



SPIRAL STEEL PIPES FORMING

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ABSTRACT

Forming spiral steel pipes with roll bending is metal forming process which sheet metal become tube, cylinder and others. To get certain curvature radius and efficient phase roll bending is hence needed by a good planning and as accurately as in order to get the product which with quality. Roll bending planning that is roll diameter 164 mm, two roll of under diameter 150 mm of second roll distance of under 203 mm, and upright 159 mm hence can be searched of curvature with decrease upper roll Δh . To get certain curvature radius, used the formula relation its is roll for with curvature radius that happened. The formula result for the curvature radius equal to 2,585.5 mm needed of step roll bending 4 times, that is decrease upper roll Δh in mm respectively is 15; 30; 45 and 70. Bending radius in mm is 12,366.69 ; 6,099.59; 4,045.5; and 2,585.5. Bending force in kg respectively is 1,831.58; 6,836.27; 17,400.58; and 41, 890., 87. From four times of roll bending process, the bending power is 2013, 64 kW.

Keyword: spiral pipes, roll bending, reduction, curvature radius, bending force.

1. INTRODUCTION

The spiral pipe is produced from steel plate that rolled like spiral spring then united by welding. At the production process has many stage of forming until finishing. The steel spiral pipe used to Surabaya-Madura bridge that produced more than regular production. The spiral pipe is designed especially for heavy load so it is important to pay attention highly about strength of material.

At steel spiral pipe production has important stage that influenced to production result. The most influence stage is metal forming that caused metal properties. The important stage at metal forming process is loaded from external load that used to form metal until plastic deformation so that depended formability metal. The parameter process is forces that loaded at metal forming process and needed power to process done. The steel spiral pipe produce used steel type SS 410 with different stage forming process. The forming processes are: uncoiling, edge cutting, scalp, welding, forming, cutting off, Hydrostatic Test, Finishing (by Coating).

2. LITERATURE REVIEW

The spiral steel production use rolling process that do by roll forming machine that more precisely than manual process because the machine operated semi automatic. The precise production result is depended effectiveness machine design and processing control for production process [1] that seen at curve frame pipe rolling. The influenced parameter to pipe rolling result is radius roll [2]. The radius at test process did at 500, 1000, 2000 and 3000 mm. The test result can be concluded higher radius diameter that makes bend strength until special size. When level size passing that caused material become yield that make hardness and bend strength decrease. The other phenomenon rising on forming roll at pipe production process is spring back [3]. By stress analysis simulation result with FEM is showed spring back phenomenon that test at different thickness and material type. The roll bending parameter can give different effect

to force and power [4] that test at shaft diameter 2.6, 3.3, 3.6 cm. The material yield strength must be considered that influence the pipe rolling result [5]. The pipe result with best quality is needed when planning machine design for steel pipe forming that tested at pipe with thickness 18 to 28 mm.

2.1 Cold metal forming

The cold metal forming is formed metal at recrystallization temperature that did at room temperature. The cold metal forming can cause strain hardening at metal that can raise hardness metal and metal become fracture? That phenomenon is showed decrease mechanical properties at metal and cause metal damage.

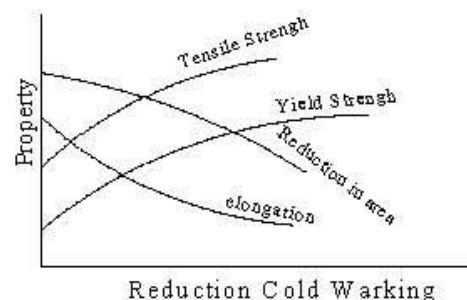


Figure-1. The mechanical properties changed caused by cold metal forming.

3. MATERIAL MECHANICAL PROPERTIES

A. Yield strength

The yield strength is tension that needed for produce a little constant plastics deformation.

B. Ductility

The ductility is mechanical properties ability that can get load without fracture. The ductility gauged by conscionably from tensile test that used ϵ_f be strain at fracture stage (engineering strain). The formula is used defined engineering strain showed follow [8].



$$e_f = \frac{L_f - L_0}{L_0} \times 100\%$$

$$q = \frac{A_0 - A_f}{A_0}$$

C. Rolling process

The rolling process is used be first step to change ingot and billet become final product. The profile form is be a kind of hot roll product and sheet, palter and strip is a kind the other product of cold working. The rolling process is did by pressing base metal with 2 roll that circulating move on different direction. The schematic rolling process is showed Figure-2.

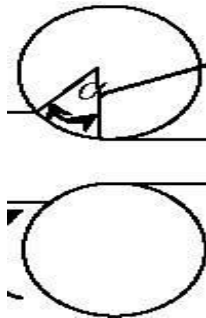


Figure-2. The rolling process.

The roll forming is only change two dimensional. That could be one stuck area (angle of bite) that berasio of T and t. The angle of bite (α) may not high because roll can work and make fracture on metal surface but if small its can profit economically. The roll pressure variance can show as function of angle position between two roll gaps.

D. Rolling forming

- Outside from neutral point [6] : $\frac{P^+}{S} = \left(1 - \frac{t_a}{s_a}\right) \frac{h}{h_a} e \mu H$
- Entrance side(before neutral point): $H = 2 \sqrt{\frac{R'}{h_a}} \tan^{-1} \sqrt{\frac{R'}{h_a}} \alpha$

$$\text{with } R' = R \left(1 + \frac{c}{\Delta h} \frac{P}{w}\right)$$

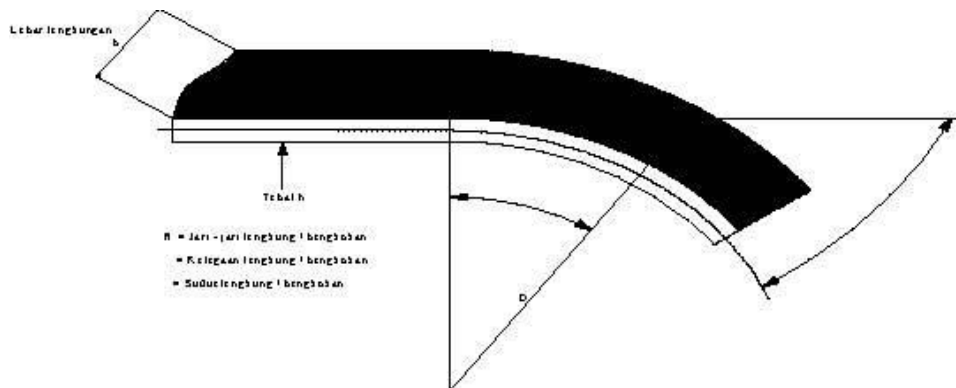


Figure-3. Definition of bending process with dimensional characteristics.

$$= R' d\alpha \left(1 - \frac{\alpha^2}{2}\right)$$

If $\alpha \leq 0.1$ radian (6°)

$\frac{1}{2} \alpha^2 \leq 0.005$ can be negligible

$$\text{So: } P dx = p R' d$$

$$\text{The roll force per width unit from strip [9]: } \frac{P}{w} = \int_0^{\alpha} p R' d\alpha$$

Assumed R' constant at contact area for process: $\frac{P}{w} = R' \int_0^{\alpha} p d\alpha = R' \int_0^{\alpha} P^+ d\alpha + R' \int_{\alpha}^{\alpha} P^- d\alpha = R' x$ (curve area is rolled)

F. Torsion

At torsion deformation area is produced from circular curve force. (friction force) multiply by curve distance toward roll center.

$$\text{Curve circular force per width unit: } \frac{\mu P}{w} = \mu R' \int_{\alpha}^{\alpha} P^- d\alpha - \mu R' \int_0^{\alpha} P^+ d\alpha$$

$$\text{Torsion per-width unit: } \frac{T}{w} \mu R. R' \left(\int_{\alpha}^{\alpha} P^- d\alpha - \int_0^{\alpha} P^+ d\alpha \right)$$

Where $R' - R$ very small, so $R' \approx R$ be area destination be difficult because R' dan R almost equal.

The different way to define torsion is,

G. Power

For machine with 2 roll and 4:

$$\text{Power Total: } 2W_R + 4W_N = 2T\theta + \mu_n P d\theta$$

$$\text{Motor Power: } W_M = \frac{1}{\eta_m \eta_t} (2T + \mu_n P d) \dot{\theta}$$

$$\text{The simple calculating to find rolling force is } \frac{P}{w} = K \sqrt{R \Delta h} Q$$

Where:

K = Yield strength average (atau S)

Q = Factor can find from sims function at table/chart.

H. Bending process

the bending is a process that change straight form become curve. As generally bending form is showed at Figure-3.



Where

- R = a half curve radius (mm)
b = bending width (mm)
h = thickness (mm)
 α = angle curve (degree)

The minimum a half radius can be indicated of metal ability to be curve without fracture as $R = 3 \times \text{tebal plat}$. As generally radius for high strength sheet alloys is $R_{min} \geq 5$ times material thickness. R_{min} can be defined more precise from face area reduction that find from tension test (q).

If the neutral center change is negligible so $\frac{R_{min}}{h} = \frac{1}{2q} - 1$ for $q < 0.2$

If neutral center is considered, so $\frac{R_{min}}{h} = \frac{(1-q)^2}{2q-q^2}$ for $q > 0.2$

I. Spring back

Springback is dimensional change at form after working load disappear that cause material can be *spring back* and curve angle radius become high that showed at Figure-4.

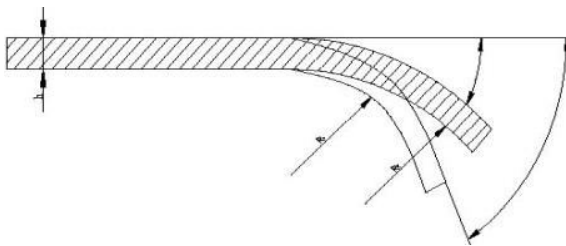


Figure-4. Spring back bending.

Then it can be defined empirically with equation

$$[10]: \frac{R_0}{R_f} = 4 \left(\frac{R_0 \sigma}{hE} \right)^3 - 3 \left(\frac{R_0 \sigma}{hE} \right) + 1$$

The needed force for bend length L can be counted with equation [7]: $P_b = \frac{\sigma_0 L h^2}{2(R + \frac{1}{2}h)} \tan \frac{1}{2}\alpha$

Where

- P_b = The Forming Force
 σ_0 = The yield strength
L = Bending gap
h = Metal thickness
R = Bending radius
 α = Bending angle

J. Methods

Steel Spiral Pipe Forming Process
Roll Bending Machine Specification:

Machine name Spirall Welded Pipe
Merk PIMSF
Model SPR 12706
Minimum material thickness: 3 mm
Maximum material thickness: 50 mm
Upper Diameter roll 164 mm
Lower Diameter roll bawah 150 mm
Roll width 1500 mm

Roll revolution 50 rpm
Motor Power 2500 KW

The stage material Straightened

The straightened material stage is used to get straight surface that process showed at Figure-5.

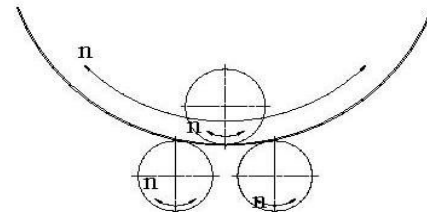


Figure-5. Rolling stage.

K. The bending roll stage

This stage has purpose to get curve form or roll bending radius. At steel spiral pipe forming process had been done by the following steps: the material flowing from uncoiler enter between upper roll and 2 lower roll that did to define straightened roll and plat and material flattening before roll process

The bending roll process I

After material surface flattened correctly, then material flow to first roll for first rolling process and upper roll lay down as 15 mm from neutral position then lower roll circulating move until curve reach average before material flow second roll.

The rolling process is started with lay down an upper roll then the second lower roll circulating move until material entering between 2 roll then become a curve.

The bending roll process II

If rolling process stage I completely then process continued to process II that the material flowing to rolling process III where upper roll lay down as 30 mm from neutral position. At this process like process I but radius roll used different.

The bending roll process III

The third roll lay down as 15 mm from second roll position position roll-2 and the process has a same as process I. The rolling process III as same as process II but radius settled as desired value.

The bending roll process IV

At The process IV, the roll is lay down as 25 mm and rolling radius almost closed a desired value.

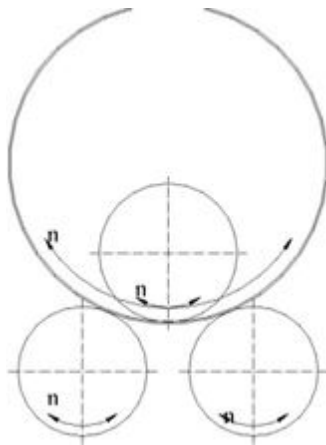


Figure-6. The bending rolling process.

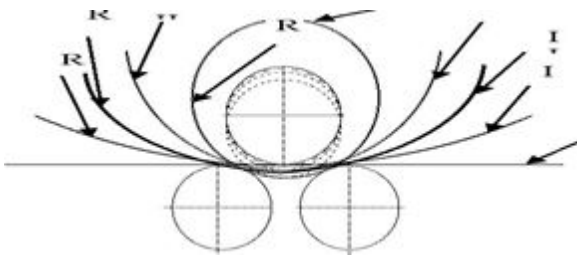


Figure-7. The bending roll process generally.

Where:

I = Stage I R I = Bending radius stage I
II = Stage II R II = Bending radius stage II
III = Stage III R III = Bending radius stage III
IV = Stage IV R IV = Bending radius stage IV

RESULT AND DISCUSSIONS

At Figure-8 is tensile test result that figure acceleration between strength and elongation. Ductile is defined by percentage face area decrease:

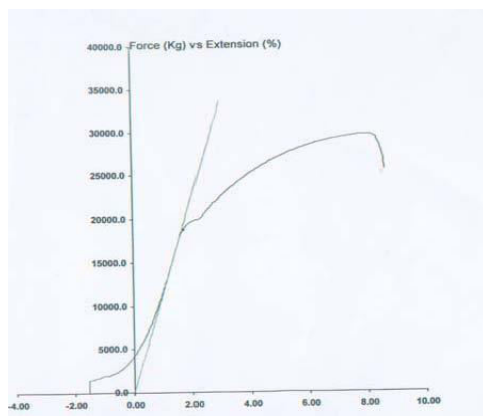


Figure-8. Tensile test chart.

where: $A_0 - A_1 = 550 - 486.7 = 63.3 \text{ mm}^2$

$$\frac{A_0 - A_1}{100\%} = 0.633\%$$

Table-1. The tensile test specimen result.

Test type	Test result
Tensile test:	
-elongation limit, kg/mm ²	35
-tensile strength, kg/mm ²	54
-strain, e, %	13

L. The curve radius

The curve radius at bending stage can define with empirical equation:

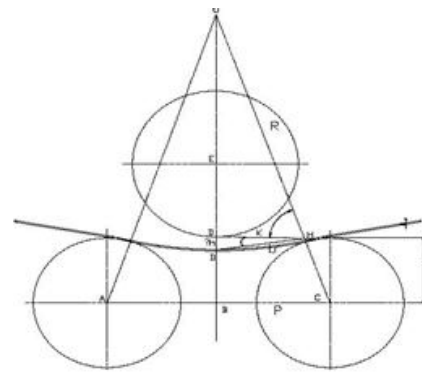


Figure-9. The correlation between upper roll with lower roll and curve radius that appear at process.

Where

O = Center point of pipe (pipe diameter)
R = Bending radius (curve radius)
E = The center of upper roll
H = Contact point material with lower roll
K = Contact length between roll and material
 θ = Roll lay down angle
 Δh = Roll lay down distance
h = Material thickness
L = Material length has formed
D = Center material curve
 α = Material formed angle
A = Center of lower roll II
P = A half track second lower roll
C = Center of lower roll III
B = Radius of track between upper roll and lower roll

With Pythagoras theorem: $R = \frac{p^2}{2\Delta h} + 0.5\Delta h - (r + h)$

where:

R = curve radius (mm)
 Δh = lay down upper roll height (mm)
P = half track 2 lower roll (mm)
r = radius of lower roll (mm)
h = tebal material (mm)

M. The roll position

The position of roll upper side and lower roll can find with gauges number direction on machine by moving



upper roll then it's calculated by formula: $R = \frac{P^2}{2\Delta h} + 0.5\Delta h - (r + h)$
constants K at spiral pipe forming with 2500 mm is
 $\frac{OD}{OB} = \frac{K}{BC}$

where: $OD = R - \Delta h = 2430 \text{ mm}$

$OB = OD = 2505 \text{ mm}$

$B = \sqrt{(R + h + r)^2 - OB^2} = 609.16 \text{ mm}$

So: $\frac{2430}{2505} = \frac{K}{609.16}$

$K = 590, 92 \text{ mm}$

for distance D' to H = b

$D'H^2 = \Delta h^2 + K^2 = 354086.45$

$D'H = 595.05 \text{ mm}$

to analysis at each lay down roll stage on spiral pipe forming follow:

stage I (lay down roll as 15 mm)

$\Delta h = 15 \text{ mm}$

$\theta = \sin^{-1} \left[\frac{\Delta h}{b} \right] = \sin^{-1} \left[\frac{15}{595.05} \right]$

$\theta = 1.4^\circ$

$R = \frac{371075.9}{30} + 7.5 - 100 = 12366.69 \text{ mm}$

the analogy upper ways can be count the other stage follow:

N. Roll bending loading stage analysis at bending roll process

At load process the roll lay down as 70 mm and flow on 4 stage lay down are stage I as 15 mm, stage II as 15 mm, stage III as 15 mm, and stage IV as 25 mm. then load count did by the following formula:

$$P_b = \frac{\sigma_0 \times L \times h^2}{2 \times \left(R + \frac{h}{2} \right)} \tan \frac{\theta}{2}$$

where

P_b = bending load (kg)

L = roll width (mm)

h = plate thickness (mm)

σ_0 = yield strength (kg/mm²)

R = plate forming radius (mm)

so, the load at roll bending process stage IV lay down as 15 mm, 15 mm, 15 mm and 25 mm) is follow

1. Bending roll load at stage I:

Where $L = 1500 \text{ mm}$

$$P_b = \frac{\sigma_0 \times L \times h^2}{2 \times \left(R + \frac{h}{2} \right)} \tan \frac{\theta}{2} = 1831.58 \text{ kg}$$

the analogy upper way can be used to count the other stage Power at bending roll analysis power at each rolling stage

can be count by equation: $N = \frac{2\pi K P n}{60,000}$

where:

N = power (kW)

K = contact length between roll and billah(meter)

P = Roll force (Newton)

n = roll rotation (rpm)

so, rolling power at each stage can be count by equation follow:

rolling power at stage I:

$$K = \frac{590.92 \text{ mm}}{1000 \text{ m}} = 0.591 \text{ m}$$

$$P \text{ I} = 1831, 58 \text{ kg} \times 9, 58 \text{ m/sec}^2 = 17546, 54 \text{ N}$$

$$P \text{ II} = 6836, 27 \text{ kg} \times 9, 58 \text{ m/sec}^2 = 65491, 46 \text{ N}$$

$$P \text{ III} = 17400, 58 \text{ kg} \times 9, 58 \text{ m/sec}^2 = 166697, 56 \text{ N}$$

$$P \text{ IV} = 41890, 87 \text{ kg} \times 9, 58 \text{ m/sec}^2$$

$$\text{so : } N = 54.27 \text{ KW}$$

3. CONCLUSIONS

Based on the above result for bending roll process at steel spiral pipe manufacture with material type low carbon steel type SS 410 with 10000 mm length, 25 mm thick and 1500 width is formed be spiral steel pipe with 2500 mm diameter, 25 mm thick and 1500 mm 33000 mm length that need 4 stage lay down roll as:

- Position I. Lay down roll as 15 mm can form roll radius 12366,69 mm, bending roll load be 1831,58 kg , power 54,27 kW.
- Lay down roll at 30 mm that can form radius roll as 6099,59 mm, load 6836,27 kg, and power 202,56 kW
- Lay down 45 mm at stage III form roll radius 4045,5 mm, load 17400,58 load 515,58 kW.
- Lay down 70 mm that form roll radius 2585,5 mm, load 41890,87 kg, power 1241,23 kW.

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