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Development of an Eco-Efficient Automatic Paper Cutting Machine Using Reverse Manufacturing.

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ABSTRACT
As the world population is increasing, there is an importance need of an efficient resources management in production to maintain a relatively low living cost. An approach to reduce cost and to transform waste using reverse manufacturing Waste is presented in this paper. This paper developed an automatic paper cutting machine using reverse manufacturing. Eight precentage of material used in the construction of this prototype were from reversed manufacturing of waste and this yield an optimum result in production cost reduction. As an input to smart industry, this paper also present automation in paper cutting technologies.

Keywords: Paper Cutting; Waste Technology; Cost Effectiveness in Design; Industry 4.0; Artificial Intelligence; Production Management; Machine Design; Reverse Manufacturing.

I. INTRODUCTION

In the world economy generally over the years has enjoyed the grand massive results of technological advancement in various sectors most especially in the usage of materials and recycle of scares material. Industries and firms have continuously devised innovative plans to keep customers at arm's length with the introduction of new technology, products and services that would help make life easier to people in general. As a result of this upshot, urban areas have appreciably expanded with rapid increase in population resulting in a high percentage of goods consumed per area which leads to recycling of materials. Goods after been put to use, are often times wrongly disposed or rather poorly managed, bringing about several hazardous effects in the environment and the ecosystem at large. Alare T. et al. (2021) developed a mathematical model can used to determine the amount solid in our environment.

Waste management is the collection, keeping, treatment and disposal of wastes in such a way as to render then harmless to human and animal life, the ecology and environment generally (Oyelola O. T. et al., 2008). In order to achieve an effective waste management, several public bodies have set a zero waste policy with a target of zero waste by, for example 2020 (Christensen, 2010). As a means of adopting zero waste policy, some innovative technologies had been done to transform waste into useful products (Ojelola Kayode S. et al., 2020). This paper also present another innovation which is reverse manufacturing, reverse manufacturing is the reuse of waste in manufacturing another product (Charles D. W. et al., 2003). Reverse manufacturing has adopted in computer manufacturing as means reducing e-waste. Charles David White et al. (2003), presented reverse manufacturing in
computer industry as a way of reducing cost of production and creating an environmental conscious manufacturing.

Paper has become an important commodity for daily living and almost all activities of humans involves the use of paper. This implies that we can reduce the cost of living by reducing the cost of production of paper. Paper cutting is the process of cutting paper into various sizes. It is important say that paper constitute the highest percentage of solid waste. In order to minimize paper waste accumulation there must be an effective paper cutting. An effective paper cutting is cutting paper into useful size with minimum waste generation. To achieve this, the concept of automation and digitalization is introduce to paper cutting. Yanxi Liu et al. (2005) developed a model of digital paper cutting to optimized paper cutting efficiency. To have an effective paper cutting, paper cutting system should be close with feedback or feed forward signal (B. Wang and H. Liu, 2013). B. Wang and H. Liu (2013) design a control system

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paper cutting machine with a feed forward motor. The Ergonomics of paper cutting machine has to be improved in term safety and operator conveniences. Putting operator safety into consideration, Lavhate S.S. et al. (2014) developed a model of advanced paper cutting machine using ARM7 controller As an approach to smart manufacturing and zero carbon emission, this paper presented the development of an automatic paper cutting machine with minimum downtime. The aim of research is to developed an cost effective paper cutting as means of reducing the cost of production of paper and to developed the machines in various sizes for various uses (portable for official use and large for industrial use). To achieve this a reverse manufacturing of solid waste was adopted. 80% of the materials used was gotten from plastic waste and e-waste. Cheap materials such as wood was used. The performance of machine in term of functions and cost was computed. Akinnawo O. et al. (2020) developed an automatic paper cutting machine which can be use to cut various sizes of paper with minimum human inteferace.

II. MATERIALS AND METHODS

The machine is design to cut ≤210mm×297mm×2mm paper size, less power will be required and less vibration will be developed. Therefore, material selected is mainly plastic, rubber, wood and thin mild steel. Eighty percentage the material use is gotten from waste. The electric motor used is also gotten from e-waste. The following methods were used in the cause of the research: Design of the machine using AutoCAD, Design of the controller program using C# programming language, Design calculation of the automatic paper cutting machine, material selection for the development of the machine using reverse manufacturing, performance evaluation of the machines and discussion.

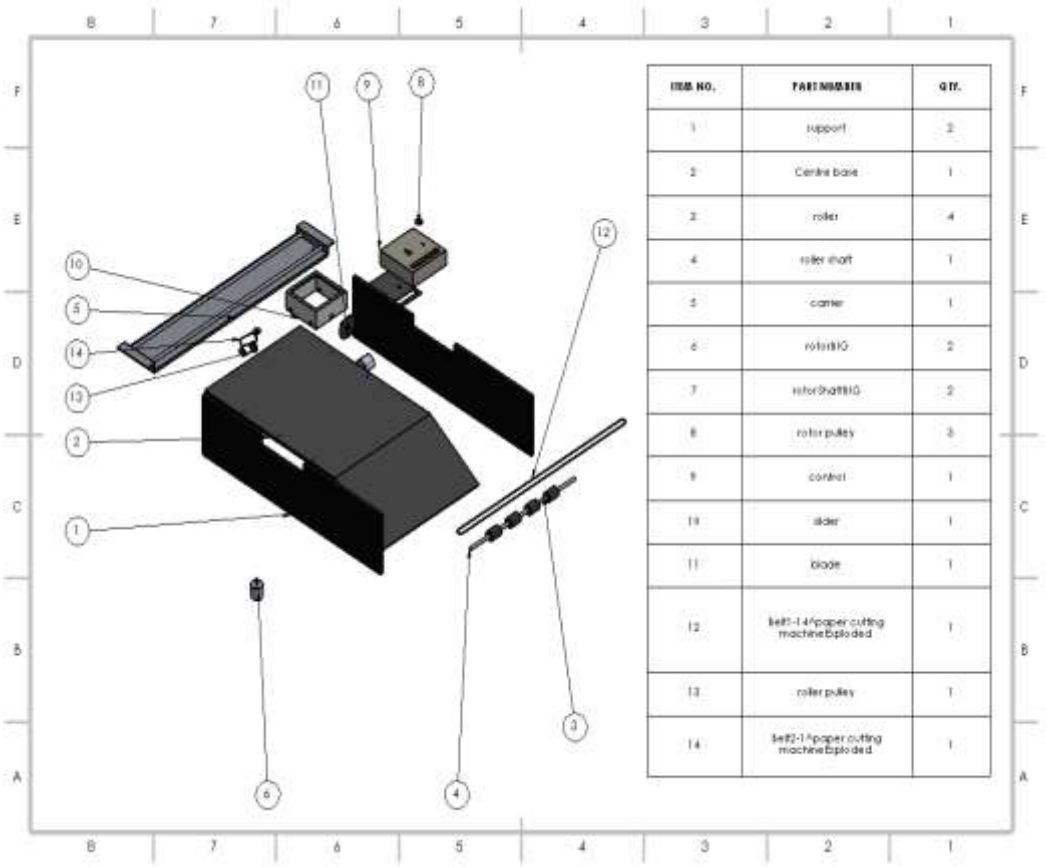

Fig. 1.0 Design of the automatic paper cutting machine (exploded view).

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Fig.2.0. the paper cutting machine side view.

Fig. 3.0 Model of carrier

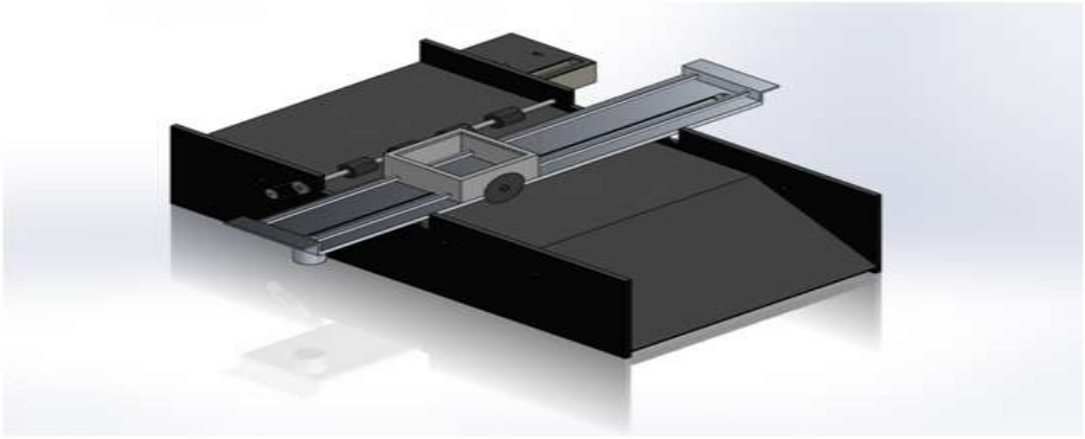

Fig.4.0. Model of the total Assembly of the paper cutting machine

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The project like other cutting machine has a circular blade which performs the cutting action through the motion produced by the prime mover (electric motor) by a slider mechanism, the machine is designed to work in a mechanism which rolls the paper to the cutter by means of a stepper motor. Power is transmitted from the stepper motor to the roller by an open rubber belt. The mechanism is designed to cut (210mm×297mm×2m) 20 A4 size papers at a cut, the paper is fed by hand to the roller to pick up the paper, the roller moves the paper towards the cutter which cuts the paper. The prime movers are powered by DC current which is rectified by a power unit from an AC current source. The control features a display screen and keypads to give the required input control which controls the process through the stepper and servo motor as pulses of DC current. The project is a machine which works on the principles of mechatronics to achieve variable paper and variable length paper cutting, its system has mechanical, electrical, electronics and computerized components which function together to perform the aim of variable paper and variable length paper cutting. The figures inputted on the remote is processed and converted to the speed of the roller motor which determines the exact cut length of the paper for continues cutting.

The rolling power, cutting power, overall power input per cut and power efficiency per cut for a cut of 20 A4 papers was calculated. The rolling and cutting operations was expected to be performed sequentially so a downtime of 0.5seconds was considered in the design.

Feed input: 20 A4 papers.
Dimension=210mm×297mm×2mm.
Cutting Area(Ca)= 0.297×0.002= 596×10^-6m²
Area density (A)= 80g/m² ×20 = 1.7Kg/m²
Machine demension = 500mm×400mm.
Desire downtime= 5secnds
rolling length per cut= 210mm. Cutting length= 400mm.
Rolling Area(Ra)= 0.21×0.0002 =42×10^-5m²
Cutting stepper motor parameter: 200rpm, 12v roller motor parameter: 200rpm, 12v
Cutting time = rolling time = downtime = 0.5s
Operational cutting time = cutting time +rolling time = 1second
Cutting speed(Vc)= cutting length/ cutting time = 0.8m/s
Rolling speed(Vr)= rolling length per cut/ rolling time = 0.42m/s
Cutting force= ACaVc/t = 0.00152N. Cutting Torque (Tc)= cutting Force × Cutting Length = 0.00152×0.4= 0.00061N-m Cutting Power (Pc)= cutting force×Vc = 0.001216watt. Power input = Tc × cutting stepper motor speed =0.002033watt
Cutting Efficiency= Pc/power input = 0.598 or 59.8% Electric current (Is)required by the stepper motor Is = Power input/ 12v = 0.17mA
Rolling force= ARaVr/t = 0.00056448N. Rolling Torque (Tr)= rolling Force × rolling length per cut = 0.0001185N-m Rolling Power(Pr)= rolling force×Vr = 0.0002371watt. Power input= Tr × roller motor speed = 0.0001185×200/60= 0.00395wattt. rolling efficiency= PR/power input = 0.60025 or 60%. Electric current (Ir) required by the roller motor= Power input/12v = 0.03mA
Total current required by the machine = Is + Ir (parallel connection) = 0.2mA
Total power input per cut= Total current × supply voltage = 0.0002× 12= 2.4×10^-3watt
Total power require per cut = Pc + Pr = 1.45×10^-3watt
Overall power efficiency per cut = Total power input/power required = 0.6042 or 60.42%.

Fig 5.0 & 6.0 showing the views of the automatic paper cutting machine

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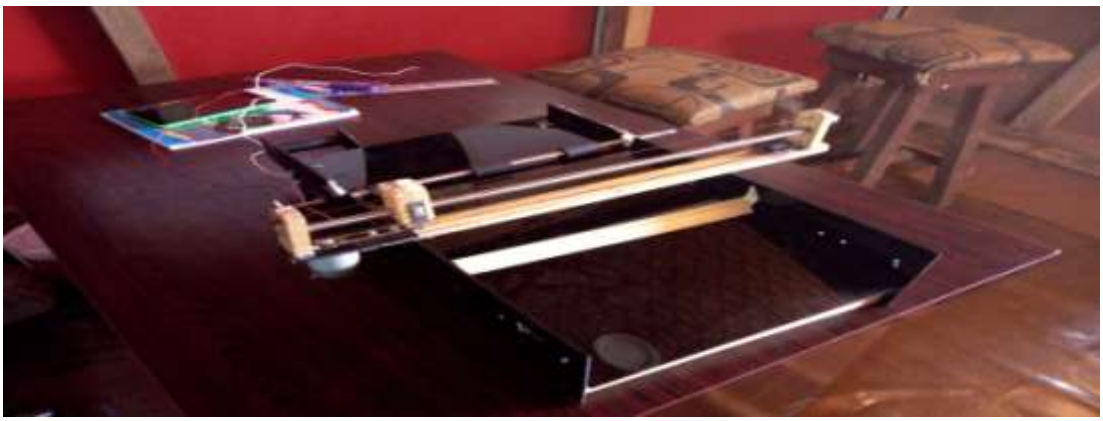

Figure 7.0. Developed Automatic paper cutting machine.

III. RESULT AND DISCUSSION

The performance of the machine over 100s of centimeters rolling length and the result was computed in in the graph below.

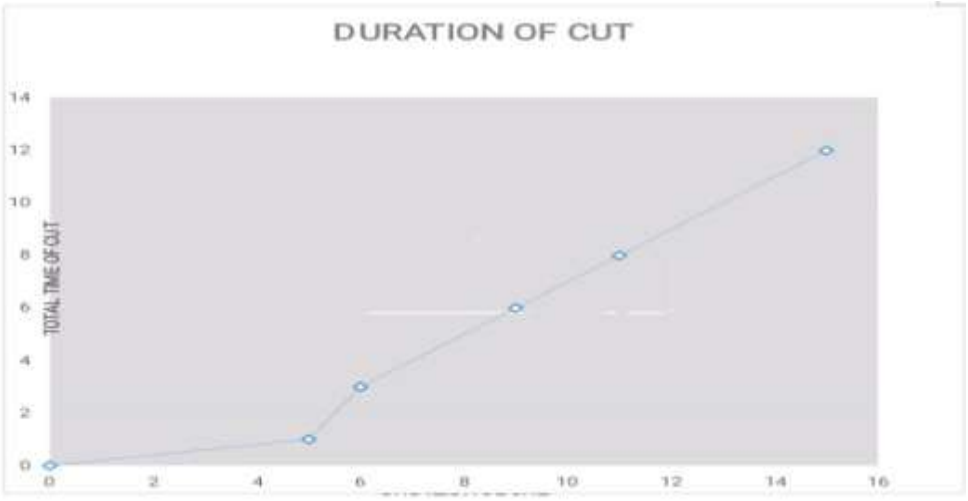

Fig. 8.0 A graph showing cutting time of machine to cut A4 paper size against 100s of centimeters rolling length.

The machine had steady retardation in cutting speed has the rolling length (operations time) increased but maintained a nearly constant cutting speed after cutting 600 cm rolling of 20 A4 papers. The efficiency of the machine is 60.5%. Although the technical efficiency is relatively low but the economic efficiency is high because 80% of the materials used were from reversed of manufacturing of waste. This reduce investment cost of this prototype by 55% and make more cost effective. If the method of manufacturing this prototype is adopted it will reduce cost of producing paper.

The efficiency of the machine can be improve for industrial type and since power input is small the machine can be powered by a renewable energy source. It is our recommendations that an improved model with low cost should be develop in order to reduce cost of paper production and reduce carbon emission.

Theproblemthatwasevidentwhentheprototypewascr eatedandtestedwastheroughnessthecuttingbladespro vided.Inthetestingphase,asharpenedcuttingbladewas testedandafterawhileitstoppedcuttingandslideoverth epaperwithoutmakingcutonthepaper.Thiseffectwasn otsoprevalentintheprototypewhichwemadeuseofado ttingblade.This can be corrected by further researches.

The Machine is design various of paper ≤400mm width size but the performance was evaluated base on A4 paper.

IV. CONCLUSION

This paper shown the importance of reverse manufacturing in producing a cost effective product. Reverse manufacturing or scrab technology knowledge should be formerly recognised because it does not only reduce cost of production it also prevent environment harzard. Reverse manufacturing is not limited to electronic or computer industry but very production industry. The inductive reason of "if a system is bad, all is components are bad" is not technically right. The money, time and energy duplicating a part which is in existence can saved and environment can be free of waste and the cost of living can be reduced.

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