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Design and Evaluation of a Simplified Rolling Mill with Simple Drive Mechanism

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Abstract

A rolling mill design is a difficult undertaking that calls for both a solid process understanding and the capacity to make sound decisions in order to balance a number of competing objectives. The aim of this study, is to design and evaluation a simplified rolling mill with simple drive mechanism. A feasibility study was conducted to determine the suitability of the machine. Design considerations were drawn and conceptual design generated based on the consideration. The best concept was selected using a decision matrix. The materials were created using standard fabrication techniques in accordance with the features that were designed. A Lincoln 6010, φ2.5mm, low hydrogen electrode was used to penetrate the prepared joints, and a 7018, φ4mm, low hydrogen electrode was utilized for filling and capping with a 500Amps Kaleida DC welding machine, in order to assure high integrity of the welded joints, particularly the roll carrier portions. Test evaluations were conducted using an Al-6061 alloy with width and thickness of 500 mm and 95 mm, respectively. It was found that the medium rolling mill torque and force were 1670.22 Nm and 422536.98 N. Furthermore, a rolling power of 7 hp and a solid roll shaft diameter of 80 mm were determined. After rolling, the final thickness was between 102.11 and 102.13 mm. Likewise, the actual draft varied from 7.11 to 7.13 mm. Also, 500 mm, 7.118 mm, 88.975%, 95 mm, and 102.118 mm, respectively were determined as the average width, average actual draft, average efficiency, average original thickness, and average final thickness of Al-6061 alloy. The Al-6061 alloy's final thickness of 102.118 mm and efficiency of 88.975% show how well the medium rolling mill performs.

1. Introduction

Ever since its inception, heavy industry has been vital to the nation's continued progress. Higher standards have been set for the quality of industrial items due to the economy's and science's rapid advancement.

Nomenclature	
ΔH	Draft
ds	Diameter of shaft

F_R	Rolling Force
M_b	Bending moment
M_t	Torsional moment of the shaft or torque
N_1	Speed of gear 1
N_2	Speed of gear 2
N_3	Speed of gear 3
N_4	Speed of gear 4
P	Power
R	Radius of roller
T	Torque requires
W	Maximum rollable width of ingot (mm)
y	Mean yield strength

The deck of a ship must be able to withstand the massive impact of frequent landings by carrier-based aircraft; steel plates used for tanks and armored vehicles must be able to withstand the penetration of armor-piercing bullets; steel plates used in the construction of large bridges must be able to withstand the frequent vibrations of trains running at high speeds, etc. [1]. Other examples of materials that must be able to withstand extreme stress and inertial forces include aerospace materials made from Aluminium and its alloy with an estimated stress of 690 MPa and high-speed rotation of rotating parts. For instance, aircraft wheel hub should possess good strength because it plays a vital role in the landing scenario of an aircraft. It is critical for aircraft safety and performance upon landing and taxiing on the ground [2]. Besides, the significance of high strength and rigidity are fundamental prerequisite for any vehicle occupant's cell, this cannot be overemphasized due to the protection it provides against accident, particularly side impacts which greatly rely upon rigidity of what is referred to as safety cage [3-5]. The development of steel and associated metals is critical to the strength and economics of industrialized nations worldwide. Rolling mills are essential to the manufacturing of semi-finished and finished goods since rolling is one of the most significant industrial metal-forming processes. Numerous industries, including the automotive and agricultural equipment sectors, the manufacturing sector, the steel sheet industry, threaded parts (such as bolts and screws), rods, seamless hollow tubes, etc., all use the rolling mill process. Rolling is the technique of applying compressive forces through a group of rolls to reduce thickness or alter the cross-section of a lengthy workpiece [6-10]. In basic metal industries, metal rolling techniques are used to create a range of goods. The number of rolls, the configuration of the rollers, or the metal's temperature during rolling are the three main classifications for rolling processes. The rolling procedures are either hot or cold depending on the working temperature. Big metal objects, such as steel billets or slabs, are heated above their recrystallization temperature during the hot rolling process, causing them to plastically distort [11-14]. The metal's average grain size is decreased while the microstructure is left intact. To obtain the proper shape when cold rolling, many rolls are typically needed [15]. To close the gap between previous research studies and this one, a thorough survey of relevant literature in this field is given here. To plastically deform AA6061 sheets at room temperature, [16] employed cold rolling. They then examined how the microstructure, texturing, and local deformation of the cold-rolled AA6061 sheets changed as a function of thickness reduction. Ďurovský [17] used evolutionary algorithms to study the relationship between friction forces on rolling mills with a single stand. The goal of the research thread is to superimpose tension, speed, thickness, and flatness with the flatness value. The results show that employing a new rolling lubricant can improve cold-rolled surface cleanliness and rolling lubricity by a moderate 20–40%. Soszyński [18] provides a perceptive explanation of the behavior and mechanism of defect generation. The study noted that deviations from the flat sheet's initial geometric shape might be used to evaluate flaws originating from cold plastic deformation. Additionally, [19] created a unique mill type that uses five-gear motors rated at 15 kW to produce rotation via the bearing stand while reducing the diameter of the working rolls. The results that are currently available show that the mill rollers experienced a moderate amount of elastic deformation and displacement when rolling in the new mill. Similarly, two clever high-rolling mills for decreasing sheet metal ingot were proposed by [20]. The rolling mill's design called for a draft value of 0.25 mm each pass and a maximum width of 100 mm. To take things a step further, [21] constructed a disruptive roller design with top and bottom rollers for the unfold length calculations and the resulting floral pattern design.

As per reference [22], it is crucial to regulate the roll separating force, driving torque, and end crop length to ensure quality production, maximize output, minimize rolled bar process scrap, maintain mill safety, and minimize energy consumption. Roll diameter, rolling speed, billet temperature, reduction ratio (strain), billet size (cross-section area), and other process factors are dependent upon these reaction parameters. Additionally, accumulative cold rolling at room temperature was used to create ultrathin foils (CoCrNi) and medium-entropy alloy (MEA) ultrathin foils with terminal thicknesses of 77 μm [23]. The rolled ultrathin foils' quasi-static tensile characteristics were examined. EBSD and TEM were used to investigate the effects of the reduction ratio and thickness values on their mechanical properties. As the thickness of the CoCrNi MEA ultrathin foils approached

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160 µm, the tensile strength increased to 1.69 GPa at a tensile elongation of 7%, according to the results, demonstrating exceptional tensile performance. Grain boundary and dislocation strengthening made up the main strengthening processes of the CoCrNi ultrathin foils, according to microstructure characterization. In particular, "work hardening" resulted from increased dislocation and grain size strengthening when the thickness exceeded 160 µm, and the strength progressively rose as the thickness decreased. The mechanical properties of the foils were strongly influenced by the strengthening effect caused by dislocation banding, twinning, and multistage twinning delivery when the thickness was 160 µm. The process of "work softening" happened when the thickness was less than 160 µm. This was primarily caused by the interplay between dislocation growth and annihilation in the grain, which caused the strength to gradually drop with decreasing thickness. Additionally, [24] stated that maintaining the consistency of product quality is largely dependent on the strip rolling mill's stable functioning. Existing domestically imported and self-developed strip rolling mills have limited design capabilities, and the manufacture of high-end strip goods is severely limited by the frequent occurrence of mill vibration and instability issues in operation. Additionally, in order to improve the dynamic performance of induction motors used in rolling mill applications, [25] suggested a revolutionary two-loop model predictive control (TLMPC). In these applications, induction motors are fed by two separate voltage source inverters and are coupled in a back-to-back fashion to the grid. Its undesirable behavior impairs induction motor speed regulation, which is a critical need in the rolling mill sector. In order to regulate the power flow by determining the optimal switching state of the grid-side converter, the suggested TLMPC incorporates a short-horizon finite set model predictive control in the inner loop. Furthermore, by forecasting the DC-link voltage across a finite time horizon, a long-horizon continuous set model predictive control is created in the outer loop to modify the inner loop's set point value. To apply the approximated non-linear model of the grid-side converter in the outer loop, an identification strategy is utilized. The suggested TLMPC's robust stability is demonstrated mathematically, and its real-time implementation is also certified.

The flat rolling operation (Fig. 1) involves the rolling of slabs, strips, sheets, and plates work parts of rectangular cross section in which the width is greater than the thickness. Additionally, rolling mills as components of manufacturing machinery have made a significant contribution to the development of national economies and technological prowess [26–28]. The work is compressed between two rolls during the flat rolling process, reducing its thickness by a quantity known as the draft. The roll stand [10,29,30] is the fundamental rolling mill equipment that directly guarantees the source of plastic deformation, to which additional accessories (devices) are connected. These include the work rolls, which transfer force and torque load to ensure the required shape, dimension, and surface quality of the rolled metal; housings, which build the rolling mill stand and absorb all metal pressure on rolls during the rolling process; bearings, which enable precise roll neck mounting in both horizontal and vertical planes; adjusting, roll counter-balancing, and roll changing equipment, pinion stands, and reducers, which adjust the main motor's revolutions to match the number of revolutions needed for the rolls; spindles, base plate, motor, couplings, and base plates. Each of these parts has been chosen or designed as part of the project process.

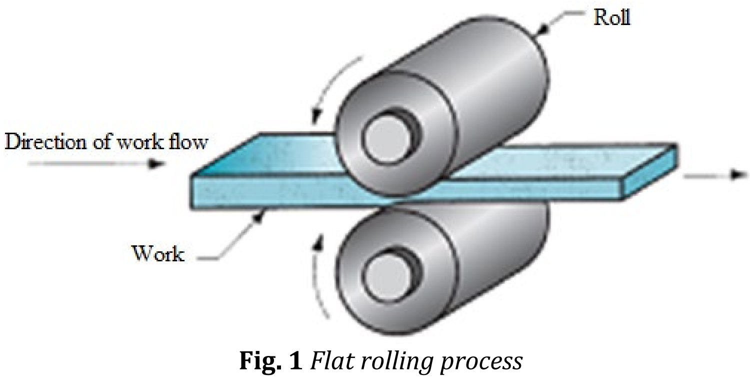

Fig. 1 *Flat rolling process*

Using locally produced and upgraded machinery and work tools can lead to an adequate improvement of local manufacturing processes [10, 31, 32]. This essential metal-forming (rolling) machine is not available in the Nigerian Niger Delta, according to an assessment of engineering labs and locally accessible metalworking firms. Because of this, the use of rolling machines, their operations, and the final goods they process have been scarce in this area. Some engineering schools do not allow their graduate students to participate in practices involving the use of this machine; small-scale industries are unable to regulate the properties of metals used in these practices, which leads to some failed products because of inadequate regulation of metal strength; and high costs further prevent some engineering outfits from purchasing such machines. In order to increase product quality and shapes, these necessitate the construction of functioning rolling machines that are utilized in the metalworking processes in various industries and laboratories across the region. Such advanced machinery would support local, industrial manufacture of these kinds of machinery even more. Also, the rolling mill can be used to optimize and control the microstructural properties of treated metals. This is a crucial component in establishing the mechanical characteristics of the product, and therefore its strength, ductility, corrosion resistance, dependability, and many other attributes. The study therefore considered the design and evaluation of a simplified rolling mill with simple drive mechanism, use of locally available materials and suitable ergonomics for easy machine operation and production. The study aims to fill the gap in the production of metallic materials caused by the unavailability of rolling machines in our locality (engineering laboratories and small-scale metal processing industries). With the help of the developed machine, the country's technological and economic progress will be aided in the practice of flat metal rolling as well as the optimization and assessment of metal and alloy properties, such as brittleness, strength, machinability, etc., both in the laboratory and on an industrial scale.

2. Materials and Methods

When designing a rolling mill, the mill designer uses his experience, selects the right analytical tools, looks for empirical relationships when analytical methods are not fully developed or when analysis time is limited, and then continues to make decisions at different points in the design process. Feasibility study and selecting the product's considerations are the first step in the design process. A certain degree of flexibility is allowed in the specs, which eventually solidify into a clear form as the design moves forward. The kind of roll arrangements, an appropriate roll-drive mechanism, the kind of motor, etc. were taken into consideration at this point. Ultimately, a thorough design is completed, and the device is set up. Common steel members were utilized in the machine's construction. The materials were created using standard fabrication techniques in accordance with the features that were designed. A Lincoln 6010, φ2.5mm, low hydrogen electrode was used to penetrate the prepared joints, and a 7018, φ4mm, low hydrogen electrode was utilized for filling and capping with a 500Amps Kaleida DC welding machine, in order to assure high integrity of the welded joints, particularly the roll carrier portions. The design dictated the procurement of more machine parts, including steel rods, electric motors, gears, bearings, and other components. Among the instruments utilized were a portable drilling machine, an industrial lathe machine, and grinding machines.

2.1 Feasibility Study

In order to ascertain whether or not institutions in the Niger Delta region of Nigeria may benefit from the design of the rolling mill, a feasibility study was conducted through the use of questionnaire. The outcome of the questionnaire will aid the design considerations. Surveys were sent to faculty members and technicians in the Faculty of Engineering, after visitation of institutions in the area. The primary purpose of this was to ascertain whether rolling mills were available in the area. Based on staff records from universities in the research area, the population size was approximated. Statistical computations utilizing the Yamane (1967) formula yielded the study sample size, which is as follows:

$$n = \frac{N}{1 + N\,e^2} \tag{1}$$

where,
n = Sample size
N = Population size (Staff records) = 1589
e = Level of precision or confidence level = 0.05

Hence,

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{1589}{1 + 1589\ \times 0.05^2} = 400$$

Consequently, 400 questionnaires in total were required for the research. In order to gather data for this study, three different approaches were used: questionnaires, interviews, and observations. The first two approaches were non-formal and relied on the degree of communication and mutual understanding between the researcher and the institution's employees. Utilizing a five-point rating system, a questionnaire was created for the third approach. It was created using the results of the preliminary exploratory survey. The questions were concise and precise, written in the most straightforward manner without compromising clarity. Respondents were asked to check the option that best reflected their feelings for each of the questionnaire's issues.

2.2 Design Considerations

In order to get the best possible performance out of this machine, careful thought was given to defining and identifying the issues that prevented it from performing as well as locating the causes and limits. During the design process, the availability and choice of materials, the rollers' surface finishing, functionality, performance, reliability, safety, cost, usefulness, durability, convenience of use, and maintenance were all taken into account. Throughout the design process, the project's design is guided by the design requirements. The medium rolling mill machine's estimate of power consumption (watts), the approximate roll length (mm), the rolling force (N), the gear speed (rpm), and the torque transferred (Nm) were all determined when designing the design requirements.

2.3 Conceptual Design

Four (4) distinct conceptual designs (Fig. 2) were implemented in order to get the final result. A concept is an idea for a more focused implementation of the selected strategy. A decision matrix (Fig. 3) was created based on the following design factors: cost, functionality, performance, safety, and dependability. A decision matrix is a list of values in rows and columns that allow an analyst to systematically analyze and rate the performance of relationships between sets of values and information. Each category is assigned a weighing factor base on believe which measures its relative importance. This helped guarantee that the best concept was selected for detailed design.

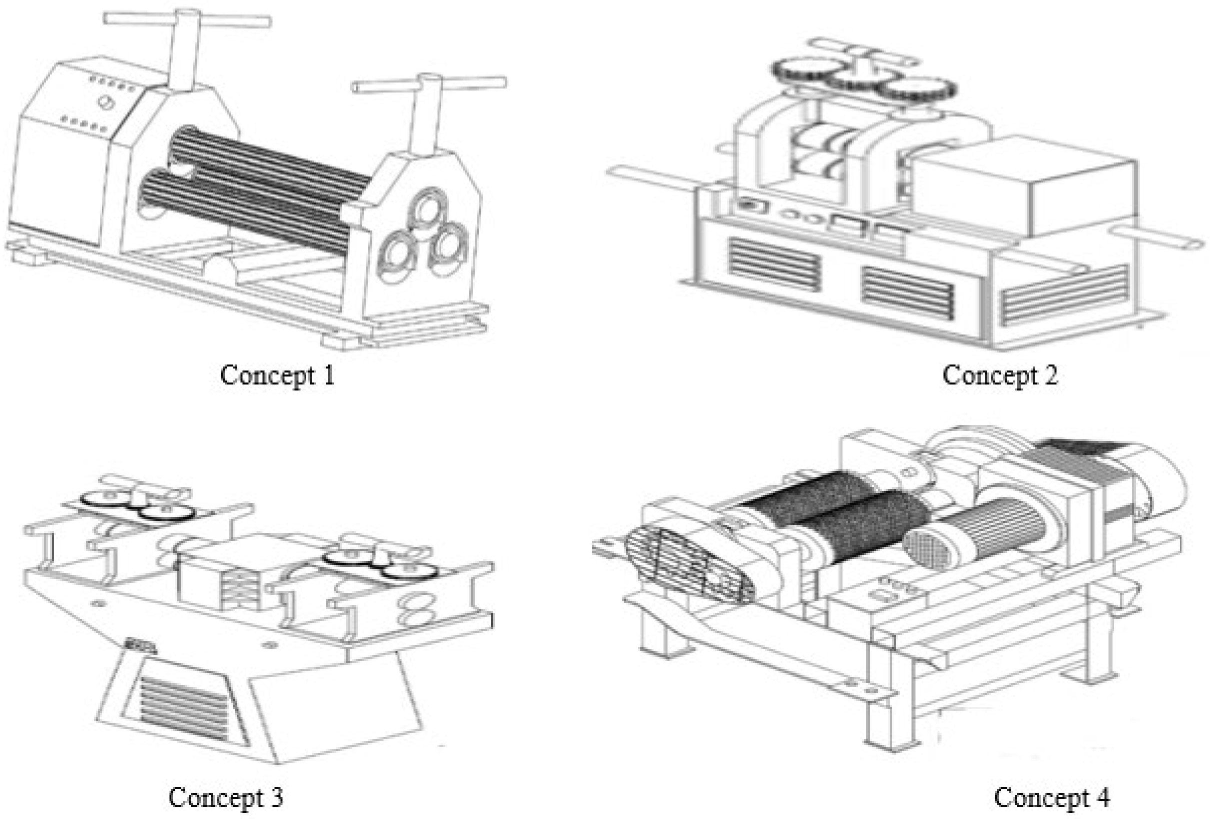

Fig. 2 *Conceptual design*

Based on ranking, fourth concept has the best ranking (i.e., 7.85), hence the fourth concept was selected for detail design.

	Functionality	Performance	Reliability	Safety	Cost	Rank
Weighting factor	0.25	0.30	0.15	0.15	0.15	1.0
First Concept	6 / 1.5	2 / 0.6	4 / 0.6	2 / 0.3	4 / 0.6	3.60
Second Concept	3 / 0.75	6 / 1.8	6 / 0.9	4 / 0.6	6 / 0.9	4.95
Third Concept	4 / 1.0	7 / 2.1	7 / 1.05	6 / 0.9	8 / 1.2	6.25
Fourth Concept	5 / 1.25	9 / 2.7	8 / 1.2	9 / 1.35	9 / 1.35	7.85

Fig. 3 *Decision matrix*

2.4 Detailed Design

To ascertain the precise design of the necessary characteristics and components, a design analysis was done. This phase expands on the previously created concept with the goal of fully describing every facet of the project through working drawings, specifications, solid modeling, and mathematical modeling. Equation (2) provides the rolling force needed by the medium rolling mill, and Equation (3) provides the torque needed by the medium rolling mill.

$$F_R = y_s\sqrt{R\Delta H \times W} \quad (2)$$

$$T = F\sqrt{\frac{R\Delta H}{2}} \quad (3)$$

where,
F_R = Rolling Force
Y_s = Yield stress of cast Iron
R= Radius of roller
ΔH = Draft = Initial thickness − Final thickness
T = Torque require
W = Maximum rollable width of ingot (mm)

The power required by the medium roll mill is given by Equation (4)

$$P = Tw \quad (4)$$

where,

$$w = \frac{\pi DN}{60} \quad (5)$$

Equation (4) becomes,

$$P = T\frac{\pi DN}{60} \quad (6)$$

Since the speed ratio of gear is the ratio of the speed of the driver to the speed of the driven or follower and the ratio of speeds of any pair of gears in the mesh is the inverse of their number of teeth, therefore:

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$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \quad (7)$$

Also,

$$\frac{N_3}{N_4} = \frac{T_4}{T_3} \quad (8)$$

where,
N_1, N_2, N_3, and N_4= Speed of gear 1, gear 2, gear 3, and gear 4
T_1, T_2, T_3, T_4 = Number of teeth on gear 1, gear 2, gear 3, and gear 4

Similarly, the roll shaft is solid and transmits power from the electric motor to the machine rolls via the gears mechanisms. The diameter of the shaft is calculated using Equation (9).

$$d_s = \left(\frac{32}{\pi y}\sqrt{[(M_b)^2 + (M_t)^2]}\right)^{1/3} \quad (9)$$

where,
ds = The diameter of shaft (mm),
M_b =Bending moment (Nmm),
Mt = Torsional moment of the shaft or torque, and
y = Mean yield strength (MPa).

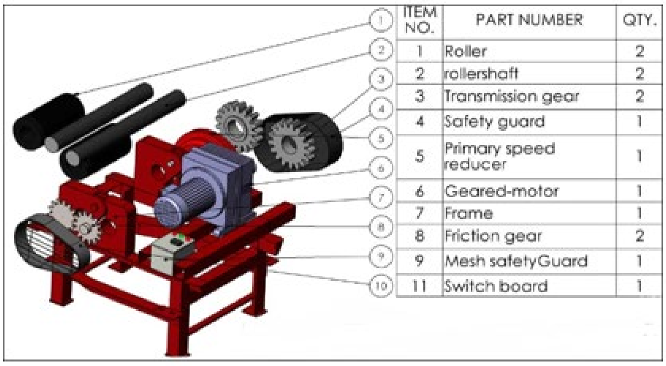
As suggested by [25], the mean yield strength of mild steel was taken as 250 MPa for shafts with allowance for keyways.

2.5 Basic Components of the Rolling Mill

An angle bar made of mild steel with a thickness of 10 mm and a width of 100 mm was used to construct the medium roll mill machine's main structure. The frame was created by joining the angle bars with a 500-amp Kaleida DC welding machine. Attrition between the feed and the two rollers mills the roll. The roll can be driven in opposing directions thanks to the gearbox configurations. Either the rolls can be tightened to prevent rotation, or they can be made to rotate about their connecting axes. Since the rolls rotate in the direction of the feed, the rolling force decreases with increasing rotational freedom. Therefore, when the rolls are stopped from rotating about their axes and only the roll carrier spins, the rolling force is greater. The machine that powers the medium-rolling mill is an electric motor. Power is transmitted to the milling chamber at a lower speed and higher torque via a gear speed reduction mechanism. This makes it possible for the rolling mill machinery to rotate, which rolls the non-ferrous metals. The rolling mill has four gears that are used in its motion. The driver gear one (G1) is connected to the electric motor. It moves at a 1:2 speed ratio with the gear two (G2) (i.e., follower gear). Both G2 and gear 3 (G3) are carried by the main shaft, and they move in the same vertical, clockwise direction as the main shaft, which also dictates the rolling mill carrier's direction of motion. Nonetheless, G3 causes gear four (G4) to move horizontally in an anticlockwise direction. The diameter and speed of G3 and G4 are the same. The rolling miller is driven in the same vertical anticlockwise direction by G2, which is securely attached to the rolling mill chamber. This causes the roll carrier to travel in the opposite direction. Tangential force is used to transfer power, and the torque (or twisting moment) that is created inside the shafts, as a result, enables the power to be transferred to different machine parts that are connected to the shaft. The different elements, including gears, bearings, belts, etc., are fixed on the shaft in order to transfer the power from it. The base support serves two purposes and was built using an angle plate. In order to offer adequate rigidity and mounting, it first serves as the foundation seating for all machine accessories or the entire assembly. It also acts as a connection via which the machine can be connected to the machine frame using bolts and nuts in the slot.

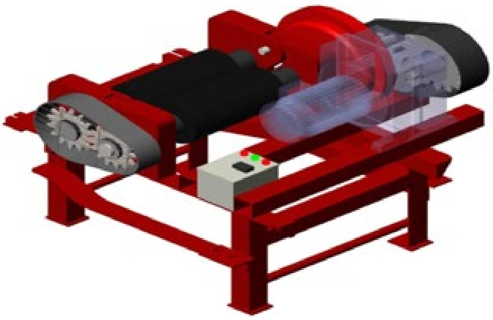
2.6 Configuration of the Rolling Mill

The exploded view, isometric view and picture of the fabricated medium roll mill is shown in Fig. 4.



ITEM NO.	PART NUMBER	QTY.
1	Roller	2
2	rollershaft	2
3	Transmission gear	2
4	Safety guard	1
5	Primary speed reducer	1
6	Geared-motor	1
7	Frame	1
8	Friction gear	2
9	Mesh safetyGuard	1
11	Switch board	1

i. Exploded view of medium roll mill



ii. Isometric view of medium roll mill

iii. Picture of fabricated medium roll mill

Fig. 4 *Configuration of the rolling mill*

3. Results and Discussion

Three hundred and sixty-five (365) out of the four hundred (400) questionnaires that were issued were returned. The questionnaires were distributed and collected using a person-to-person method. Both structured questionnaires and in-person interviews were utilized to gather the data for this investigation. The information gathered is based on replies from teachers, students, and technology in universities located in the region. The graphical analysis of respondents about their use of rolling mills in institutions located throughout district is displayed in Fig. 5.

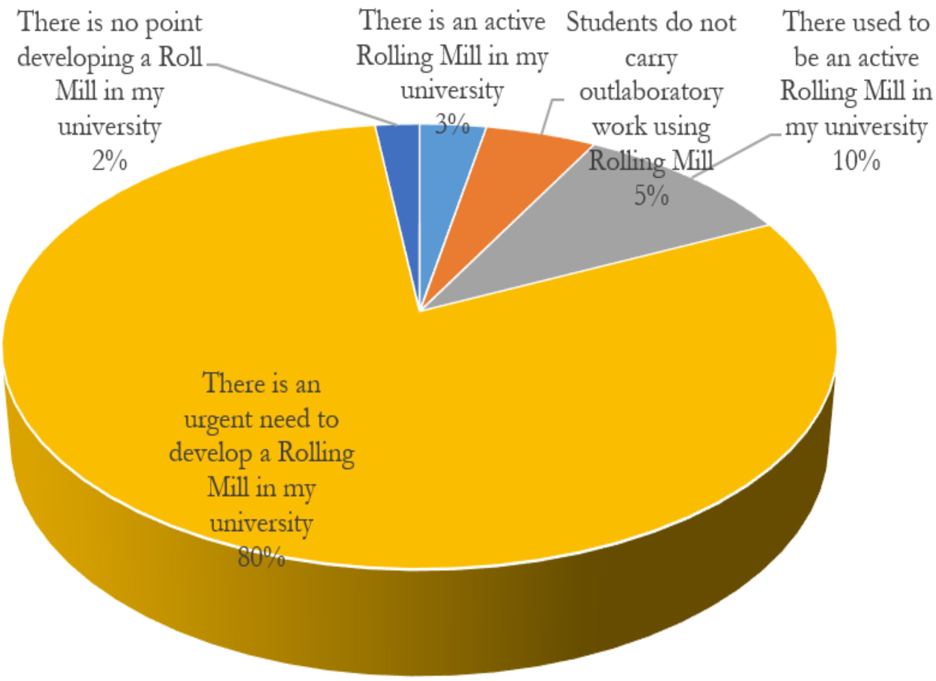


Fig. 5. *Graphical analysis of respondent in relation to their usage of rolling mill*

Higher education institutions in the region were consistently requesting the construction or acquisition of roll mills. Eighty percent of respondents agreed on either developing or buying a rolling mill. Furthermore, 10% of respondents said that their institution had formerly had a rolling mill. Additionally, 5% of the respondents concurred that students do not use rolling mills for laboratory work. This suggests that the machine should be developed immediately to allow for adequate training of students in rolling mill technique, which is a requirement for all engineering students, particularly those studying mechanical engineering. Thus, an adaptive design was used in the development of the rolling mill. The rolling mill force requirement was found to be 422536.98 N and this was minimal as compared to existing works in literature [27]. This figure was used to calculate the minimum torque necessary for the machine to operate smoothly. The results showed that 1670.22 Nm is the minimal torque needed. Additionally, a solid roll shaft diameter of 80 mm was established and employed for the design, and the rolling power was found to be 7 horsepower. The medium rolling mill was constructed with these design parameters in mind. Equation (10) was utilized to assess the medium rolling mill efficiency based on the determined value of the planned draft, which was 8 mm. The manufactured rolling mill was tested using Al-6061 alloy material, and the outcomes are shown in Table 1.

$$Efficiency\ (\eta) = \frac{Actual\ Draft}{Designed\ Draft} \times 100\% \tag{10}$$

Table 1 *Performance test results*

S/N	Width of Al-6061 Alloy (mm)	Original Thickness of Al-6061 Alloy (mm)	Final Thickness of Al-6061 Alloy (mm)	Actual Draft (mm)	Efficiency (%)
1	500	95	102.13	7.13	89.125
2	500	95	102.11	7.11	88.875
3	500	95	102.12	7.12	89.000
4	500	95	102.13	7.13	89.125
5	500	95	102.12	7.12	89.000
6	500	95	102.12	7.12	89.000
7	500	95	102.11	7.11	88.875
8	500	95	102.12	7.12	89.000
9	500	95	102.11	7.11	88.875
10	500	95	102.11	7.11	88.875
∑	5000	950	1021.18	71.18	889.75
Ave.	500	95	102.118	7.118	88.975

The difference between the Al-6061 alloy's initial and final thickness, as seen in Table 1, was a sign of the developed rolling mill efficiency. The ultimate thickness after rolling fell between 102.11 and 102.13 mm. In a similar vein, the actual draft varied between 7.11 and 7.13 mm. The results of the analysis of the rolling mill draft, efficiency, and thickness fluctuation are shown in Fig. 6. The result showed that the end thickness of the Al-6061 alloy had a larger value than the starting thickness of the alloy, which had a smaller constant value. Additionally, it was noted that the medium rolling mill efficiency was high for each test, with values in the 88.875% to 89.125% range.

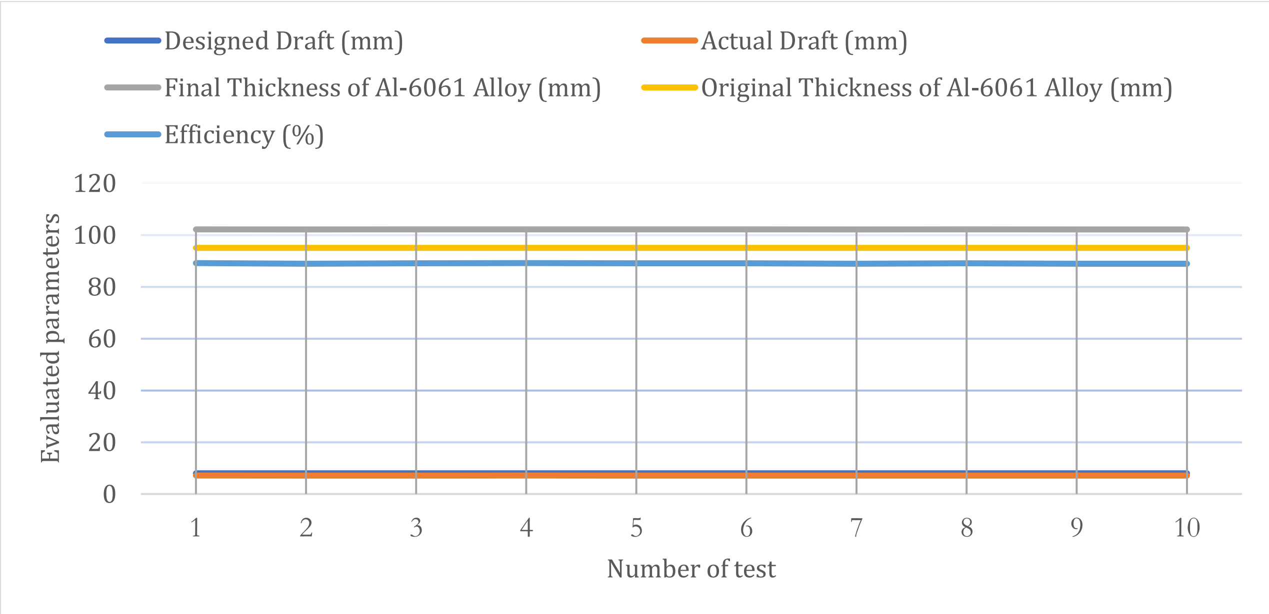


Fig. 6 *Analysis of thickness variation, draft and efficiency of the rolling mill*

Fig. 7 displays the rolling mill average alloy thickness results. The average width, average actual draft, average efficiency, average original thickness of Al-6061 alloy, and average final thickness of Al-6061 alloy are 500 mm, 7.118 mm, 88.975%, 95 mm, and 102.118 mm respectively, as illustrated in Fig. 7. The achieved average efficiency of 88.975% and 102.118 mm demonstrate the medium roll mill's strong performance. This agrees with the research work of [21] and [23]

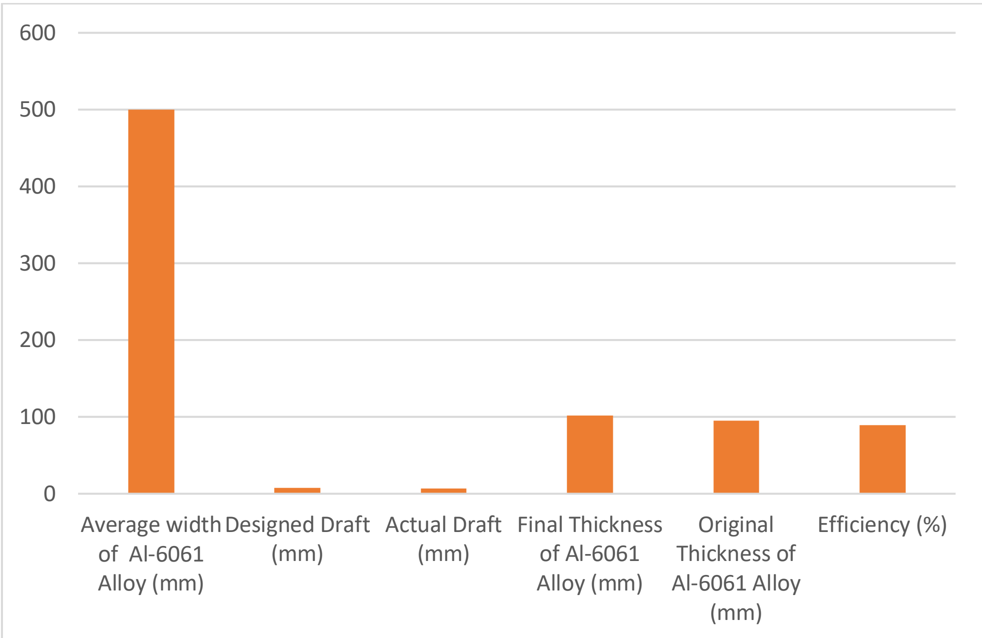
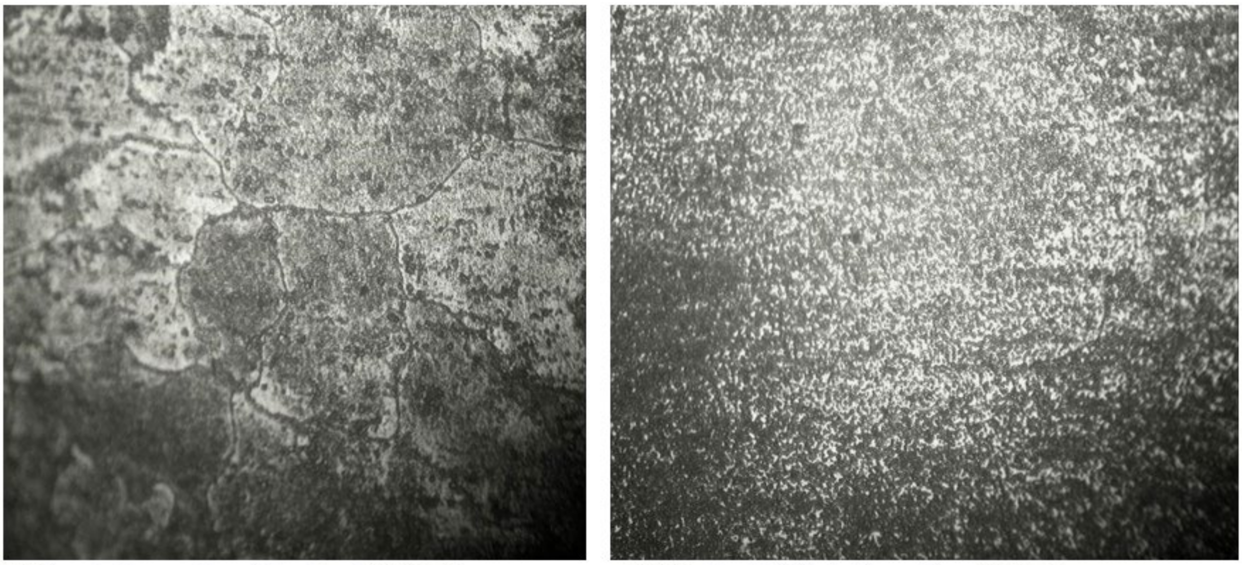


Fig. 7 *Results of medium rolling mill average alloy thickness*

As shown in Fig. 8, cold rolling the alloy just after quenching can increase its hardness to a certain extent. The control sample made of Al-6061 aluminum alloy has a coarse microstructure with wide grain boundaries, as seen in the optical micrograph. Also, high dislocation density or pile-up between precipitates and grain boundaries were present. On the other hand, the coarse microstructure of grain refinement, sliding, and pilling of dislocations is seen in the optical micrograph of the cold-rolled samples. As shown in Fig. 8, cold rolling the alloy just after quenching can increase its hardness to a certain extent. According to [10, 33, 34], the inserted dislocations capture the quenched vacancies and prevent clustering. On the other hand, deformation hardening produces temper hardness, which may jeopardize the material's formability during the stamping process. However, this process has an advantage in that rolling metals cause plastic strains due to the motion of dislocations, and as dislocations interact and multiply, the resistance to plastic flow increases, strengthening and shaping the metals. Because they create additional barriers to the dislocations' path, the finer precipitates that are produced during rolling contribute to the alloy's strength. The alloy's mechanical characteristics increased as a result of the degree of irregularity in the lattice that was produced during the cold rolling process. The Al-6061 alloy's strengthening effect can be ascribed to foreign particles of any other phase interfering with the dislocation's mobility.



(i) Control sample without roll (100x) (ii) Rolled 10% deformation (100x)

Fig. 8 *Evaluation of microstructure of rolled Al-6061 alloy*

4. Conclusion

A rolling mill was created for the purpose of rolling metallic materials. Three distinct methods were employed to collect data for this study: observations, interviews, and questionnaires. The questionnaire was developed utilizing the early exploratory survey results and a five-point scoring system. Considerations and criteria for the design were sketched. The project's design is directed by the design specifications at every stage of the design process. When creating the design requirements, the rolling mill machine's estimated power consumption (watts), approximate roll length (mm), rolling force (N), gear speed (rpm), and torque transferred (Nm) were all calculated. Of the 400 questionnaires that were distributed, 365 of them were returned. The findings of the study indicated that universities in the area were often asking for rolling mills to be built or purchased. Eighty percent of those surveyed were in favor of either creating or acquiring a rolling mill. The results showed that 422536.98 N of rolling force and 1670.22 Nm of minimum torque were needed, respectively. Additionally, a solid 80 mm roll shaft diameter was determined and used in the design; rolling power was discovered to be 7 hp. Furthermore, a high rolling mill efficiency was observed for each test, with values ranging from 88.875% to 89.125%. Besides, with the developed rolling mill, several engineering schools in the region can engage their graduate and undergraduate students in practicals involving the usage of rolling mill. Furthermore, the qualities of the metals used in these processes may now be regulated by small-scale enterprises, which has resulted in some unsuccessful products in the past due to inadequate regulation of metal strength.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

Every section of this paper has been contributed to by the writers. The machine's design and analysis were done by Ejiroghene Kelly Orhorhoro; a feasibility study and rolling mill fabrication was done by Lucky Chughiefe; Rogers Ibunemisam Tamuno assessed and analyzed the microstructure of rolled Al-6061 alloy; and Patrick Okechukwu Ebunilo overseen the work.

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