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Design and Simulation A Automated Pipe Cold Rolling Machine

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ABSTRACT
In the past industry, the rolling of steel product details could be done by manual or semi-automatic machines, leading to time consuming and labor intensive work. large scale, but productivity and efficiency are not high. In Vietnam, there are also many different types of corrugated iron rolling machines, but most of them are imported from abroad, so the price of the machine is very high. The production of such products in the country will contribute to the ability to improve the competitive position of domestic production compared to the world market. Simulation research is an extremely important step in the product manufacturing process, and this is very important for the production of complex mechanical systems. Stemming from that actual need, the team researched, designed and simulated the operation of automatic steel rolling machines with the product being motorcycles. Currently, the research team has come up with 2D machine design, 3D overall drawing and operation simulation of automatic pipe rolling machine. Although there were many errors in the research process, the team tried to fix them to ensure the best operation of the machine.
Keywords: *Design, simulation, rolling machined, automated.*

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I. INTRODUTION

Production automation (automatic production line) is the application of high technology to production. In which the stages are performed completely automatically or with very little human intervention. Playing a key role in the automation process are automated machines and automated robots. With that practical need, the automatic pipe rolling machine has shown its preeminent ability [1]. In the application of automation technology in production and many improvements compared to traditional manual methods and previous generations of machines, such as [2]: Production time has been shortened since then; increased productivity and high quality of products; Reduce labor and human intervention in production; Reduce the cost of the machine, increase the competitiveness in the market; The system operates automatically; Convenient for moving machinery.

During the rolling process, a large amount of heat generated in roll rolling is transferred to the working rolls and strips [3]. The working rolls are cooled by means of cooling on both the inlet and outlet sides of the mill. The transient cooling behavior of the coil affects the temperature distribution and thermal profile. Band distortion is caused by a number of factors; where we cite the uneven distribution of fluid flow along the coils [4]. The direct consequence of this phenomenon is that the temperature profile is not uniform, causing expansion of the work roll at various points. One of the effects of this expansion is the banding disturbance at the exit of the roller [5-7].To overcome this problem, we were forced to study the roll behavior affected by the temperature distribution and the thermal figure profile. The figure quality of the cold rolled strips is very important. Temperature lamination is also used to improve the surface quality of the strip and the quality characteristics of the product [8-10]. In order to optimize the properties of cold rolled steel, the deformation of each product needs to be strictly controlled. Therefore, control of the cooling head system is essential [11].

Stemming from practical production requirements, the research team has researched, designed and manufactured automatic pipe rolling machines for stainless steel. This machine is designed to minimize human involvement in the production process, all stages from billet feeding, pipe rolling and product delivery are performed automatically. Workers only need to put the workpiece into the feeder, press the button to operate the machine and the product will be completed. The project expects the project to learn, research, and manufacture automatic pipe rolling machines from the structures and components available in the country to reduce product costs and be suitable for the domestic production scale. This paper describes some basic theories of cold rolling and analyzes the temperature field occurring during cold rolling. The stages of machine design are described in detail. The machine model is simulated in 3D. These results will help analyze the characteristics of the cold rolling process, and thereby contribute to improving the productivity and quality of rolled products.

II. THEORY AND THEORETICAL CALCULATIONS

2.1. Theory of cold rolling

a. Minimum allowable radius for bending

- The minimum allowable bending radius is the value of the limit bend radius that can be bent for a given material.

- When bending the metal fibers, the outer surface of the workpiece is stretched and stretched if the bending radius is too small, it will cause the outermost metal layer to be stretched and possibly broken. Therefore, it is necessary to determine the minimum allowable radius when bending to avoid the phenomenon of metal fracture in the outermost layer. This radius value is consistent with the ductility of each material. Determined on the limit of deformation of the outermost metal layer [12]:

+ When the degree of distortion is small:

$$r_{min} = \frac{s}{2.\varepsilon_{max}} - \frac{s}{2} \qquad (1)$$

+ When the degree of distortion is high:

$$r_{min} = \frac{\varepsilon + 2.\Psi_{max} - 2}{2.(1 - \Psi_{max}) - \xi} . \xi. s \qquad (2)$$

In there : Ψ_{max} : Maximum allowable shrinkage of the cross-section of the material when pulled.
S: Bending workpiece thickness, mm.
ε : The coefficient depends on the type of material.

b. Determine the length of the workpiece

- Determine the length of the workpiece to ensure that the part after bending is right [12]:
+ Determine the position of the neutral layer, the length of the neutral layer in the deformation area.
+ Divide the structure of the bending part into simple curved and straight segments.
+ Add the length of the segments together, the length of the straight segments according to the detailed drawings, the curved part is calculated according to the length of the neutral layer.
- With billet plate [12]:
+ The length of the intermediate layer of the curved segment is determined by the following formula:

$$L = \frac{\Pi \cdot \varphi}{180} . (r + x.S) \approx 0{,}017. (r + x.S) \qquad (3)$$

When $\varphi = 90^0$ then we have:

$$L = \frac{\Pi}{2} . (r + x.S) = 1{,}57. (r + x.S) \qquad (4)$$

In there: φ: angle of the bend.
x: coefficient determined from the position of the neutral layer.

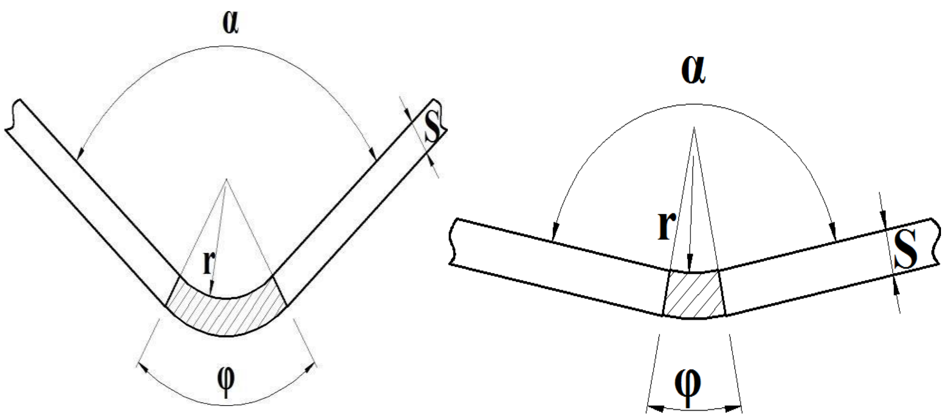

Figure 1. Relationship between bending angle and section to be bent

When $\varphi = 90^0$ the angle of the new bend is equal to the inside bend, remaining in all cases $\varphi = 180^0 - \alpha$. Where α is the bending angle as shown in Figure above.

2.2. Thermal profile distribution in cold rolling system

For cold rolled model with R is the radius of the roll rotating, and considering the following as sumptions [13]: Long cylinder; that is, temperature variation along the axial direction is neglected; Uniform thermal and mechanical properties of the roll material; Steady-state temperature; Rotational speed is constant; Uniform heat flux distribution at the interface. The whole model consists of two elements, predicting at the beginning of rolling the temperature distribution within the work roll and then converting this to the work roll radial expansion. The heat transfer model is given by [13]:

$$\frac{\partial T}{\partial t} = \alpha.\Delta T + \frac{\theta_I}{\rho C \pi r} q - \frac{\theta_{II}}{\rho C \pi r} h_{II}(T - T_{II}) - h_{IV}(T - T_{IV}) \quad (5)$$

with ΔT is the Laplacien of T.

III. RESULTS AND DISCUSSION

3.1. The heat transfer along a cold rolling system

Table 1: Parameters of billet plate (steel C45)

Parameter	Valua	Unit
L(length)	400	mm
W(weight)	250	mm
S (thickness)	1,2	mm
σ_b (tensile)	610	Mpa
σ_c (yield strength)	360	Mpa
Hardness	23	HRC

Using Abaqus software to simulate the billet rolling process. The workpiece plate and 2 rollers are brought into the working environment with the correct size of the machine (Figure 2).

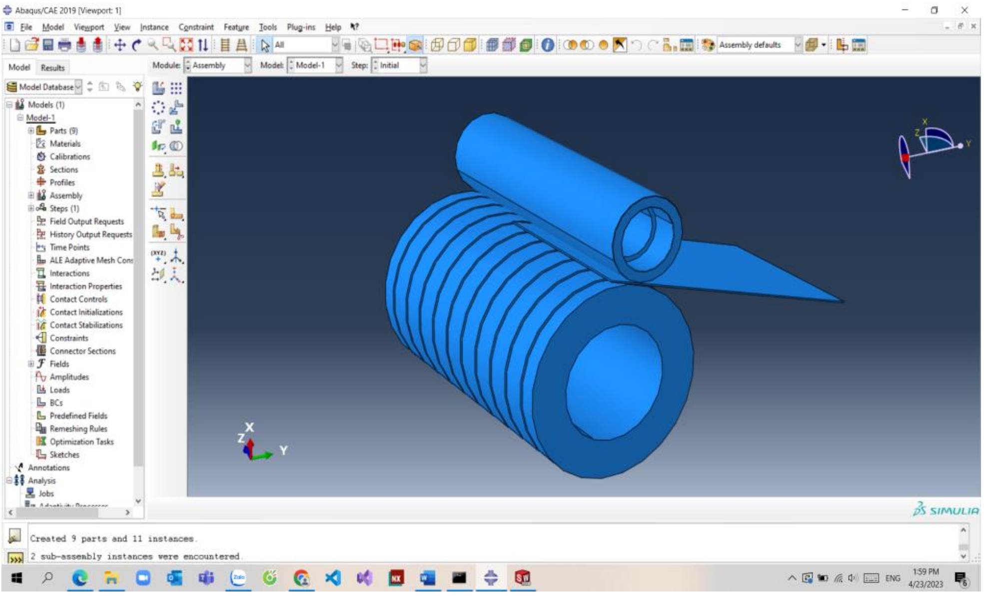

Figure 2. Work environment

The fixed roller and the plate blank are assigned C45 steel with mechanical properties selected as (Figure 3). The active roller is assigned PU plastic material.

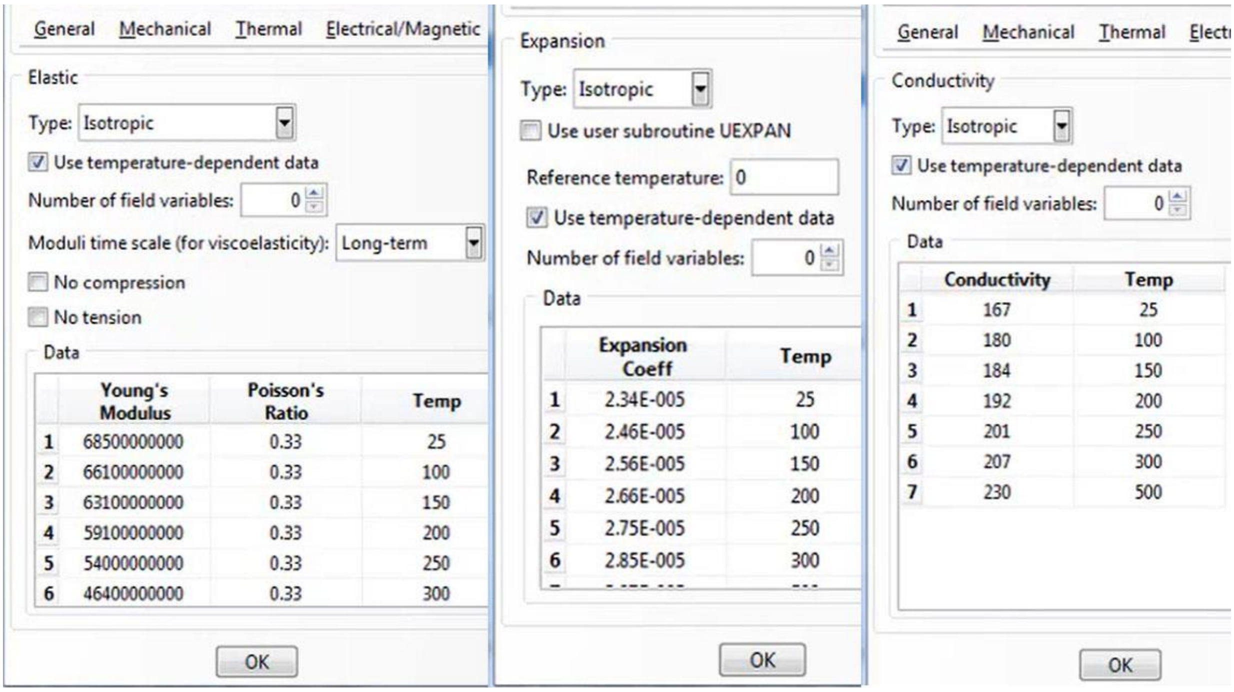

Figure 3. Choose material

The two rollers and the workpiece are coupled together and boundary conditions are set (Figure 4).

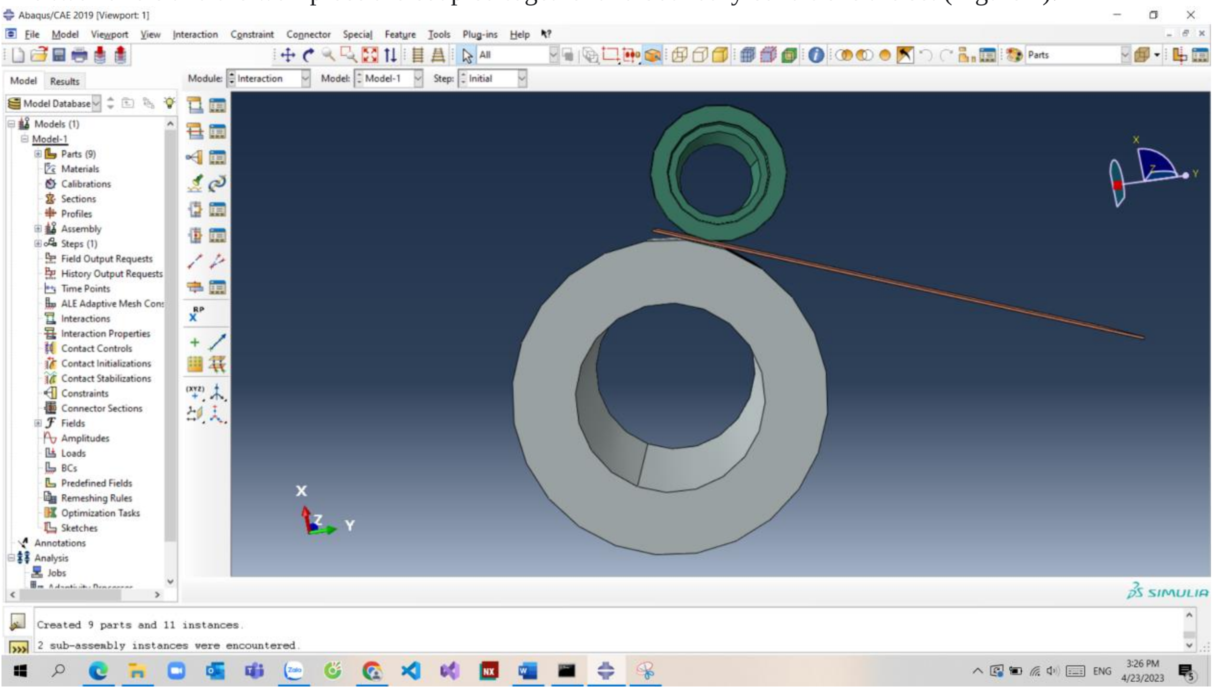

Figure 4. Assembly environment

After fixing the position and setting boundary conditions, we assign movements and apply forces to the roller assembly and the plate: the upper rigid roller will be fixed, the lower elastic roller will be pressed against the plate workpiece surface, the workpiece plate moves inward by the rotational force of the elastic roller, Figure 5.

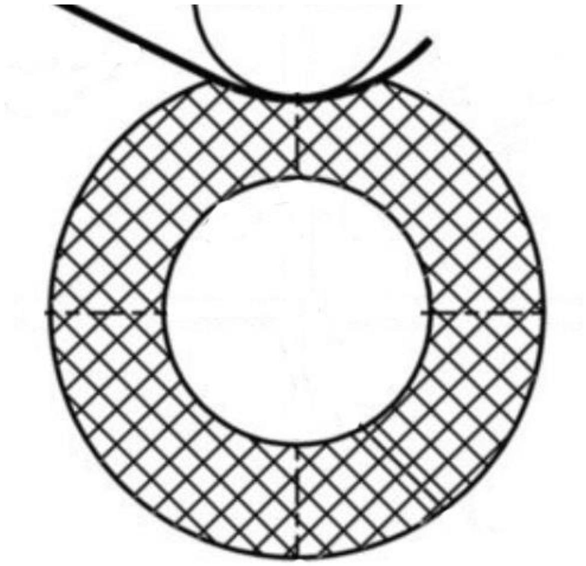

Figure 5. Billet during rolling

When the rigid roller is pressed against the elastic roller with certain stiffness and elasticity, the elastic roller deforms in the concave direction, and the material sheet loaded between the two rollers is bent by the reverse force of the deformation elastic material to control elasticity.

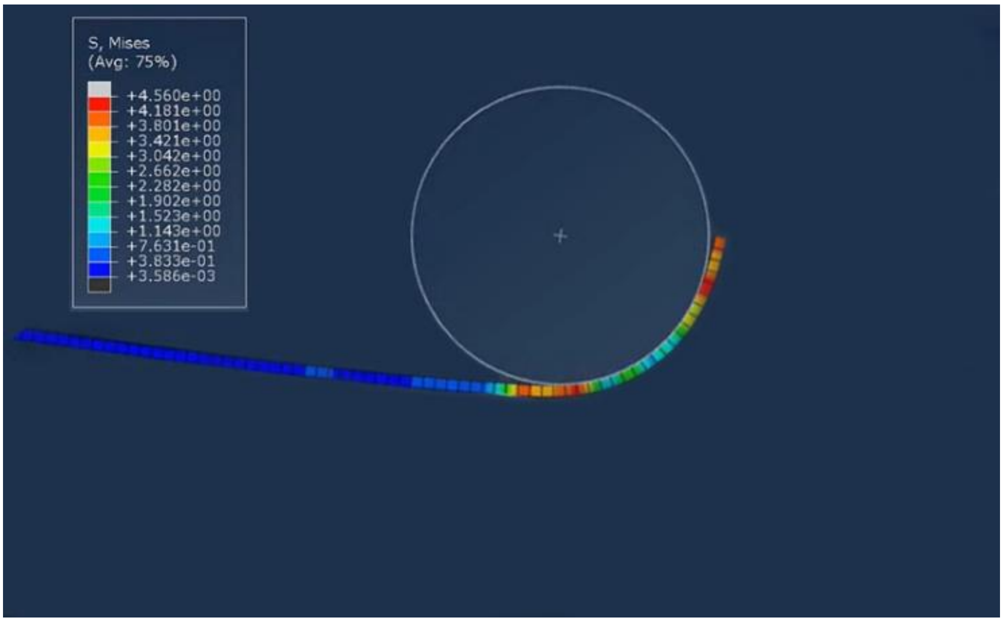

Figure 6. Workpiece deformation field during rolling

When putting the workpiece into the rolling pin, the active roller (made of PU plastic) will tend to go up, creating an elastic force acting on the workpiece, causing the workpiece to curve up and be rolled according to the Figure of a fixed roller (made of steel C45). According to the analysis, the plate workpiece deformed the most in the area of contact with the fixed roller (Figure 6).

In addition to the operation simulation during rolling, we can also use the tool to check the deformation stress of the sheet billet and find out the strength limit for the workpiece during rolling.

Choose any point on the billet that is in the process of rolling, set the time interval for each calculation to be 0.2s, we get the stress-strain graph (Figure 7):

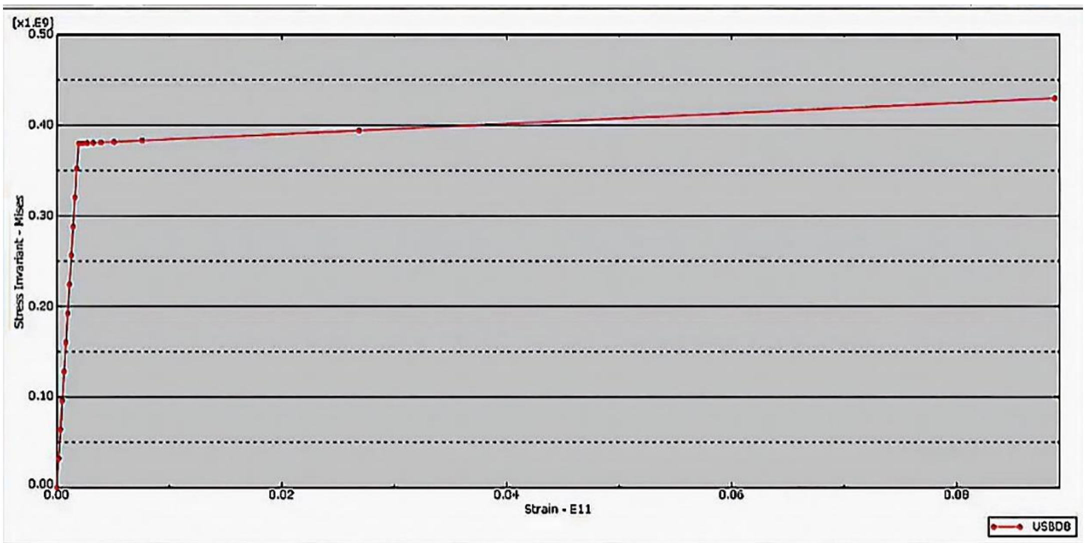

Figure 7. Stress graph deformation

The von Mises (standard) stress (Figure 6) is also known as the "maximum distortion energy criterion" of the octahedral cubic shear stress principle, or the Maxwell-Huber-Vonmises stress principle- Hencky is often used to calculate and evaluate deflections with ductile materials. The Von mises criterion tells us: The failure of the material will occur when the distortion energy reaches the corresponding energy value of the yield stress of the material.

According to the analysis of (Figure 7) from Top and Bot VonMise results, the maximum VonMise stress is 45.60 MPa (Column stress all values are positive). Comparing the VonMise stress value with the yield stress of 360 Mpa material (table 1), the structure of the workpiece is not deformed.

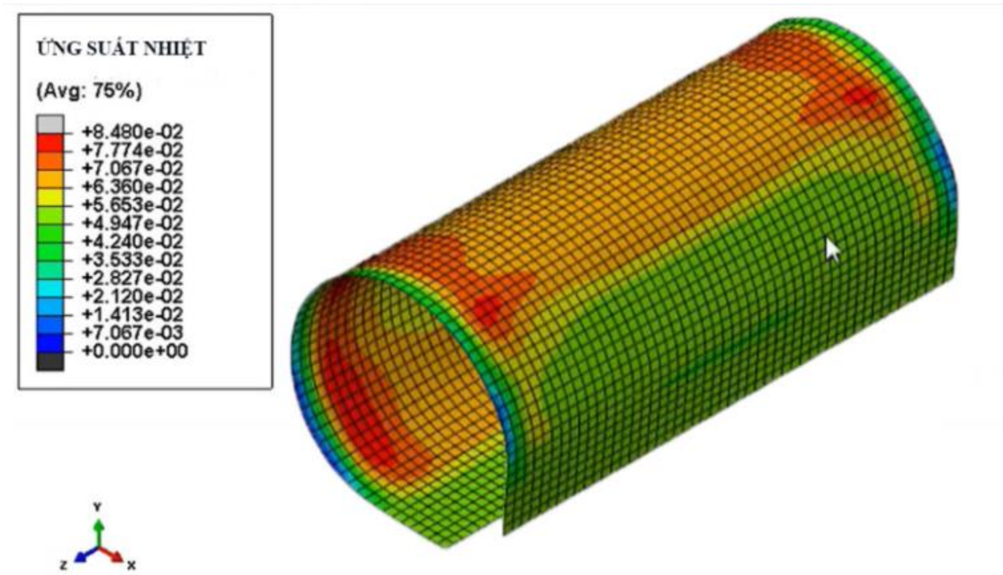

Figure 8. Thermal stress diagram when rolling

According to the analysis results, we see that the stress in the steel plate at the first time after rolling is mainly tensile stress, compressive stress appears mainly at the two ends of the steel plate, Figure 8. This can be explained by the fact that during this time period is the steel plate heating period, when the inner steel part tends to increase in temperature because it is the middle part that bears the most rolling force and it has a large variable amplitude, so the stress arising mainly in the block is tensile stress. Meanwhile, at the two ends of the steel plate, the deformation amplitude is small and tends to shrink due to being pushed out by the inner metal layers, so the compressive stress of the steel plate is generated at these positions.

3.2. 3D model of Automated pipe cold rolling machine

The automatic rolling production process consists of 3 main machine clusters, each of which takes on a different task, Figure 9-10. Designed to be flexible, closely linked to ensure synchronous operation of the machine and load equipment, in accordance with the process, limiting energy loss due to operation. The part is divided into 3 parts as shown in Figure 9, and the authors have selected part 2 of the product to design the rolling machined.

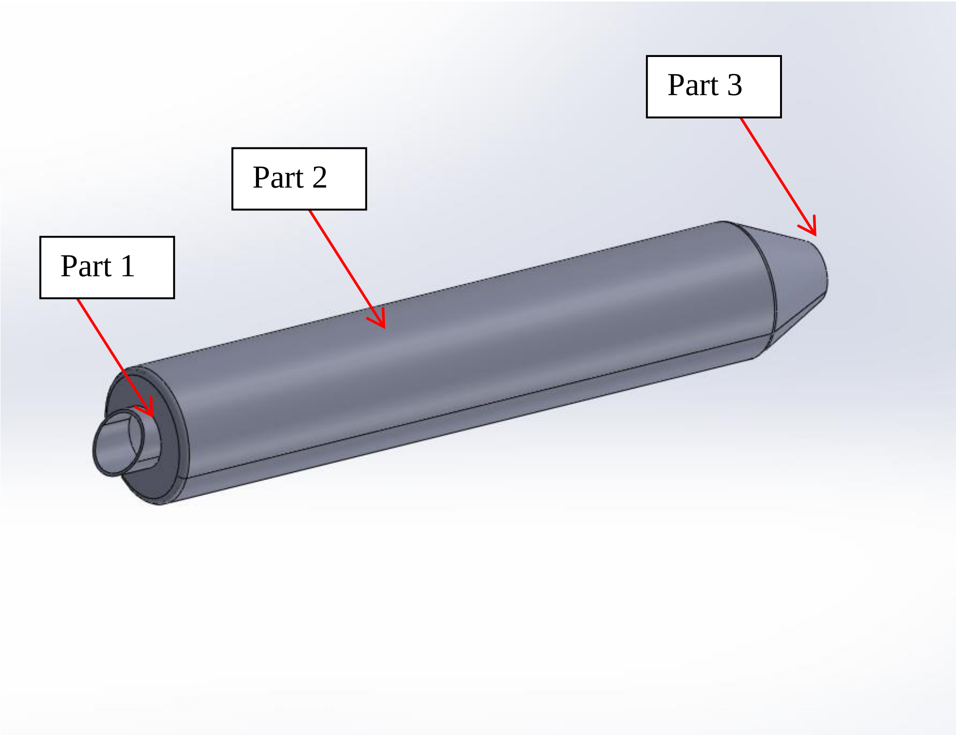

Figure 9. Real product 3D drawing

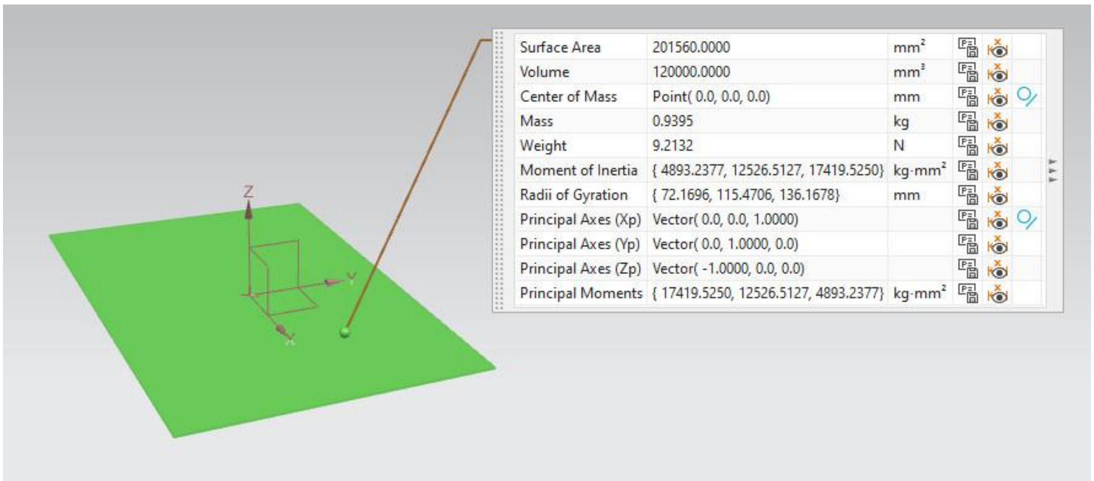

Figure 10. Workpiece specifications

Billet material: Steel C45
Thickness of workpiece S = 1.2 mm
Length a = 400 mm, width b = 250 mm.
Machine diagram design: the machine consists of 3 main assemblies including billet feeding assembly, billet bending unit and billet ejector assembly after bending, Figure 11-12. Each moving cluster has different options:

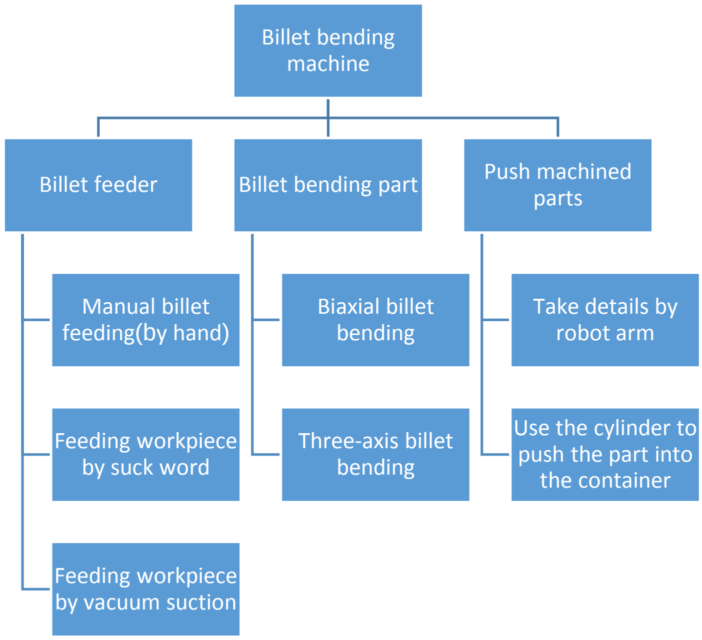

Figure 11. Machine design diagram

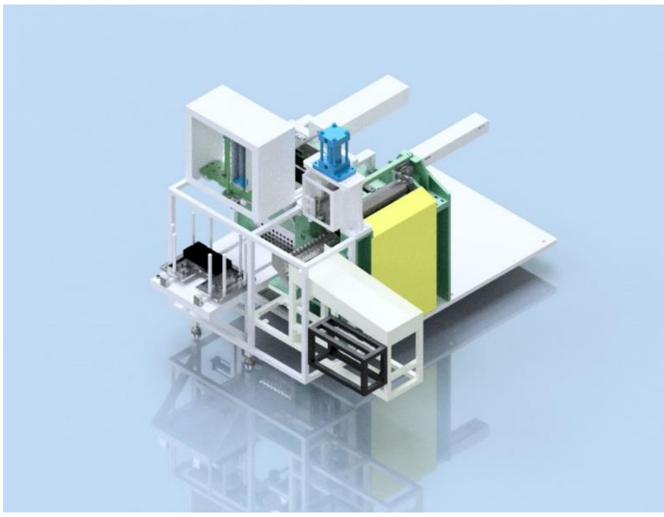

Figure 12. Overview model of automatic pipe rolling machine

Billet Feeder Parts: Using the workpiece suction unit is a vacuum suction cup, simple structure, low cost, easy to repair and replace when there is a problem, Figure 13.

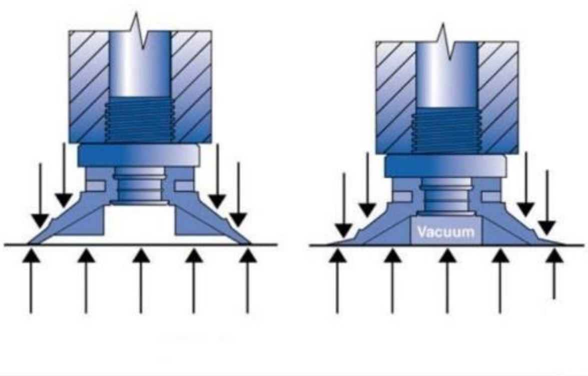

Figure 13. The operating mechanism of the vacuum cup is based on pressure and vacuum force

By pressing a suction knob on any surface, the air inside of the knob is pushed out, Figure 14. The inside of the knob is suppressed by a pressure of 101.3 Kpa (atmospheric pressure), forming a vacuum space. However, there is still a certain pressure on the outside of this rubber knob, causing a pressure difference between the inside and outside of the knob. This makes the knob suck and stick more firmly to the surface.

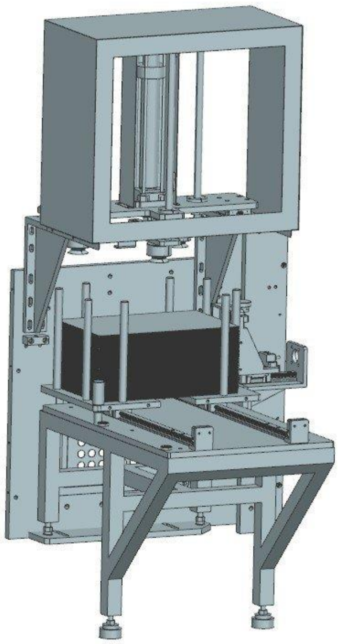

Figure 14. Automatic bar feeder

Billet rolling parts: This is the main part of the whole machine that is responsible for changing the figure of the original workpiece, Figure 15. Turn flat-shaped corrugated sheet into tubular form. Use the two-axis workpiece rolling direction.

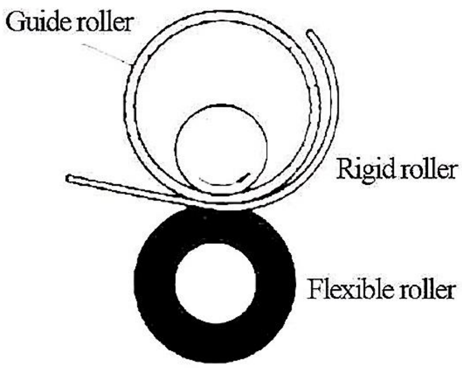

Figure 15. Two-axis rolling diagram

The two-roller sheet winding machine consists of a rigid roller and an elastic roller, Figure 16. When the rigid roller is pressed against the elastic roller with the most stable stiffness and elasticity, the elastic roller deforms in the convex direction, and the material sheet loaded between the two rollers is rotated by the force of the reverse deformation. elastic material to elastic control. Roller, to achieve continuous rolling of the plate.

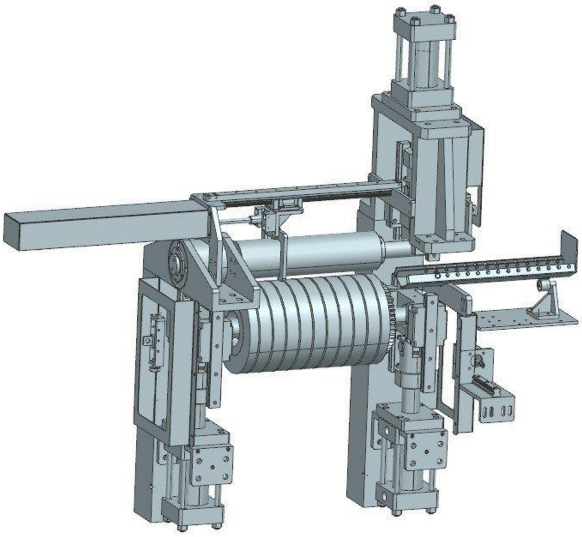

Figure 16. Billet rolling parts

Machine part push the work piece: Use the cylinder to push the part into the container, Figure 17.
Working principle: When air is compressed into the cylinder through the piston head and thus takes up space inside the cylinder and causes the piston to move, the cylinder slides in the axial direction to push the part.

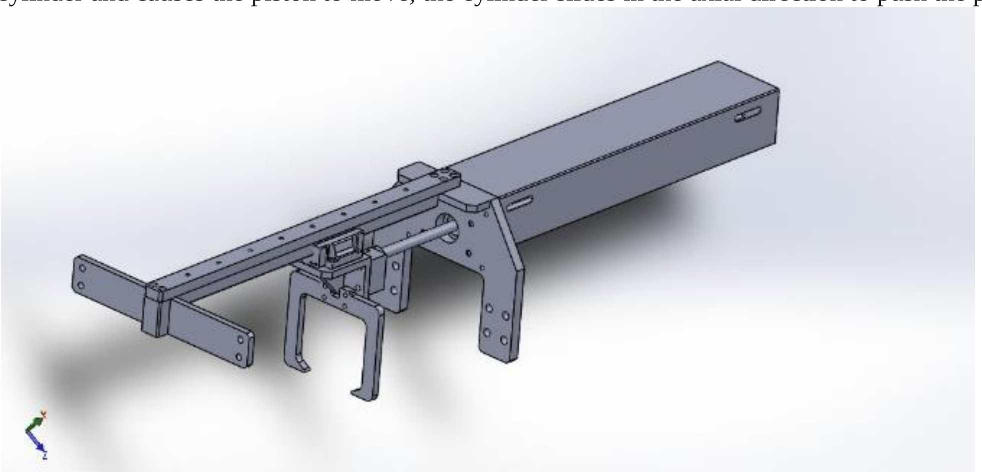

Figure 17. Machine part push the work piece

IV. CONCLUSION AND SUGGESTIONS

Through this study, the authors came to the following conclusions:
- Better understand the knowledge related to plastic deformation processing and rolling process.
- Analyze the heat change during cold rolling process, this helps to adjust the process technology parameters. It contributes to improving the quality of rolled products.
- Propose possible solutions in the process of calculation, detailed design, argument to get the optimal plan.
- Improve the function and use of the machine in the working process.
- Provide a simulation of the machine's operation, thereby bringing the design closer to reality.

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