Design and Analysis of Rotary Draw Tube Bending Machine

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Abstract-**Tube bending is the metal forming processes used to permanently form pipes or tubing. One has to differentiate between form-bound(secure with a cover of bending) and freeform-bending procedures, as well as between supported and cold forming procedures.**

Form bound bending procedures like press bending or rotary draw bending are used to form the work piece into the shape of a die. Straight tube stock can be formed using a bending machine to create a variety of single or multiple bends and to shape the piece into the desired form. This process can be used to form complex shapes out of different types of ductile metal tubing. Freeform-bending processes, like three-roll-push bending, shape the work piece kinematically, thus the bending contour is not dependent on the tool geometry. The main goal of this project is composition of deformation in tube or pipe bending theory and the effects of Rotary Tube bending machine parts including; clamp die, bend die and supporter die to obtain optimum bending requirements.

Rotary draw tube(pipe) bending is presented alongside machinery parts with their function and effects on bending moment and failure types along with their reasons.

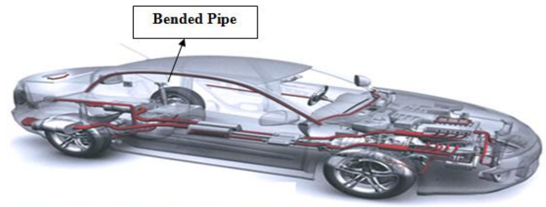
Deformation of tubes can be achieved in numerous ways. One of the most useful type is rotary tube bending machines which is used in many industries such as aerospace, automotive, HVAC systems and so on. It is important that all components of system should mate properly after producing and because of this bend shaping requires sensitive operation on each component to ensure regularity of production processes with high quality end-product. However it brings some troubleshooting like wrinkling, spring back, breakage and validation. This failure depends on geometry of the material such as bending radius, tube thickness and also friction factor between dies and the tube. Effects of all parameters should be examined before generating the theory for a best solution. Therefore, prediction of the required moment for the proper bending process with low cost and shortened production time is needed.

Pinion gears, spur gear teeth, solved using radioss solver, rotational force analysis is solved using radioss and moment is applied for complete assembly of motor and gears. Rotational force is solved for checking the pressure values at the component level while rotating. Moment analysis is carried out to check the strength of the assembly component. Moment analysis is carried out to check the strength of the machine assembly and static analysis for stand, clamp die, pressure die models to check while tube bending process the surface attached to pipe is safe or not. To check that we done static analysis for those components.

The solid model is generated in CATIA-V5. Then the model is imported to HYPERMESH 11.0 through IGES format. The quality mesh is prepared in HYPERMESH for converged solution and the solver set as RADIOSS (analysis package with high optimizing results).

I. INTRODUCTION

Pipe bending is an item that most people think little about. Other than the obvious exhaust pipe or water lines, many do not know what it is used for. Yet each day they travel by planes, trains and automobiles to their homes. Here they find comfort using the gas range and furnace, sitting in comfortable lawn and kitchen chairs, or loading the dishwasher after eating out of their refrigerators. All are made available by the use of tubing. Lightweight and practical tubing is used by almost everyone in the world every day, but where was tubing only a few short years ago We would never think of tubing as being of the metal industry, but truly tubing is relatively new. But nowhere do you hear about tubing. To move water, solid rock was hollowed out or aqueducts(A bridge like structure supporting a conduit or canal passing over a river or low ground.) were built. There was no need for gas lines and oil still came from whales. People are used furnace process of making malleable low carbon steel in 1926 allowed steel to be rolled practically into a hollow bar. Adding the technology of electric arc welding we had a method to produce tubing economically. Today we call this method Cold Rolled Electric Welded steel tubing (CREW), or if using hot roll steel (HREW). That means electric weld tubing has only been around for 75 years. Truly we having few DOT-COMS of the tubing industry.



Automotive Solution

Home Appliances

Different Types of Bending

i. CNC Mandrel Bending:

Our Computer Numeric Controlled (CNC) Mandrel benders give us the capabilities to bend high volume multiple bend parts in much less time. They include multiple stack benders capable of more than one radius to 6" diameters. The speed of these machines makes them valuable assets to not only Woolf Aircraft, but our customers as well.

ii. Roll Bending:

We can roll bend tubing in sizes up to 2 1/2" in diameter. Roll bending allows us to form any radius larger than 4 times the diameter. Roll bending differs from Mandrel Bending in that the bend is not supported by an inside mandrel. The process is simple to set up, and allows for an infinite amount of bend radii, without re-tooling

iii. Hydroforming:

Another type of bending is Hydroforming (Internal fluid supports wall while being pressed into a cavity). We specialize in Pre-forming tubes for Hydroforming. We can Mandrel Bend difficult shapes, which our customers Hydroform in heavy presses. Compression Bending is another form of bending offered in the tube industry, it is a process where the tube is pressed into shape using a simple machine that forces the tube around a radius without any interior support. Most automotive exhaust pipes, with their many flat spots and wrinkles, use Compression Bending.

i) Hydroforming *ii) Roll Bending* *iii) CNC Bending*

Application of Pipe Bending:

Tube benders can be used in a number of sectors: from the automotive hydraulics sector to the interior design sector. Some applications mentioned below.

- Hydraulic connections
- Hydraulic system (oil pipes for diggers, cranes, etc.)
- Fuel pipes for diesel motors
- Motorbike and scooter accessories
- Iron, steel and aluminium furnishings and accessories for interior and exterior design (Chairs, tables, shelves, ironing boards, lamps, etc.)
- Shop furnishings
- Office furnishings
- Hospital furnishings
- Beautician and hairdresser furnishings
- Children’s playground
- Gym equipment
- Exhausts
- Zootechnical equipment (cowsheds, pigsties and sheep barns)
- Boat and swimming pool furnishings
- Supermarket and airport trolleys
- Trim for train and bus windows
- Bathroom furnishings and taps and faucets
- Prams and pushchairs
- Butcher's guides
- Equipment for the food industry

Overview of Project

Description of the problem:

Over the last decade bending technology has been a sensation in the field of engineering because this area can be continuously improved, resulting in higher quality with less troubleshooting and manufacturing defects. In this manner, Research and Development(R/D) departments provide time budgeting toward this issue. Before starting to analyze the theory of bending is good to understand the bending process.

Bending is a straight tube to form an elbow is a process of metal flow. All of the dimension in the elbow changes as the flow rules; this is consistent with the deformation theory. Thus, deformation is the best theory to assess tube-bending topics. In addition, one of the most useful type is ROTAARY DRAW TUBE BENDING machines used in many industries such as aerospace, automotive, HVAC systems

The solid model is generated in CATIA-V5 Then the model is imported to HYPERMESH 11.0 through IGES format. The quality mesh is prepared in HYPERMESH for converged solution and the solver set as RADIOSS (analysis package with high optimizing results).

Main goals of This Project

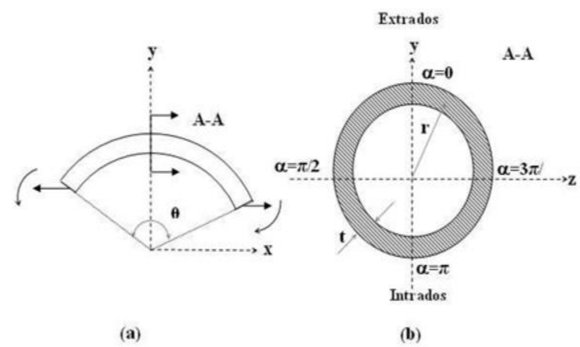
1) To develop an analytical geometry model using cad softwares (CATIA-V5) with this tool designing 3D-model, 2D-drawing & GA (general assembly) drawing.
2) Importing 3D model (IGES) data in HYPRMESH-V11 software and doing FEA (finite element analysis). Verifying the 3D-model design with standing or not after receiving stress, rotational and displacement forces results ,hence updating design concepts. Comparing the results obtain by the analytical model for loading conditions with the results obtain from the Finite element analysis (FEA).
3) Reducing the motor speed ratio for bending a pipe smoothly.
4) Selection Of material to be necessary.
5) Manufacturing Cost estimation of Rotary Draw Tube bending Machine (working proto type).
6) To show working machine with as per required aspects of pipe bending with an angle of 26º.

Analytical Model

This chapter presents an analytical model to say wall thickness distribution along the cross section of the tube and the cross section distortion of the tube. An analytical model provides an accurate prediction of final pipe geometry in a comparatively smaller computing time than that for FEA. A generalized model is developed to predict the wall thickness change and cross section distortion of the tube for combined internal pressure and axial pull.

The coordinate system used in the analysis is shown in Figure 1-1. On the bending plane, a tube of radius r (tube center to the mid wall) and wall thickness is bent over a die of radius R with bending angle θ. Axial force F, applied at the end is equal to zero in case of pure bending and bending with internal pressure only. On the cross section, the Circumference of the tube is represented by span angle α. The extrados (The upper or outer curve of an arch.) is defined by $0 \leq \alpha < \pi\ 2$ and$3\pi\ 2 \leq \alpha < 2\pi$. The intrados is the section where $\pi\ 2 \leq \alpha < 3\pi\ 2$. Internal pressure, applied to the inside surface of the tube is equal to zero in the case of pre bending and bending with axial pull only. The relevant assumptions for the analysis include:

1. A plane perpendicular to the tube axis before deformation remains plane and perpendicular to the axis after deformation.
2. Wall thickness of the tube is small in comparison to the length and radius of the tube. Hence deformation due to transverse shear is neglected.
3. The deformation is symmetric with respect to the x-y plane and the plane normal to x-y plane at θ/2.
4. The material is incompressible, elastic strain is neglected, and work hardening is not considered.
5. Friction between the tube and tooling is neglected.
6. Neutral axis shift during pure bending (bending without additional loading) is neglected.

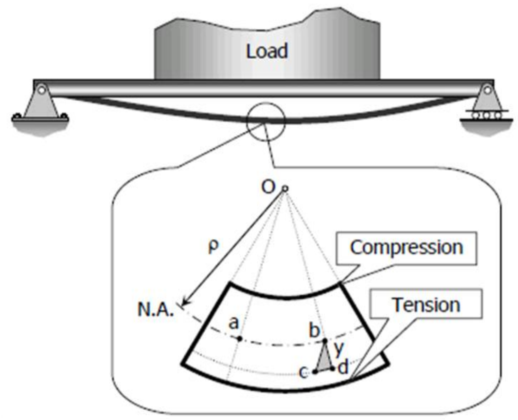


Coordinate System Of The Bending Analysis
(a) *Bending Plane (b) Cross Section Tube*

Bending Moment Force Acting On Pipe

Stresses caused by the bending moment are known as flexural or bending stresses. Consider a beam to be loaded as shown in below fig.

Consider a fiber at a distance' *y'* from the neutral axis, because of the beam's curvature, as the effect of bending moment; the fiber is stretched by an amount of *cd*. Since the curvature of the beam is very small, *bcd* and *Oba* are considered as similar triangles.



Load Applying on Pipe

Bending Equation:

where R is the radius of curvature of the beam in mm, *M* is the bending moment in N·mm, *fb* is the flexural stress in MPa., *I* is the centroidal moment of inertia in mm^4, and *c* is the distance from the neutral axis to the outermost fiber in mm.

Bending Equation Is Given By,

$$M/I = f/y = E/R$$

Where

M = Bending Moment

I = Moment of inertia about Neutral axis (N.A.)

f = Bending stress

y = Distance of the fiber from N.A.

R = Radius of Curvature = 210mm

E = Young's Modulus.

$I = bd^3/12 = b(d_1 - d_2)/12$

d_1 = Pipe O.D =20mm

d_2 = Pipe I.D = 17.4mm

$I = bd^3/12 = 2.6(20-17.4)$

$I = 3.808\ kg/m^2$.

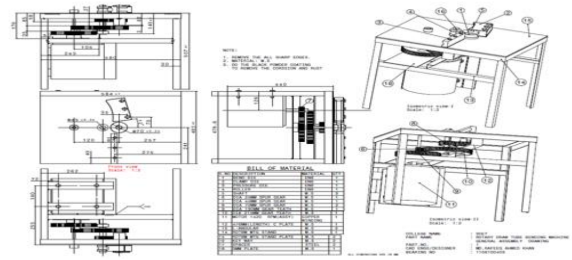
M/I = E/R

M/3.808 = 210000/210

(Bending Moment) M = 3.8 mpa

(Bending Moment)M = 38.749 $kgf/cm^2 \sim 40 kgf/cm^2$

For bending a straight pipe in to at an angle 26º with a radius of curvature 210mm ,bending force to be required $40 kgf/cm^2$.



Draft view of Assembly

Design Literature Survey:

In this research have worked on cross section distortion, wall thickness variation, and wrinkling issues related to pure bending process of tubes. To study the distortion of round tubes in bending using energy minimization. Expressions of bending moment and flattening ratio in terms of radius of curvature were obtained. Considering a finite length tube to bend in proper method to solve for the distortion shape and wall thickness variation of deformed tubes. We are going to improving expressions for calculating the magnitude of stresses in simple tube bending. Wall thickness change, shrinking rate at the bend section, deviation of the neutral axis, and feed preparation length were derived based on pipe deformation theory. Finding the instability (wrinkling) of infinite length, cylindrical and tubes under bending.

How Rotary Draw Tube Bending Machine Work

Working Principle

This machine is working Friction & Rotary force Principle. When pipe is getting in contact with rotating bending die due to friction & rotating force the pipe is dragged in .Now the clamp lock is adjusted to the required angle. For rotating the roller die and bend die, the power is supplied from a motor through gear mechanism.

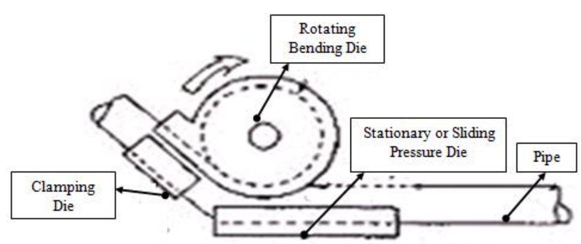
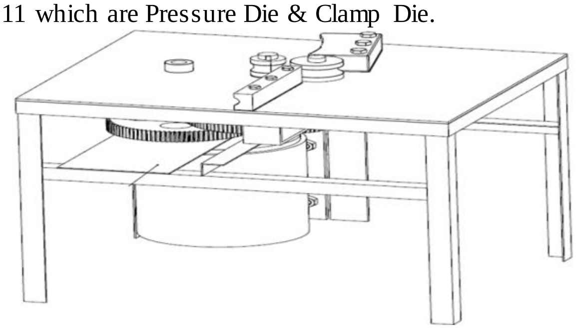


Fig.3.1: Rotary Draw Tube Bending 2D Conceptual Sketch

Here pinion gear is connected to the A.C motor shaft when we are giving power supply to the motor the motor shaft will be rotate due that bevel gear rotates opposite direction to the pinion gear similarly the adjacent bevel gear(roller) to be rotate as per pinion gear rotational direction.

These gears are connected with shaft and the gear shafts are connected with bend die, roller due to the interconnection of all the machinery parts the machine will run without any problem. In this Rotary draw tube bending machine, two main stationary parts are kept at respective places was shown in Fig: 11 which are Pressure Die & Clamp Die.



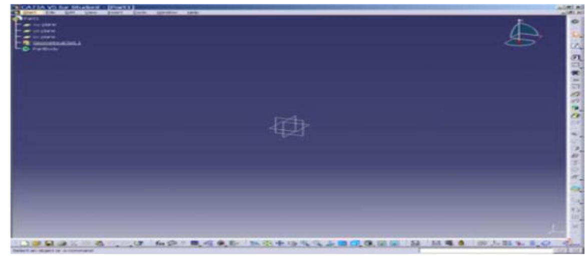
3D-Modeling & 2D-Drawing Images in CATIA-V5 Software

This ROTARY DRAW TUBE BENDING MACHINE is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

The same CATIA V5 R19 3d model and 2d drawing model is shown below for reference. Dimensions are taken from. The design of 3d model is done in CATIA V5 software, and then to do test we are using below mentioned software's.

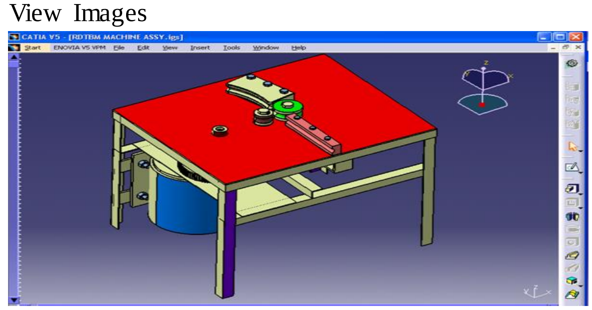
CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

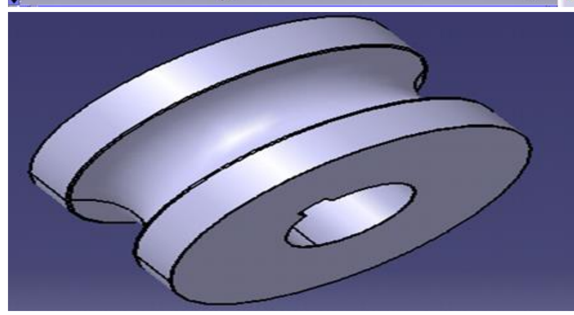
The 3D CAD system CATIA V5 was introduced in 1999 by Dassault Systems. Replacing CATIA V4, it represented a completely new design tool showing fundamental differences to its predecessor. The user interface, now featuring MS Windows layout, allows for the easy integration of common software packages such as MS Office, several graphic programs or SAPR3 products (depending on the IT environment).



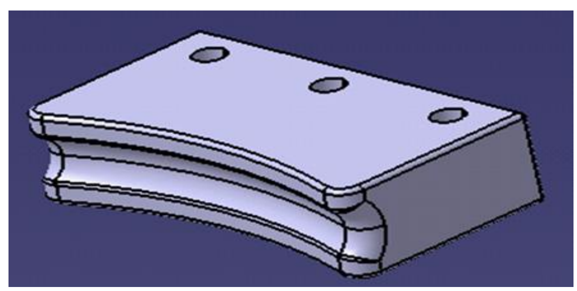
Main Window of CATIA-V5

Rotary Draw Tube Bending Machinery Parts ISO-View Images

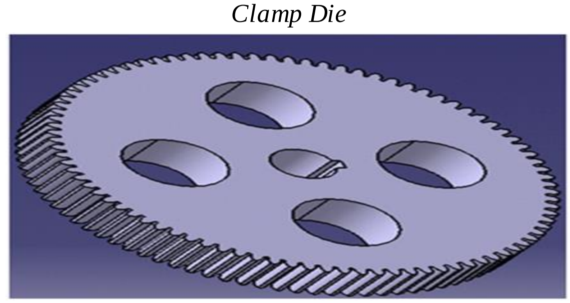




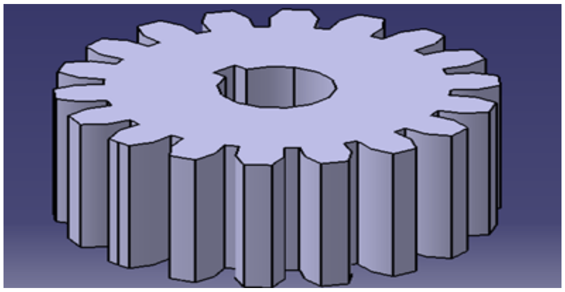
Bend Die



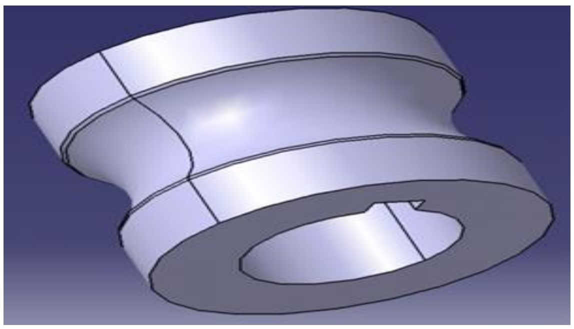
Clamp Die



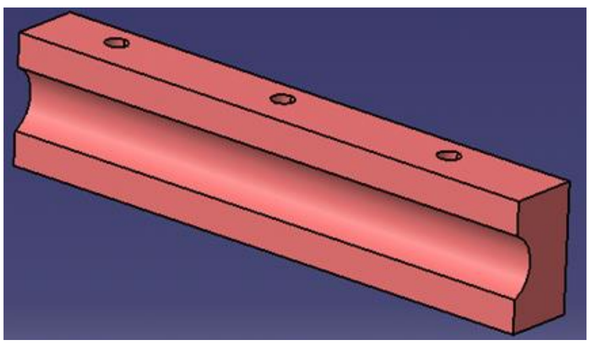
Spur Gear DIA 190mm & 210mm



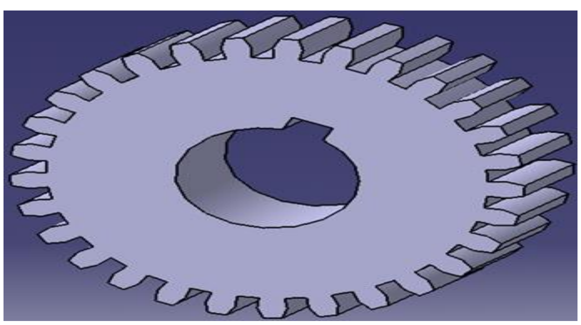
Spur Gear DIA 45mm



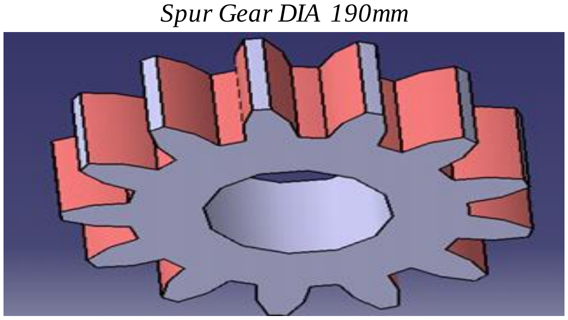
Roller Die



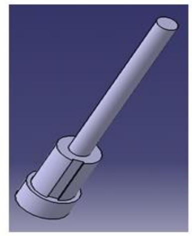
Pressure Die



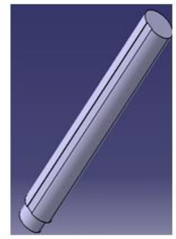
Spur Gear DIA 190mm



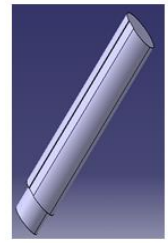
Spur Gear DIA 35mm



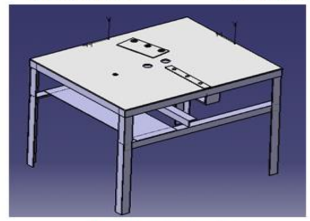
Pinion Gear Shaft



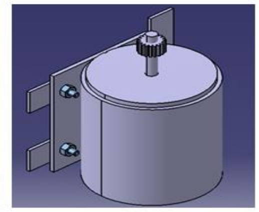
Roller Die Shaft



Bend Die Shaft

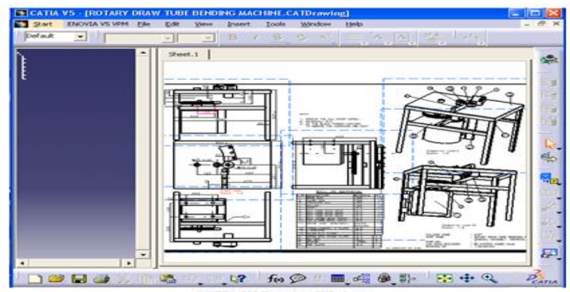


RDTBM Stand Assembly

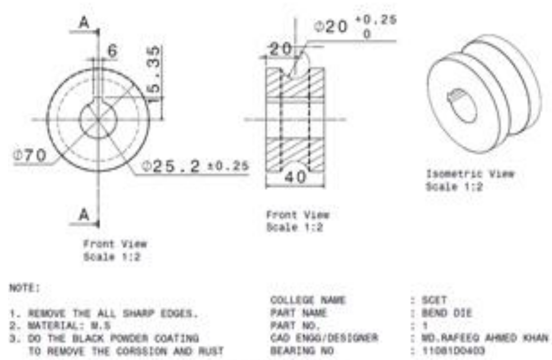


Motor Assembly

2D-Drawing Images

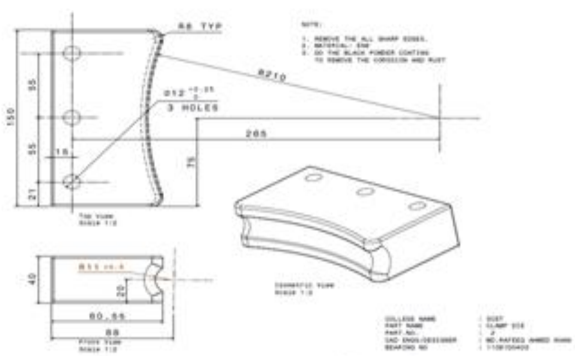


CATIA-V5 Drawing Window



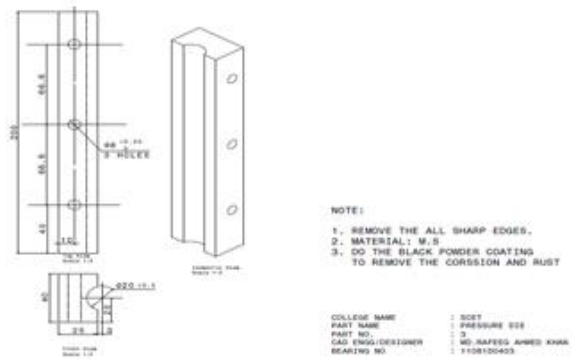
All Dimensions Are In mm

Bend Die-2D



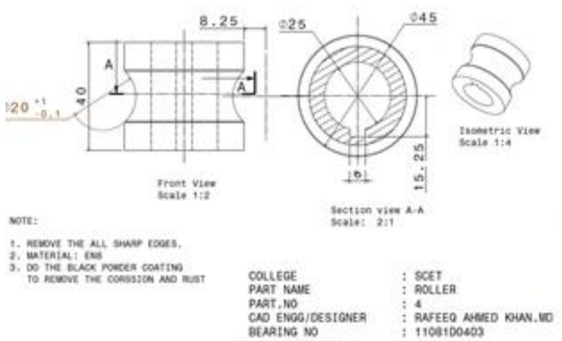
All Dimensions Are In mm

Clamp Die-2D



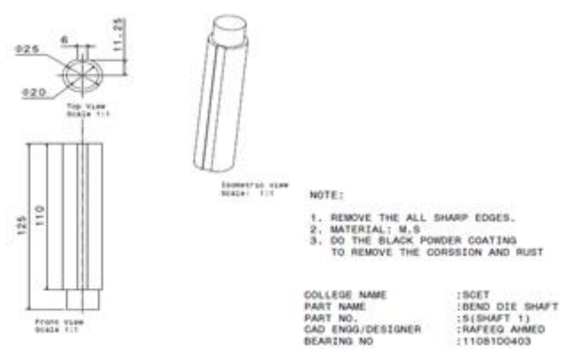
All Dimensions Are In mm

Pressure Die-2D



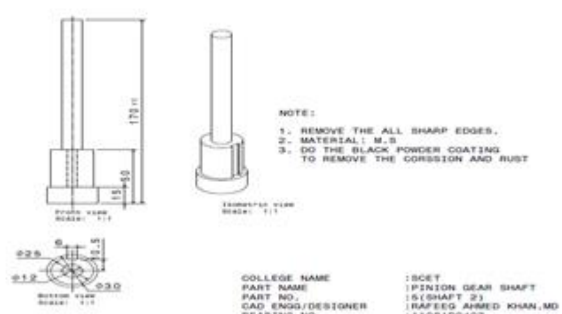
All Dimensions Are In mm

Roller-2D



All Dimensions Are In mm

Bend Die Shaft-2D



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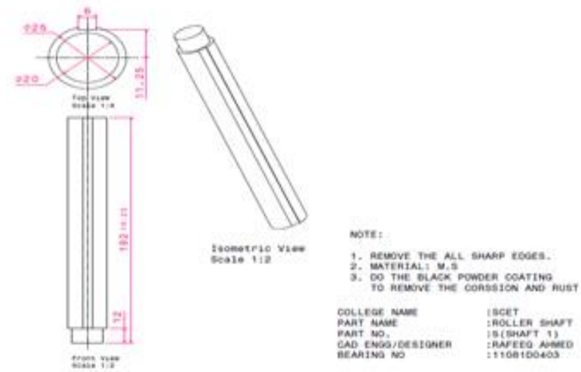
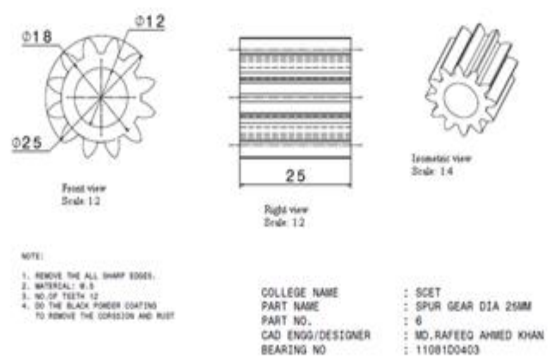
Pinion Gear Shaft-2D



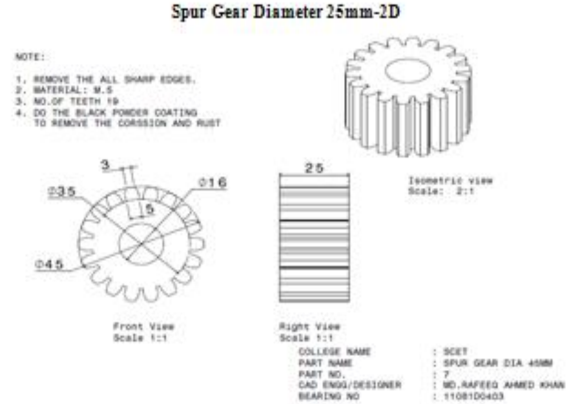
All Dimensions Are In mm

Roller Shaft-2D



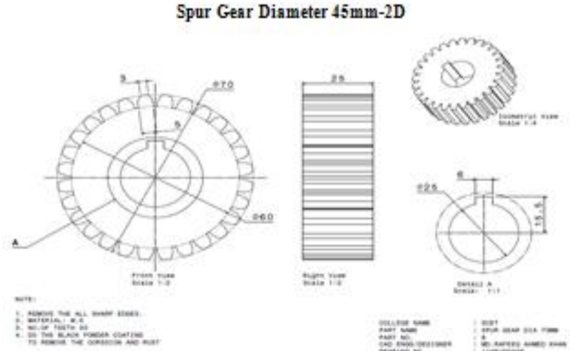
All Dimensions Are In mm

Spur Gear Diameter 25mm-2D



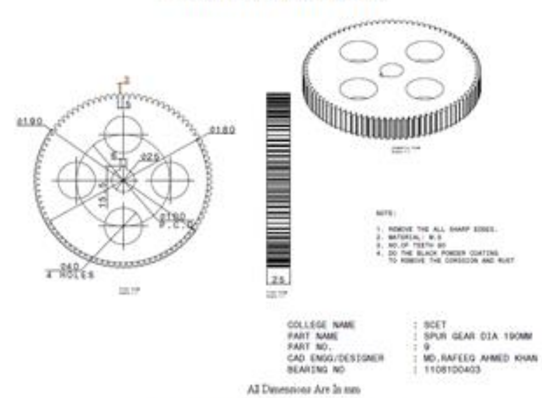
All Dimensions Are In mm

Spur Gear Diameter 45mm-2D

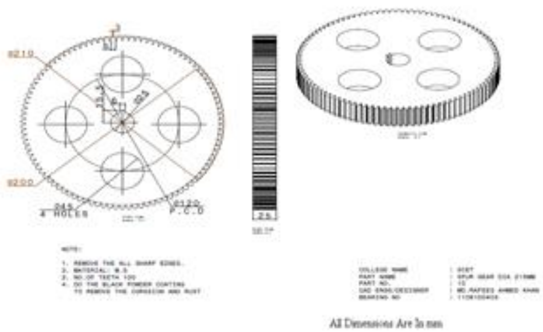


All Dimensions Are In mm

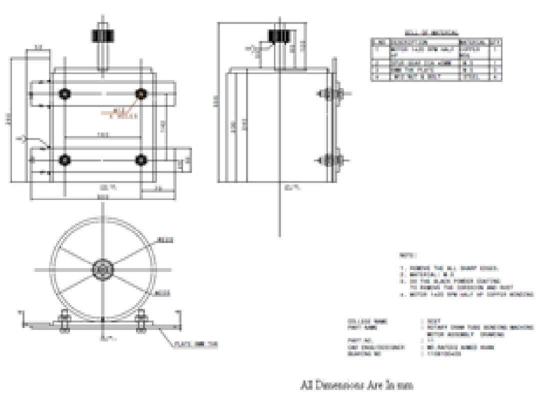
Spur Gear Diameter 70mm-2D



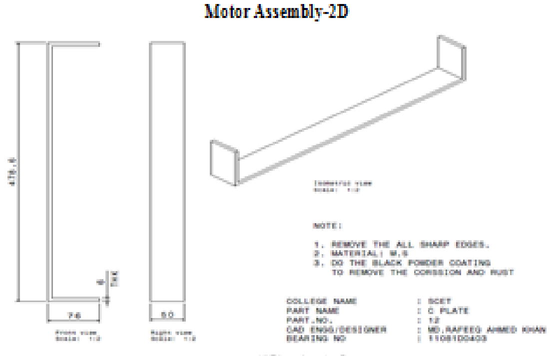
Spur Gear Diameter 190mm-2D



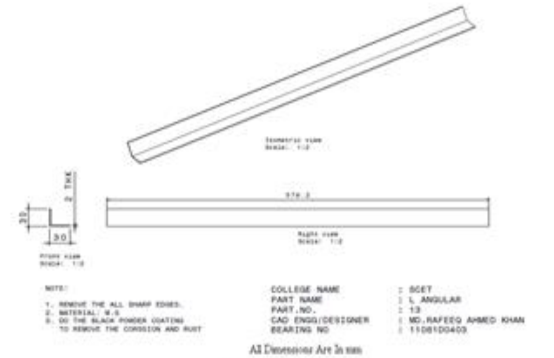
Spur Gear Diameter 190mm-2D



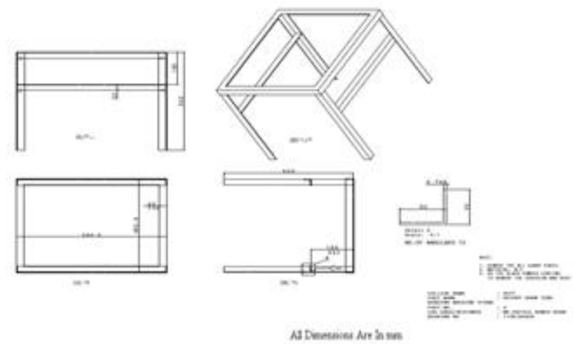
Motor Assembly-2D



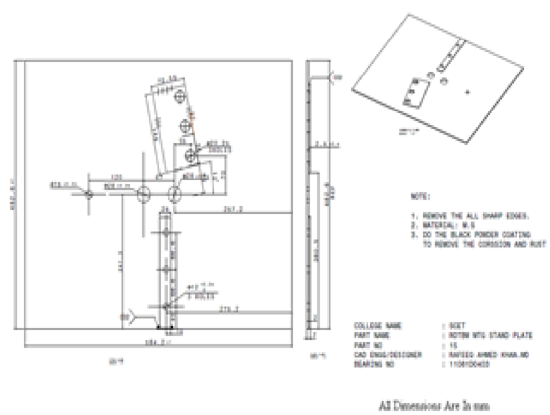
C Plate-2D



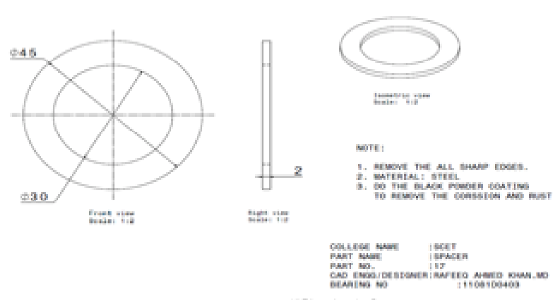
L Angular-2D



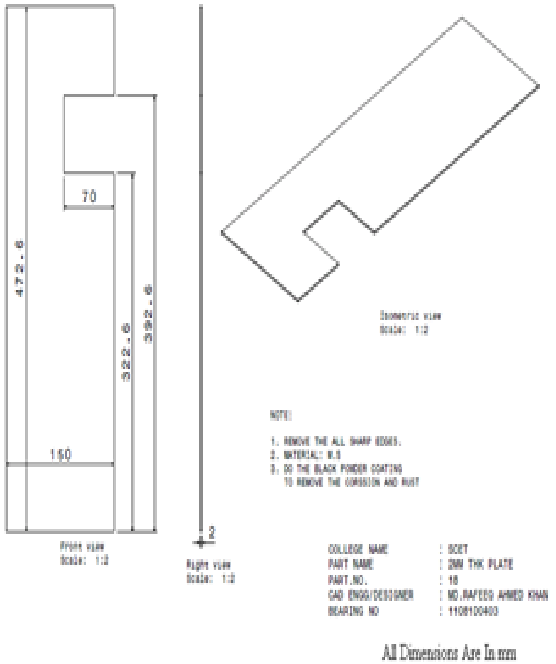
RDTBM Stand Assembly-2D



RDTM Mounting Stand Plate-2D



Spacer-2D



C Plate-2D

Materials Basic Properties

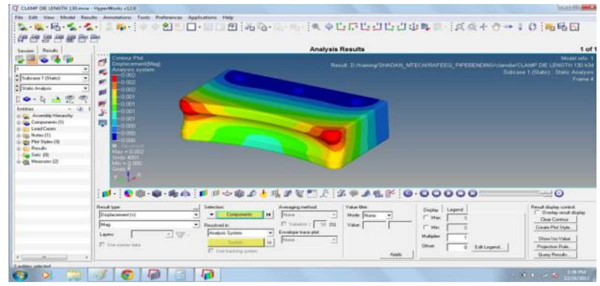
Material	Density (kg/m3)	Young's modulus (MPa)	Poisson's ratio
Mild steel	7860	2.1e5	0.27

Material Properties of Mild Steel

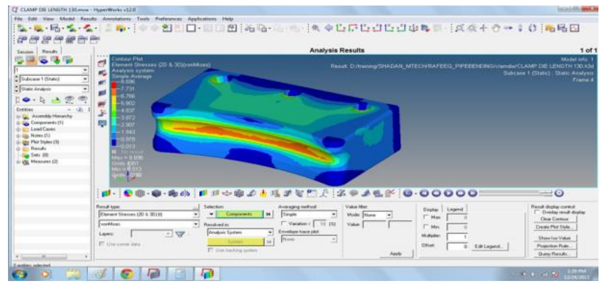
Alloy 1018 is the most commonly available of the cold-rolled steels. It is generally available in round rod, square bar, and rectangle bar. It has a good combination of all of the typical traits of steel - strength, some ductility, and comparative ease of machining. Chemically, it is very similar to A36 Hot Rolled steel, but the cold rolling process creates a better surface finish and better properties.

Mild (low-carbon) steel	Properties	Percentage (%)
Material Configuration	Iron (Fe)	98.81 - 99.26%
	Carbon (C)	0.18%
	Manganese (Mn)	0.6 - 0.9%
	Phosphorus (P)	0.04% max
	Sulfur (S)	0.05% max

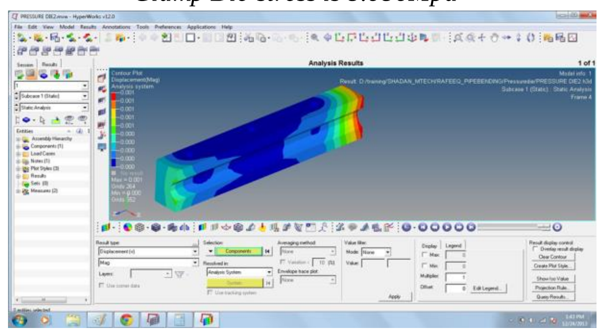
STATIC ANALYSIS RESULTS:



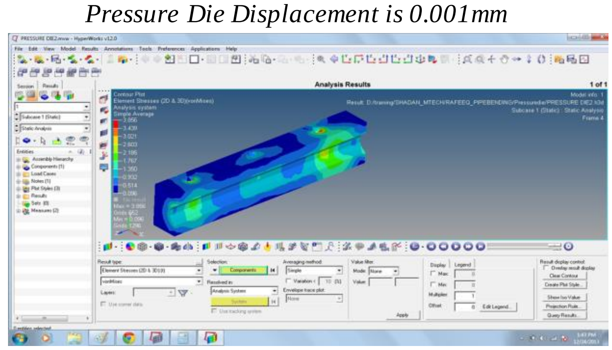
Dispalcement of Clamp Die is 0.002mm



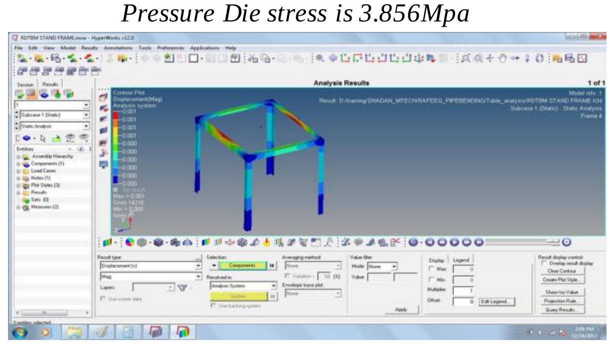
Clamp Die stress is 8.686Mpa



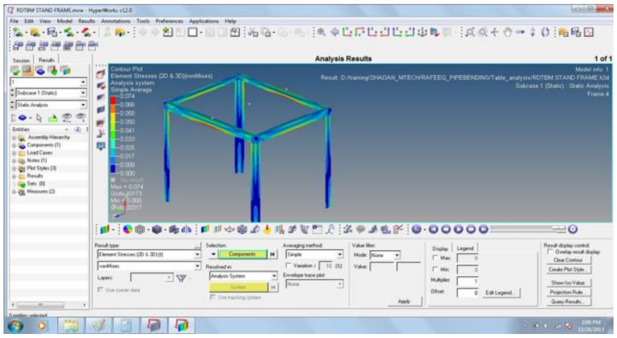
Pressure Die Displacement is 0.001mm



Pressure Die stress is 3.856Mpa



Displacement of table stands 0.001mm



Stress of table stand is 0.0074Mpa

CONCLUSION & FUTURE WORKS

As per the methodology and analysis results of moment, static and RForce analysis the displacements and stress is minimum that means these values are in limit. Gear assembly moment analysis results shown that the complete assembly is not having any deflection while in the moment of engine.

Analysis is consider for pipe pressure has been taken and analyzed on clamp die and pressure die the results which is shown is very less. That's why original equipment is working while pipe bending. RFORCE analysis is carried out for checking the stress and displacement of each component in assembly. The results are shown in less value which is under the material yeild value. Moment analysis is to check the strength analysis of complete gear box assembly the results which shown is completely the gear box is safe. Here all the remaining parts are separately analyzed.

Now It should be apparent the factors influencing a tube bending project are extensive. Criteria for evaluation should be indicative of individual company philosophies and requirements. A well Thought out, consistent approach will yield far better results than reactionary decision making.

Displacement values and stress values which we got in the above analysis, all are in the limits that means displacement is not more and stress is in limit. finally will report that there is no failure in analysis.

FUTURE WORK

The following recommendations for future work stem from the results of this thesis:

1. Changing variable diameter pipes, bending in various different angles.

2. To improve the surface finish we have to concentrate on Reducing the inch per revolution (IPR) will reduce flank wear and also prolong insert life.

- Rake angle is a variable in the insert's design that can be tailored to achieve the best surface finish.
- Ensure that the correct tool diameter is being used. The cutter should be engaged between two-thirds and three-fourths of its diameter.
- Use an insert with a wiper is always my first piece of advice when surface finish requirements are important to a manufacturer.

3. Further improvements should be made to the existing analytical bend model, such as:

• accounting for material anisotropy

• accounting for non-uniform percent boost and boost Force.

• accommodating initial small variations in original tube wall thickness, as a function of circumferential angle

• improve residual stress calculations to better approximate static equilibrium after springback.

4. Improve friction modeling in the numerical models. To facilitate this, work is underway to gather more accurate friction data from twist compression tests.

5. Increase the available boost force in the tube bender to accommodate higher boost levels in future experimental bending trials.

6. Set up an apparatus to measure relative slip between the pressure die and tube as a function of time during bending, as a means to better understand transient slip behavior and to provide better validation data.

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