Validation of ring bending machine

Validación de máquina dobladora de anillos

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Abstract

The manufacture of metal rings for the construction of buildings in Mexico has been done by hand and over time has been improving with new techniques and better technology. These elements of construction were previously manufactured entirely manually, the workers (or craftsmen) used only 2 poles of small size to support the wire rod and be able to deform it. This process causes excess tiredness to the worker and the execution time is long and it is not very effective. Then machines emerged, which performed the bending with a lever and two bearings. Nowadays there are tube machines that work automatically, however these machines are very expensive and not manageable, another disadvantage is the difficulty to operate them. In order to overcome the aforementioned deficiencies, a portable ring bending machine is designed. The prototype deforms the material using a lever and a bearing, the above is done to give a better shape to the wire rod.

Prototype, Validation, Bending Machine

Resumen

La fabricación de anillos para construcción se ha hecho de forma artesanal y a lo largo del tiempo ha ido mejorando con nuevas técnicas y mejor tecnología. Estos elementos de construcción se fabricaban anteriormente en su totalidad de forma manual, los obreros (o artesanos) utilizaban solamente 2 postes de dimensión pequeña para apoyar el alambrón y poder deformarlo; este proceso, aparte de ser muy cansado y lento, dejaba los estribos con una forma muy irregular, y en general era muy difícil trabajar con ellos. Después surgieron quienes los hacen con una maquina simple, que consta de una palanca y dos baleros. En la actualidad existen maquinas que los hacen de forma automática, sin embargo estas máquinas son muy costosas y de dimensiones poco manejable, otra de las desventajas es la dificultad para operarlas. Con el fin de superar las deficiencias antes mencionadas se plantea el diseño de una máquina dobladora de anillos de dimensiones aptas para mover en construcciones no tan grandes y que además satisfaga la demanda actual de la construcción. El principio de funcionamiento del prototipo propuesto es muy similar a los antes mencionados, la diferencia radica en que para deformar el material utiliza una palanca con un balero, esto es para darle una mejor forma al alambrón aunque continua siendo un proceso bastante lento. El presente documento contiene el diseño y construcción de una máquina dobladora de anillos útil en la construcción de edificios, se incluye las recomendaciones y conclusiones basadas en la validación del prototipo.

Prototipo, Validación, Dobladora

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Introduction

The decorative works with iron have been used since the Iron Age, the main technique was the forge. This technique consists in the heating of the pieces and their shaping with hammer blows, it was widely used to build doors, rails, balconies, furniture and ornamental objects, where you can distinguish twisted bars, spirals, rings, pineapples, shells and other figures.

During the middle ages the demand for weapons and iron armor increased due to the continuous wars, so much so that specialists began to emerge that achieved greater precision and quality.

With the industrial revolution the occupation of smith, was forced to change his work system, where the priority was serial production. However, until 2018 some craftsmen still subsist.

As part of the construction activities, is the manufacturing that is made to the rod and rod, the process is called torsion and involves twisting circularly to the profiles, plates or wire rod.

The above is done to form the castles that will be the support of the construction, figure 1 shows some types of castles or arms that are manufactured, to achieve the arillo that holds the rods, the wire rod is folded.

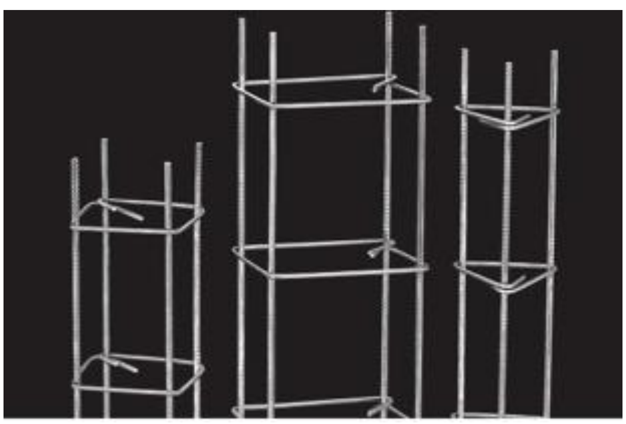

Figure 1 Castles or armes used in construction

For the manufacture of armes there are construction work tools that are very useful. In the market is a significant sum of manual machines for the realization of the bend of rods, the drawback of these machines is the time that is used in the realization of the fold due to the need to employ the labor force in this process.

The prototype presented in this document decreases: the range of error generated by the operator and the time used in the development of a bend of the rod; facilitates machine handling and increases worker productivity.

Methodology

As part of the first stage, the properties of the materials and how they can be affected were investigated. The chemical properties of the metal are modified due to the addition of various chemical elements, while the physical properties are affected by external forces such as heat, density, conductivity or melting temperature. Finally the mechanical properties tend to change due to the rolling, forming, stretching, bending, welding and machining of the material.

Fundamentals of metal bending

In figure 2 it can be seen that the bending of metals is a process that occurs when applying to a straight surface metal forces greater than the elastic limit or point of cadence, in a direction different from the neutral axis of the material, thus achieving a deformation permanent plastic curve (Doyle, 1980).

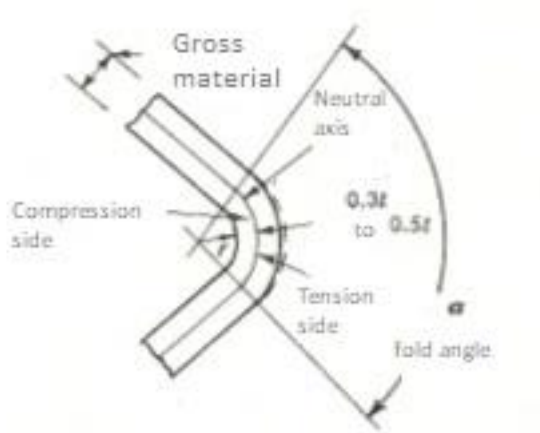

Figure 2 Nature of a metal fold

It is important to emphasize that when a metal is applied to effort beyond the elastic limit, it is able to manifest a certain amount of elastic recovery; therefore when it is doubled there is a possibility that it will return between 2° and 4°.

The bending process must be done at room temperature, avoiding heating the material, because when the temperature increases, the internal structure of the element is affected, crystallizing it, which causes a decrease in the mechanical strength of the element.

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On the other hand bending the cold metal causes that as the work increases more force is required and the hardness of the material increases, however, special care must be taken not to exceed the breaking stress of the material because from this effort the metal breaks, see figure 3, (Hibbeler, 1997).

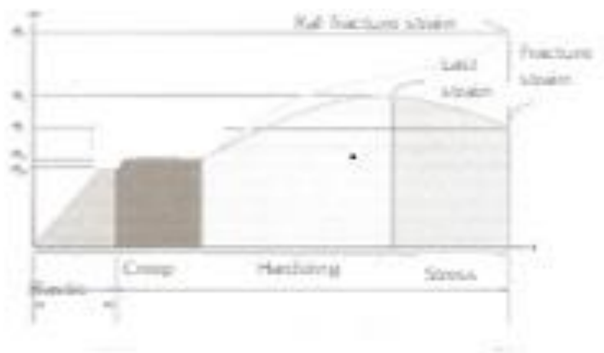

Figure 3 Unit strain deformation diagram for steel

Minimum bend radius

The quality of the curves obtained when bending a tube depends largely on the relationship between the outside diameter of the tube to bend, (Øe), and the radius of curvature obtained after bending the tube, (Rc). This relationship is known as the curvature factor (Fc).

$$Fc = \frac{Rc}{fe} \quad (1)$$

By means of the curvature factor, the minimum radius of curvature that can be given to the tube is determined in order that it does not present any achataduras, wrinkles or cracks.

Fc values between 1 and 2, indicate that the bend is of high difficulty, therefore it is necessary to heat the tube or use filler elements such as mandrels, resin, tar or dry sand to avoid quality defects.

The recommended value of the curvature factor is in a range of 2.5 to 3.5, in which the bend is considered simple.

Table 1 shows different pipe diameters, with their respective thicknesses and radii of curvature for a curvature factor 3.

Ø Nominal tube (in)	Ø Real Tube (mm)	Wall thickness (mm)	Minimum radius of curvature (mm)	Minimum radius of curvature (in)
0.5	20,63	2,5	61,9	2,4
0.75	25,05	2,5	75,2	3,0
1	**32,64**	**2,5**	**97,9**	**3,9**
1.25	42,16	2,5	126,5	5,0
1.5	48,26	2,5	144,8	5,7
2	59,24	2,5	177,7	7,0

Table 1 Minimum radius of curvature for different diameters and thicknesses with FC = 3

Bending techniques

In the second stage the different bending techniques are identified: bend by stretch, bend by tensile, bend by compression, bend in press, bend by rollers and roll extrusion.

Bent by stretching

The tube is clamped against a forming block or die that rotates and pulls the metal against the bend. The work piece that enters the bender is supported by a pressure bar. This method is widely used for working with thin-walled tubes and for small bend radii (Doyle, 1980). This process is shown in figure 4.

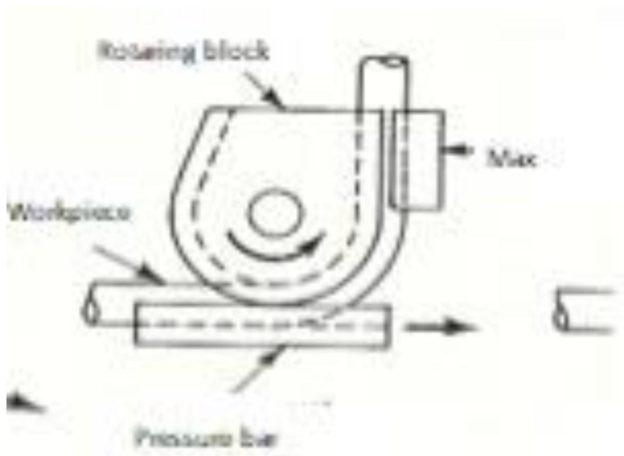

Figure 4 Bent by stretching

The maximum radius of curvature using this method is 180 degrees.

Bent to traction

Traction is exerted from both ends of the tube, while bending over a forming block, this technique is limited to large radius bends but is appropriate for curves that are not circular (Doyle, 1990). Figure 5 shows a diagram of the tensile bending.

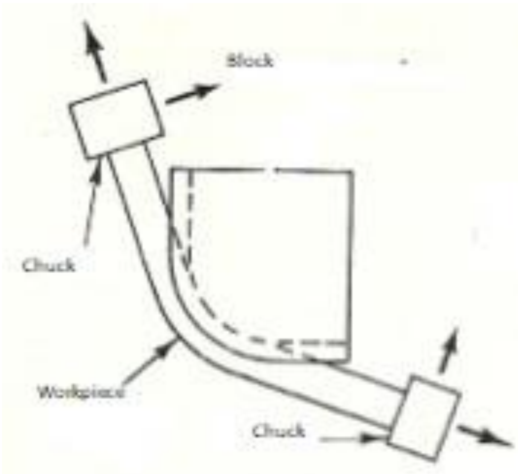

Figure 5 Bent to traction

Bent by compression

The working tube is fixed with a clamp and forced to wrap around a fixed forming die using a sliding clamp. This technique allows to make series of folds that almost do not leave free spaces between them, see figure 6 (Doyle, 1980).

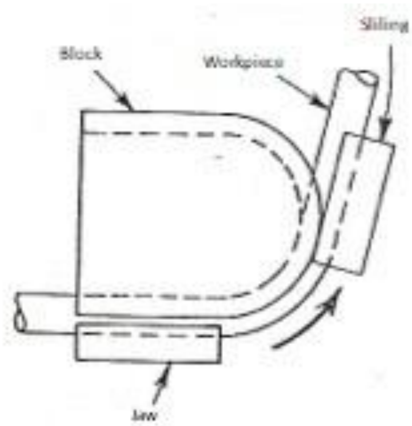

Figure 4 Bent by compression

Figure 5 Double in press or by pure flex

Figure 7 shows bending in press or pure bending. A curve is created by pressing a forming die on the tube in one movement. The tube is supported by a pair of separate dice, which rotate as the former moves toward the center by pushing the tube.

This movement wraps the tube around the former, allowing the end dies to support the tube on each side. This process is very fast and is excellent for high productions. However, the dice or their distribution must be changed to generate different varieties of curves. The maximum curve radius is 110 degrees. (DOUBATUBOS, 2008)

Bent by rollers

This technique uses three cylindrical dice to form the curve. This style of bending is typically used to develop large radius curves and to wind pipe (coils).

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Figure 6 Bent by rollers

Extrusion by rollers. A head with wide push rollers on one side and a narrow work roll on the other side is rotated inside the tube.

The tube is surrounded with work rings on the outside of the head. The work roll is moved in and out by means of cams while rotating the head in order to apply pressure to extrude metal into the pipe wall laterally, to force it to bend. As the material is worked, the tube is advanced through the head.

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This technique is mainly used to bend pipes larger than 5 inches (127 mm) in outside diameter and with thicknesses greater than 5/8 inch (15.8 mm). The outline of this process is shown in figure 9 (Doyle, 1980).

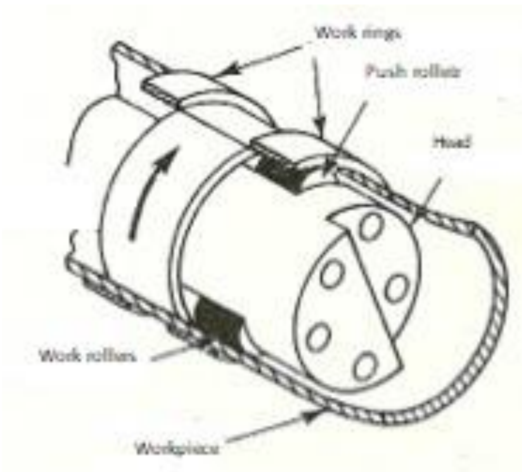

Figure 7 Roller extrusion

Benders available in the market

In the third stage some of the different bending machines available in the market are studied.

Manual benders

Figure 10 shows the Baileigh manual bending machine, has a unique die mechanism that allows you to easily bend when pulling a lever and with each movement delivers 10 degrees of curvature. It has the maximum capacity to bend 1-inch pipes - schedule 40, and 1-inch and 1-inch rectangular tubes. It is designed to bend round or square pipe, pipe, profiled angle in low carbon steel and solid rod (Fabricating Equipment Company, 2008).

Figure 8 Baileigh Bender Bender: RDB-100

The JD2 Model 3 Tubing Bender manual bending machine is shown in figure 11, accurately bends round and square tubes up to 180º, is easy to operate (Van Sant Enterprises, 2008).

Figure 9 Manual bender JD2 Model 3 Tubing Bender

Hydraulic benders

JD2 hydraulic bender model 4. The JD2 model 4 is a hydraulic machine that is easy to assemble and operate, with an anti-lock fuse that prevents the material from being returned. The dice changes are made in a fast way.

The bending capacity for round tube up to 2-½ inches (0.120 inches of wall), for square tube up to 1-½ inches and for pipes up to 2 inches - schedule 40 and 1-½ inches - schedule 8010, see figure 12 (Van Sant Enterprises, 2008).

Figure 10 Hydraulic bender JMR Air / Hydraulic Tube Bender

JMR hydraulic bending machine. The bending machine comes with dies available for 120º and 240º bends. It has aluminum and bronze bushings at the turning points, and its surface finish is black. It has been built for industrial work and is economic. It has a lifetime guarantee against dice breaks. Its round tube bending capacity is up to 2-½ inches, square tube up to 2 inches and pipe up to 2 inches - schedule 40. See figure 13.

Figure 11 Hydraulic bender JD2 model 4

Hydraulic bender Pro-Tools HB 302. The design of the machine is special to facilitate the change of the dice and tubes. It has been built to last for life. Its maximum capacity for pipes is ¾ of an inch. It has auto blocking to enable repetitive bends, see figure 14 (PRO-TOOLS, 2008).

Figure 12 Hydraulic bender Pro-tools HB 302 - 15 Ton

Hydraulic bender Huth Heavy Duty Tube & Pipe Bender. The machine is designed to bend heavy duty pipe, which uses industrial hydraulic cylinders. Folds round tube up to 3 inches, and has a maximum capacity for 2-inch pipe - schedule 80 and for square pipe up to 2 ½ inches. It has the option of auto parada13, see figure 15 (Van Sant Enterprises, 2008).

Figure 13 Hydraulic bender Huth Heavy Duty Tube & Pipe Bender

Once the mechanisms of the commercial benders were reviewed, the best practices of these mechanisms were identified. In stage 4, the design and construction of a manual bender prototype is presented (figure 16, 17 and 18), which allows to generate a curvature of 100 degrees, to bend rod and wire.

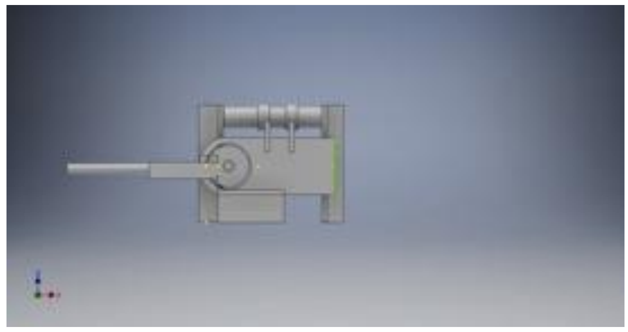

Figure 14

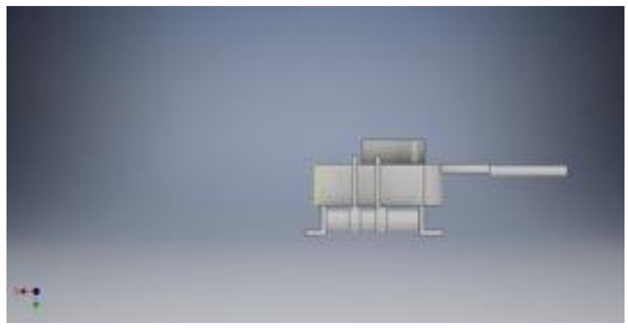

Figure 15

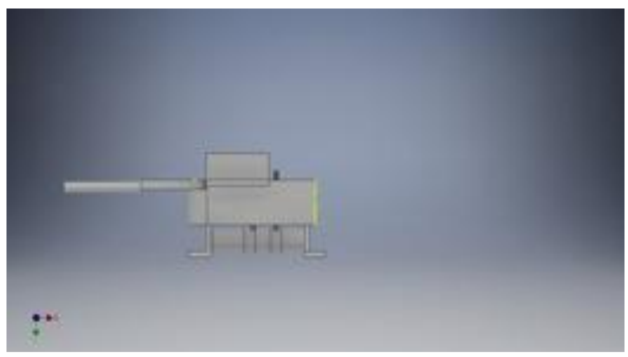

Figure 16

Figure 17 Finished prototype

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For the construction, 3 "PTR was occupied, a date of 1", rolling bearings, which will measure the ring, the production cost of the prototype is seven hundred Mexican pesos. Finally the prototype is validated, the variable object of study is the number of armed rings per minute.

Results

The study of the number of rings folded manually in a construction is made, the time of 3 different people is measured in equal conditions, to avoid factors outside the process affecting the result. Table 2 shows that in one minute approximately 0.97 rings are made manually, in order to validate the prototype the test is repeated but now occupying the bending machine and it takes a minute to make 2.03 rings (table 3).

Time (min)	Rings made manually (Piece)			
	1 Test	2 Test	3 Test	Average
1	1	2	1	1.33
2	2	3	3	2.67
3	4	5	4	4.33
4	6	7	6	6.33
5	7	8	8	7.67
6	9	10	9	9.33
7	11	12	11	11.33
8	12	14	12	12.67
9	13	15	13	13.67
10	15	17	15	15.67
12	16	18	16	16.67
14	17	21	17	18.33
16	18	22	18	19.33
18	19	23	19	20.33
20	21	25	21	22.33
22	22	26	22	23.33
24	24	27	24	25
26	26	29	26	27
28	27	30	27	28
30	28	31	28	29
Pieces made per minute				0.97

Table 2 Rings made manually

Time (min)	Rings made with the bending machine (Piece)			
	1 Test	2 Test	3 Test	Average
1	2	3	2	2.33
2	4	6	5	5
3	7	11	8	8.67
4	8	14	9	10.33
5	11	16	12	13
6	12	19	14	15
7	15	21	15	17
8	17	23	17	19
9	18	24	19	20.33
10	20	26	22	22.67
12	24	29	27	26.67
14	28	33	31	30.67
16	31	37	36	34.67
18	35	41	39	38.33
20	39	45	43	42.33
22	43	48	47	46
24	47	51	50	49.33
26	52	55	54	53.67
28	55	59	57	57
30	59	63	61	61
Pieces made per minute				2.03

Table 3 Rings made with the bending machine

Conclusions

The results show that the machine has the capacity to duplicate the manufacture of rings, besides being comfortable and easy to use as it compiles the best of existing bending machines. Torsion of square rods mechanically means that operator safety is not affected by muscular exhaustion or injury.

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