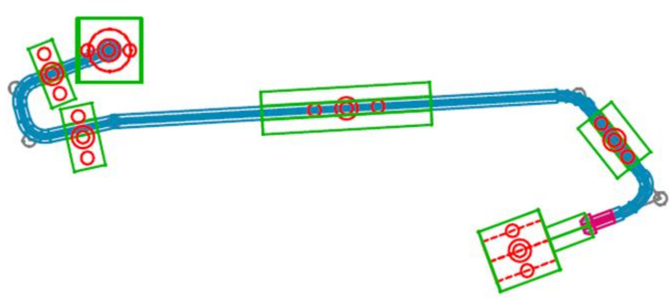

Figure 6: Pipe Design

We have calculated the coordinate points of the pipe by the help of CMM machine and have then designed the pipe on AUTOCAD. We have overcome all the shortcomings, which were there at the time of problem identification.they are as follows:

1. We maintained the centreline to centreline binding.
2. We have maintained the radius. One thing noticeable about the binding is that, there are no variations to be found as far as wall thickness is concerned.
3. We have calculated all the coordinate points of the pipe through CMM machine. After which we got accurate coordinate points through which we designed the receiving gauge.
4. We tried to maintain the radius and bending angle, so that we can overcome the problems which occurred during the process of problem identification.

PIPE CMM REPORT

ELEMENT	NOMINAL	ACTUAL	LOW_TOL	UPP_TOL	DEV
POINT PT 10					
X	0.000	0.000	-0.200	0.200	0.000
Y	0.000	0.000	-0.200	0.200	0.000
Z	0.000	0.000	-0.200	0.200	0.000
POINT PT 11					
X	0.076	0.076	-0.200	0.200	0.000
Y	0.000	0.000	-0.200	0.200	0.000
Z	-50.761	-50.761	-0.200	0.200	0.000
POINT PT 12					
X	-17.919	-17.919	-0.200	0.200	0.000
Y	-44.826	-44.826	-0.200	0.200	0.000
Z	0.000	0.000	-0.200	0.200	0.000
POINT PT 13					
X	0.000	0.000	-0.200	0.200	0.000
Y	-38.350	-38.350	-0.200	0.200	0.000
Z	-48.679	-48.679	-0.200	0.200	0.000
POINT PT 14					
X	-33.623	-33.623	-0.200	0.200	0.000
Y	0.000	0.000	-0.200	0.200	0.000
Z	-47.582	-47.582	-0.200	0.200	0.000
POINT PT 15					
X	-21.029	-21.029	-0.200	0.200	0.000
Y	220.956	220.956	-0.200	0.200	0.000
Z	0.000	0.000	-0.200	0.200	0.000
POINT PT 16					
X	-69.886	-69.886	-0.200	0.200	0.000
Y	259.668	259.668	-0.200	0.200	0.000
Z	0.000	0.000	-0.200	0.200	0.000
POINT PT 17					
X	-83.426	-83.426	-0.200	0.200	0.000
Y	222.966	222.966	-0.200	0.200	0.000
Z	27.028	27.028	-0.200	0.200	0.000

NOTE: In the above given table the XYZ coordinate points are calculated by the CMM machine. All the above readings served as the base for designing the receiving gauge and manual bending machine. With the help of the output we got, we tried to maintain the readings of the pipe which resulted into the accurate readings.

CONCLUSION

Manual bending tends to minimize wrinkling and can reduce springback. By easier design these defects can be overcome. Simpler design not only reduces defects but also helps in testing fluid pressure during bending. It is to be noted the wrinkling tendency and cross section distortion of the tube are reduced. Thus, this approach can be used for bending a thin walled tube over a small die radius, which cannot be achieved with a traditional tube bending process. In this paper, the problem of tube bending with internal pressure and axial stretching has been investigated by using The Coordinate Measuring Machine (CMM). The objective of the study is to develop a tool that accurately predicts the wall thickness variation and cross section distortion of the tube under different loading conditions. The analytical models were developed on the basis of the plastic deformation theory.

Thus it is observed in this model that internal pressure can alone remove wrinkling and provides a better cross section, but the use of internal pressure alone is limited to the capacity of pressure intensifier. And moreover beyond a certain value of internal pressure the cross section distortion increases. In such combination of axial pull and internal pressure can be used. From the parametric study it is seen that with increase in axial pull the rate of decrease in wall thickness is greater at intrados and in the case of axial pull the rate of decrease of wall thickness was greater at extrados. The parametric study conducted showed that with optimum level of internal pressure and axial pull best results can be obtained.

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