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Design and Manufacturing of Bottle Roller Machine for Laboratory Leaching Process by Using Recycled Materials

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ABSTRACT

Bottle roll is the equipment used for laboratory metal leaching tests. Leaching is a widely used metal extraction process by dissolving metal from ore using certain chemical reagents. The working principle of the bottle roll is to stir the bottle filled with a suspension sample and place it on rolls that rotate horizontally. In this research, the rotating rolls were driven by a recycled water pump electric motor which is transmitted using a pulley and belt. The research objective is to create a bottle roll machine that is practically easy and safe to carry out the leaching test or any other tests that involve agitation, especially for process engineering students. The performance validation of the equipment was done by conducting some leaching tests using the manufactured bottle roll to determine the consistency of the roll rotation, as leaching tests are generally done for a quite long period, usually 24 hours continuously. The sand sample was sieved into 100 mesh of particle size and then mixed with water to make a suspension. The suspensions were put into 2.5 liters of used glass chemical bottles and 1 liter HDPE plastic bottles with various diameters of 14 Cm, 12 Cm, and 8 Cm. The results showed that the machine could perform the leaching test at best in HDPE bottles with an average of 31 RPM of rotation speed tested for 24 hours.

Keywords: *Bottle roll, leaching test, agitation, hydrometallurgy*

1. INTRODUCTION

Leaching is an alternative metal extraction process with the principle of selective dissolving using specific chemical reagents [1]. Leaching is part of the hydrometallurgy process that becoming more popular in the past few years because of its ability to extract valuable metals from low-grade ore [2]. Several strategic metals such as gold, nickel, copper, and others can be extracted through the hydrometallurgical route by the leaching process [3–5].

The leaching process is generally carried out by stirring or known as agitation leaching. Based on the research done, stirring can significantly increase the metal dissolution rate [6–8]. In carrying out research in the laboratory, the effect of stirring in the leaching process can be obtained through mechanical stirring, magnetic stirring, and bottle rolls.

One of the advantages of bottle roll compared to other mixing methods is that the leaching process can be conducted at a larger volume of suspension and better time efficiency because several bottles can be leached at once. The working principle of bottle rolls is to place bottles containing slurry (a mixture of water and solid samples) or other suspensions on rollers that rotate on a horizontal axis for a specified time.

The laboratory leaching test is aimed to identify the leaching behavior and kinetics of a given ore prior to the scale-up plant [9]. The limitations of laboratory equipment are the background of the design and manufacture of the bottle roll machine. Thus, this research was expected to produce equipment used for leaching and other processes requiring agitation in the laboratory. This study applies the principles of a circular economy as most of the raw materials were reusable materials.

2. METHODOLOGY

2.1. Preparation

The overall manufacturing process of this bottle roll machine can be seen in Figure 1.

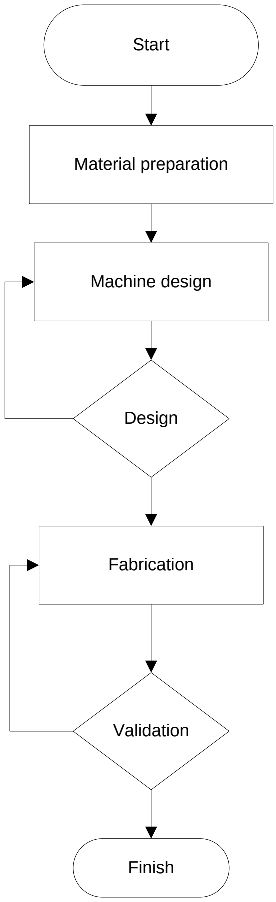


Figure 1. Flowchart of the manufacturing process.

The process of designing and manufacturing started with the search for tool components which will be explained further in section 2.2. Most of the components were used as machine components. Then, the design was created by considering some common technical aspects and criteria for metal leaching, such as %-solid (amount of solids in suspension), rotation speed (RPM), agitation speed, and leaching time. Some of the leaching variables from various researches were summarized in Table 1.

After the design criteria were determined by considering the process variables, the fabrication was carried out (explained further in section 2.4). Furthermore, to ensure the bottle roll can function according to the criterion, a validation process was conducted using sand as a solid raw material with variations in %-solid and bottle type for 24 hours with and without using an inverter as a roll rotation speed regulator. The flow chart for the validation stage of the tool is shown in Figure 2.

Table 1. Leaching Parameters [9–17]

ORE	% - SOLID	AGITATION SPEED (RPM)	TIME (HOURS)
Au-bearing ore	50	30-32	96
Gold oxide ore	30	100	48
Complex copper-gold porphyry	40	N/A	48
Rougher flotation gold concentrates	40	N/A	24
Copper concentrate	25	N/A	24
Pyrite	33	50	24
Chalcopyrite concentrate	6.25	60	96
Low grade nickel-cobalt sulfide ore	40	100	72
Betafite	N/A	23	48

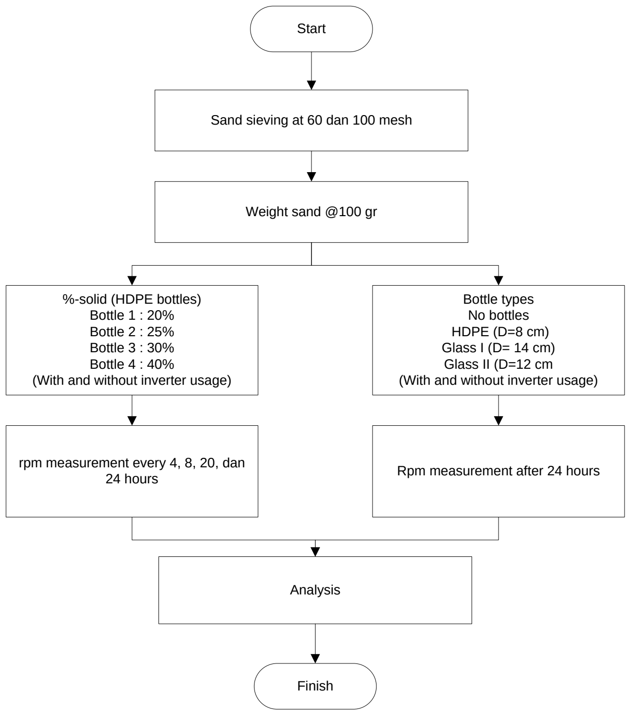


Figure 2. Flowchart of the validation process.

2.2. Materials

This research was conducted at the Metallurgical Laboratory, Faculty of Engineering, Sultan Ageng Tirtayasa University. The manufacturer of this machine used materials and components that were primarily derived from recycled goods, including:

1. Used water pump Electric motor (250W, 220V)
2. Gearbox as pulley from used washing machine
3. Used bicycle torpedo brakes
4. Lower from used Canon IR 5000 copy machine (as roll)

5. Bolt
6. Elbow steel
7. Pipe clamp
8. Bearing 6000 2 RS ASB
9. V-belt
10. Electrical tools, such as MCB, cables, etc.

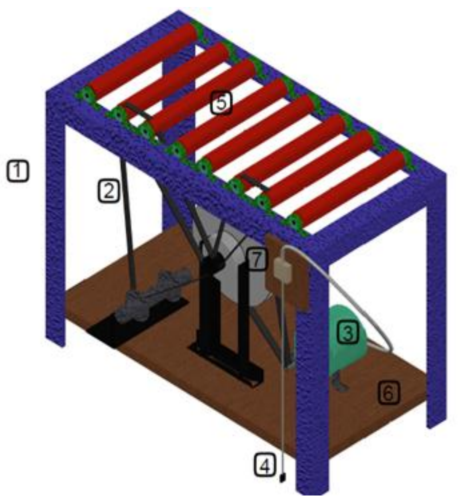
In the process of assembling these materials and components, several types of equipment in the laboratory are used, including:

1. Drill
2. Grinder
3. Toshiba Vf . Transistor Inverter
4. Shielded metal arc welding (SMAW) and other joining methods
5. TaffStudio LCD Digital Laser Photo Tachometer 2.5-100000 RPM – DT-2234C+

2.3. Design

The main function of the bottle roll machine is to carry out laboratory-scale metal leaching by agitation. Rotating rolls do the agitation process. Roller rotation comes from the driving motor, transmitted using a v-belt pulley from the power shaft to the load shaft through a belt. The rotational transmission received by the rolls causes them to rotate clockwise, and the sample bottles are placed on them. The rotation speed of the rolls can be adjusted using an inverter so that the leaching process can be carried out with a constant bottle rotation speed.

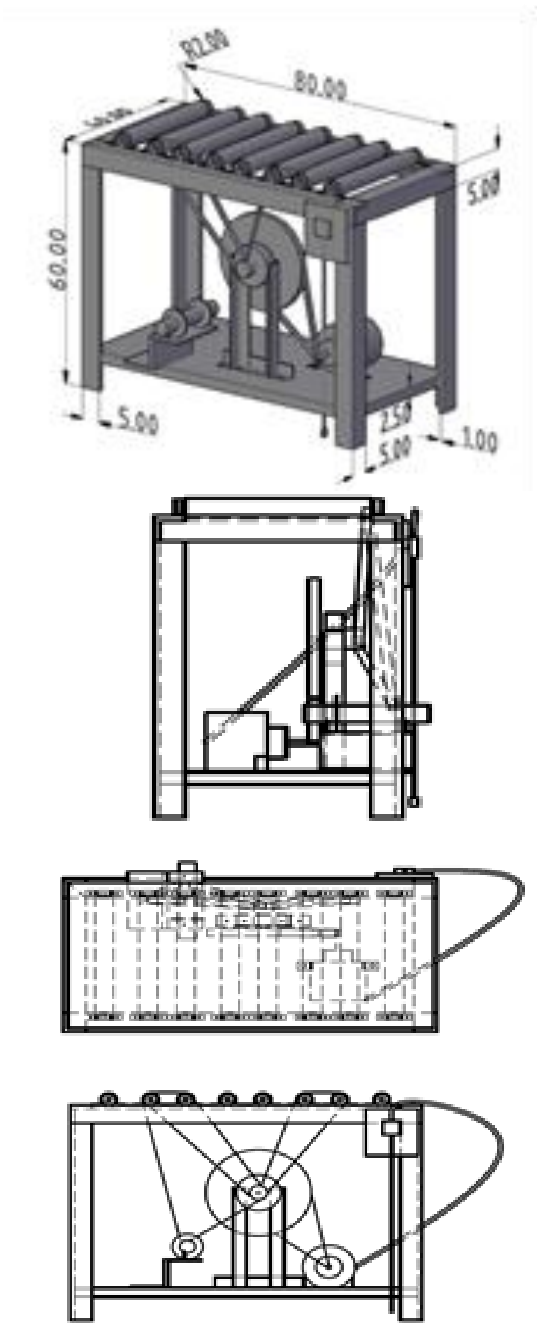
The design of the bottle roll machine was created using AutoCAD software, according to Figures 3 and 4. Figure 3 shows that the machine was designed with 80 Cm long, 40 Cm wide, and 60 Cm high dimensions.



1. Frame
2. Belt
3. Electric motor
4. MCB
5. Roll
6. Baseplate
7. Gear

Figure 3. Bottle roll design.

The machine consists of 8 rollers (Figure 4c) using the lower part of a used copy machine with a length of 30 Cm. The rolls were connected to the elbow steel of the machine frame using bolts and nuts with 10 Cm of the distance between the rolls. The SMAW technique joined the machine frame. The driving machine components were placed at the bottom of the roll and supported by a base plate (Figure 3). The engine components were from a used water pump electric motor.



(a)

(b)

(c)

(d)

Figure 4. Detail design (a) dimension; (b) side view; (c) top view; (d) front view.

The design criteria are:

1. The bottle roll can accommodate four bottles of suspension from 1 to 2.5 liters,
2. The bottle is placed between the rolls and rotate clockwise,

3. During the leaching process, the roll rotation speed should be kept constant, and
4. The rolls are equipped with a rubber seal at both ends to avoid the bottle being slipped (Figure 6). The distance between the rubber seal can be adjusted similarly to the bottle height.

2.4. Fabrication

The fabrication started with measuring and cutting the elbow steel as the machine frame. The steel was joined by SMAW and followed by connecting each component with bolts and nuts and painting to enhance the appearance of the frame and protect it from corrosion.

The copy machine lowers, which were used as rolls, were connected to the frame by drilling the frame every 10 Cm and attaching it to the frame with bolts and nuts. The final stage of fabrication was assembling the driving engine (water pump engine dynamo), installing the belt, and installing the electrical equipment.

After the fabrication was completed, it was continued further with the validation stage to see the durability of the tool and the consistency of roll rotation during the leaching process.

2.5. Transmission System Calculation

From the measurement, the diameter of the driver motor (water pump machine) is 14.6 mm with 2800 RPM. Meanwhile, the pulley diameter (washing machine pulley) is 230 mm. Therefore,

$$\frac{n_1}{n_2} = \frac{d_1}{d_2} \qquad (1)$$

$$n_2 = \frac{n_1 \times d_1}{d_2}$$

$$n_2 = \frac{2800\,rpm \times 14{,}6\,mm}{230\,mm}$$

$$n_2 = 178\,rpm$$

Where,
d_1: diameter of driver motor (mm)
d_2: diameter of pulley (mm)
n_1: rotation of driver motor (RPM)
n_2: rotation of pulley (RPM)

Since the pulley rotation measured by the tachometer is 148 RPM, so the slip factor is:

$$\sigma = \frac{V'}{V} \qquad (2)$$

$$\sigma = \frac{148\,rpm}{178\,rpm} = 0{,}83$$

Where,
σ: Slip factor
V': actual pulley rotation
V : teoritic pulley rotation

3. RESULTS AND DISCUSSION

3.1. Bottle Roll Machine

The bottle roll machine that has been designed and fabricated has the working principle of stirring bottles. It uses a rotating roller due to the rotation of the driving machine, which is transmitted through a pulley and a V-belt from the power shaft to the load shaft using a belt connected to the rollers (Figure 5).

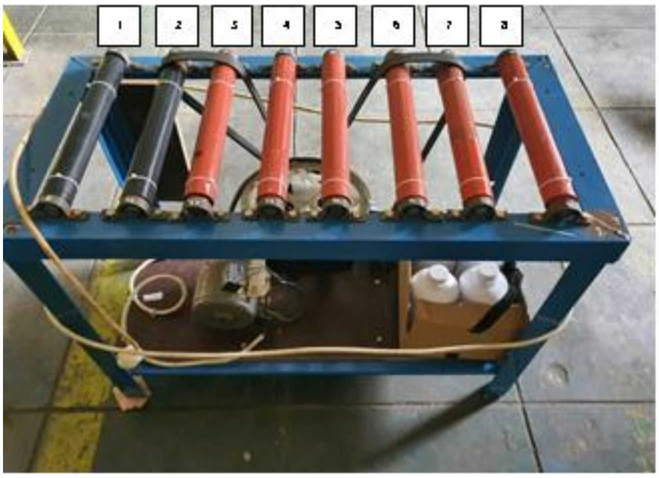


Figure 5. Fabricated bottle roll machine.

Figure 5 shows that the machine consists of 8 rollers. The rollers connect to the transmission by a belt on rollers 2 and 3 and 6 and 7. The dimensions of this equipment are 80 x 40 x 60 Cm. This tool can accommodate four bottles at once in 1 batch with the capacity of 1-2.5 liters per bottle. The leaching process is carried out by placing bottles filled with suspension between 2 rollers. The bottle will rotate along with the rotation of the roller, which produces an agitating effect on the suspension so that the metal leaching reaction will be faster when compared to without the help of agitation.

As the diffusion thickness decreases, the leaching reaction kinetics will increase with the suspension agitation. Therefore, the leaching process will be faster as well as the metal recovery [18–20].

Figure 6. Rubber seal for slip prevention.

3.2. Validation

As shown in Figure 2, validation was carried out by using sand as a solid medium and mixed with water as a solution. A solid and water mixture will form a suspension, commonly known as slurry. The sand used for making the suspension is 100 mesh obtained from sieving in a vibrating sieve shaker. The %-solid is defined as equation 1 below:

$$\% - solid = \frac{Solid\ weight}{Solid\ weight + Water\ weight} \times 100\% \qquad (3)$$

The rotation speed was measured at 0, 4, 20, and 24 hours to determine the consistency of roll rotation and the tool's durability by using a photo laser tachometer. Some tests were carried out in the validation stage with the %-solid variations of 20%, 25%, 30%, and 40% in HDPE bottles for 24 hours. The results of rotation speed measurement of bottle roll are shown in Table 2 below:

Table 2. Rotation speed measurement data on %-solid variation.

BOTTLES	%-SOLID	AGITATION SPEED (RPM)			
		0 hr	4 hr	20 hr	24 hr
Bottle I	20	30	30	29	29
Bottle II	25	31	31	30	30
Bottle III	30	32	31	30	30
Bottle IV	40	29	30	29	29

Based on the data obtained from Table 2, the %-solid variation did not cause a significant decrease in the rotating speed of the tool for 24 hours. The agitation speed decreased by 1-2 RPM for each %-solid variable.

In order to test the precision of roll rotation speed with %-solid variations, validation of roll rotation speed was also carried out with variations of bottle type and size with and without the use of an inverter. In this test, the roll rotation speed test was carried out without any load as well as using different bottles, such as HDPE bottles (8 Cm diameter), 12 Cm diameter glass bottles, and 14 Cm diameter glass bottles. Measurements were made within 24 hours. Table 3 below shows the results.

Table 3. Rotation speed measurement data on variations in bottle types and sizes

BOTTLES	INVERTER	DIAMETER (CM)	AGITATION SPEED (RPM)	
			Min	Max
Roll (no bottles)	-	-	-	150
Roll (no bottles)	√		35	87
HDPE	-	8	-	53
HDPE	√		18	36
Glass I	-	12	-	32
Glass I	√		11	24
Glass II	-	14	-	32
Glass II	√		12	24

The rotation speed of the rolls was increased along with voltage. From Table 3, it can be seen that under normal conditions (without load/no bottles), the rolls rotated at 150 RPM. Meanwhile, the rolls rotated at 35 RPM at the minimum voltage and 87 RPM at the maximum voltage of the inverter.

There was a slight difference in the variety of bottle types, whereas in HDPE bottles (8 Cm diameter, 1 Liter volume) without an inverter, the rollers can rotate at 53 RPM. Meanwhile, under the same conditions in glass bottles I and II (volume 2.5 liters), the rolls rotated at 32 RPM. The difference in bottle diameter did not appear to affect the rotation speed of the rolls.

The validation results in Table 3 can be used as a reference for researchers in setting parameters according to the desired roll rotation speed. Further development is needed to make speed regulation (RPM) automatic.

4. CONCLUSION

The design of the bottle roll by utilizing recycled materials can be used as an alternative during the metal dissolution process through the agitation leaching process. The manufactured bottle roll dimension is 80 x 40 x 60 Cm with eight rollers and used water pump dynamo as a driving motor. The driving force is transmitted through a pulley and a V-belt from the power shaft to the load shaft using a belt connected to the rolls. There was no significant rotation speed difference in the solid% variation from the validation procedure. The speed range is from 29 to 31 RPM at 20, 25, 30, and 40% solid conditions. The manufactured bottle roll also has good durability as the rotating speed remains stable for 24 hours straight that adjusted using an inverter.

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