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# Development of an Improved Automated Page Turning Machine

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**ABSTRACT: This paper presents the detailed of development and performance evaluation of an improved automated page turning device. The device is capable of turning the pages of a book in a forward or backward direction for the physically challenged who has limited use of their hands and the music players during rehearsals or live performance. The long term goal of this work is to develop an electromechanical page turner with an advance design that is superior in several respects, including reliability, portability, ease of use and affordable cost that would address design flaws prevalent in the existing patents. The report covers the design analysis of component parts of the machine which was done using various design equations and detailed drawings. The design results were used to select materials for various components. The machine performance was evaluated using adhesive gum on an A4 paper of different weight. The results show that the average response time of turning a page was 4 seconds and the machine developed achieved 90% success rate of turning pages at 15 pages/min.**

**Key words:** Page Turner, Automation, Development, Physically Challenged, Performance, Evaluation

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## INTRODUCTION

Automated page turner is a device that could turn the page of a book or magazine for individuals with limited use of hands or arms. The field of use of this device is extensive. It works with a variety of reading materials; this device helps to increase the independence of individuals who may otherwise not be able to turn pages of books. Based on recent federal census statistics, it was estimated that over 12 million Nigerians are physically challenged (UNICEF, 2008). As our society ages, assistive technology becomes increasingly important for helping not only people with disabilities but also the elderly. Assistive technology devices help these populations to improve their quality of life and interdependence, which also has an important impact on the society by reducing costs for care giving (John and David, 2005). For many people with disabilities the quality of life is severely hindered by loss of simple pleasures. These people may have limited mobility because of conditions such as quadriplegia, hemiplegia, cerebral palsy, severe arthritis, spinal cord injury, head injury and other neuromuscular disorder. For people with impeded upper body dexterity, it may be impossible as reading books as it becomes a significant challenge. This challenge thereby creates the need for a device that would aid in the successful turning of pages of a book.

Automated page turner is also relevant in the field of music. For centuries the music industry has faced a lot of challenges, one of which is experienced during live performance or rehearsal, as players are often forced to stop playing in order to turn printed sheet music or ask others to turn it for them. The challenges of having the page turned for the performer is that the page has to be read at the same pace with the performer and subsequently turned prior to the end of the music on the page (Dennis, 2008). Other unpleasant result experienced at times

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include multiple pages turned at the same time, music manuscript dropped in the lap of the performer or the page turner getting carried away by the music and simply forgetting to turn the page (Steward, 2006). Consequently, There is a need for a more reliable, simple and affordable device that will assist the musician in the conduct of the music; eradicating the need for the assistance of an individual to turn pages of a music manuscripts or the interruption that might suffice during the course of a performance or rehearsal. Over the centuries, there have been numerous unsuccessful attempts to provide a reliable and most quiet page turner that would be generally accepted. To this day, there are over sixty patents on subject of page turning but virtually all of them are marred by complexity and a lack of consideration for ill-behaved books that readily close upon themselves (Gregg, 2007).

John and David (2005) describes a page turner for book, a power driven task, a finger that protrudes from the disk to pages of the book, and a power drive. A page curler device was used to curl pages of the book in order for the finger to pull and turn the page at the curl. One major issue with this design is that it uses a rubber roller for separation. The separation of individual pages rely mostly on the frictional force generated between the separator and the pages to be turned but these actions initiate frictional forces between the pages which in turn resist page separation.

Dallas (2000) had a patent that discloses a device that employs a springy finger with a rubber tip mounted on axis above and parallel to the book spine. As the finger is rotated in either direction the rubber tip contacts the page and the finger bends. As rotation continues the leaf is supplied from one side to the other side of the book.

This mechanism has the potential to roughen pages, possibly folding them. Moreover, the nature of the design does not allow compensation for changes in the thickness of the remaining pages of the book due to variation of forces with changing thickness of pages as the forces applied will vary greatly from the beginning to the end.

Babarinsa (2009) developed a preset page turning device for turning the pages of book forward under the control of a pedal using a flat spring mechanism assembly. The operation of the device was not automated thus making it slow and strenuous to use.

Gregg (2007) presented a music page turning apparatus with two embodiments and a control. One embodiment provides a music page turning apparatus for fit to an existing music platform or the likes. Another embodiment provides a complete music stand equipped with the apparatus. The control is remotely locatable from the motor unit such that foot control is invited in turning the pages either forward or in reverse.

Many of these previous designs failed to address many problems like: reliability, portability and affordability which were solved in the design presented in this research. The research aim are the development of a page turner that could independently turn the pages of a book forward and backward for individuals with limited or no upper body motion; provision of a page turner that could repeatedly turn only single pages in a sequential order either forward or in the reverse direction and for the use of people with limited use of their hands or arms to read without the assistance of others.

## MATERIALS AND METHOD

### Design Consideration

In the course of the design analysis and development, the following factors were considered in order to achieve a functional and suitable automated page turner.

(a) Noise which is a deficiency in the previous designs.
(b) Ease of assembly at optimum cost
(c) Ergonomics for ease of use using Anthropometric data of human foot.

(d) Portability

**Material Selection**

Proper materials selection is of great importance during the course of the design of a machine. The machine elements should be made of materials which has properties suitable for the condition of operations. Availability of the materials, suitability of the materials for the working conditions in service and the cost of material were the fundamental bases applied in the selection of materials for the page turner. The material selected for each component parts of the machine is analyzed in Table 1.

**Analysis of Component Parts of the Page Turner**

The automated page tuner was designed for use by people with little or no control of their arms. By activating a puff switch, the user can turn a page of a book. This electromechanical page tuner uses a crank link mechanism to pick up the page. Components parts of the machine such as: the belt drives, machine frame and the electrical control unit of the machine was designed using equations (1) to (8).

From standard text, (Khurmi and Gupta, 2009), the velocity of the belt (Vep) transmitting drive between the electric motor and the crank link mechanism was determined using equation 1.

$$Vep = \frac{\pi D_e N_e}{60} \quad (1)$$

where:

$N_e$ is the number of revolution of the pulley fitted to the electric motor.

$D_e$ is the diameter of the pulley ûtted to the electric motor.

The length of the flat belt used was obtained from equation 2:

$$Lep = \pi\left[\frac{D_e}{2} + \frac{D_p}{2}\right] + 2\,C_{ep} + \frac{(D_e + D_p)^2}{2} \quad (2)$$

Since, $D_e = D_p$, then equation becomes

$$Lep = \pi\left[\frac{D_e}{2} + \frac{D_p}{2}\right] + 2\,C_{ep} \quad (3)$$

where:

$D_e$ is the diameter of the pulley ûtted to the electric motor.

$D_p$ is the diameter of the driven pulley

$C_{ep}$ is the centre distance between the two pulleys.

**Table 1: The materials selected for the key component parts of the page turner**

| S/N | Machine Component | Criteria for Selection | Material used for the Design | Suitable Material | Reason for Selecting the Material |
|---|---|---|---|---|---|
| 1 | Machine Frame | Strength, firmness and rigidity | Angle bar (Mild Steel) | Angle bar | It is cheap and readily available |
| 2 | Cable | Durability | 4x4mm armored cable | 4x4mm armored cable | It is well insulated, offer silent operation |
| 3 | Foot Puff Switch | Ease of operation with foot | Foot puff switch | Foot puff switch | Suitable for industrial installation |
| 4 | Electric Motor | Optimal functionality | 0.5Hp speed reduction motor of 44rpm | 0.5Hp speed reduction motor of 44rpm | Most suitable to successfully time the system |
| 5 | Flat Belt | Strength, corrosion or contamination free material | Leather | Leather | Most suitable and cheap |

Also, tension in the slack side of the belt $T_{ep2}$ was derived using the equation 3:

$$T_{ep2} = \frac{T_{ep1} - MlpV_{ep}^{\ 2}}{e^{\mu\theta}} \quad (4)$$

where:

$T_{ep1}$ is the Tension in the tight side of the belt
Mlp is the Mass of belt per meter length
Vep is the Velocity of the belt transmitting drive
$\mu$ is the Coefficient of friction between the belt and the groove of the pulley for electric motor.

$$e^{\mu\theta} = \frac{T_{ep1} - MlpV_{ep}^{\ 2}}{T_{ep2} - MlpV_{ep}^{\ 2}} \quad (5)$$

$\theta$ = $180^0$ because the diameter of the pulley are the same.

The power transmitted from the electric motor (in kilowatts) to the crank-link mechanism in the machine was determined using equation 4:

$$P = \frac{(T_{1-T_2})}{1000}\, VKw \quad (6)$$

where:

$T_1$ and $T_2$ are the tension in the tight and slack side of the belt respectively.
V is the Velocity of the belt transmitting drive.

**Design Analysis of Frame for the Page Turning Machine**

The frame supports the rotating reciprocating rod, the book table and the electric motor. Hence, it is necessary to determine the crippling or buckling load that the frame of the machine is subjected to. The type of end connection used is the fixed type because the members are welded together at the ends.

The Euler's theory for crippling and buckling load 'Wcr' under various end condition was used to carry out this analysis using equation 7:

$$Wcr = \frac{C\pi EA}{(L/k)^2} \quad (7)$$

where:

C is the Constant representing the end condition of the column or end fixity coefficient for welded and bolted points
E is the Modulus of elasticity or young's modulus for the materials of the column
A is the cross section area
L is the length of column
K is the least radius of gyration of the cross section.

where:

$$K = \sqrt{I/A} \quad (8)$$

such that I is called polar moment of area.

**Analysis of the Electrical Control of the Page Turner**

The control of the page turning machine describes the power supply from the source to the electric motor and how the contactor aids the control of the device in the forward and backward direction. The electrical system consists of 415V (3- phase AC power supply), 3

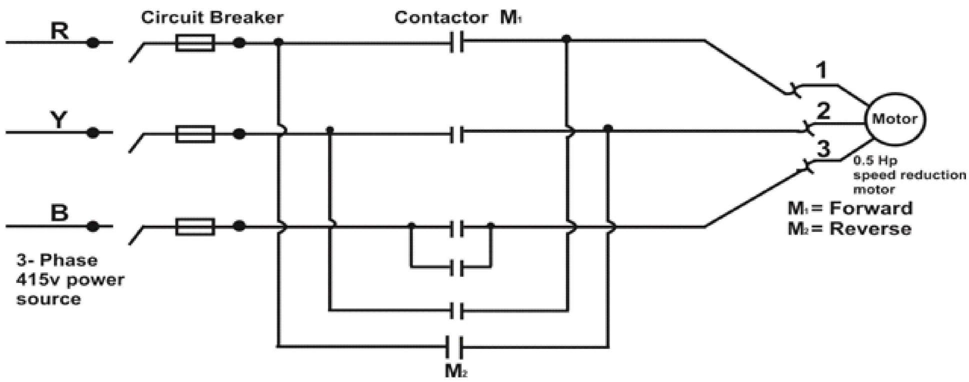



**Figure 1: Circuit Diagram of the Power Supply to the Electric Motor**

– phase circuit breaker, 3 – phase contactor, foot control switch and 0.5hp speed reduction motor. Figure 1 shows the circuit diagram of the power supply to the electric motor.

**Detailed Design Drawings**

Detailed design drawings for the machine are presented in Figures 2, 3 and 4 respectively:

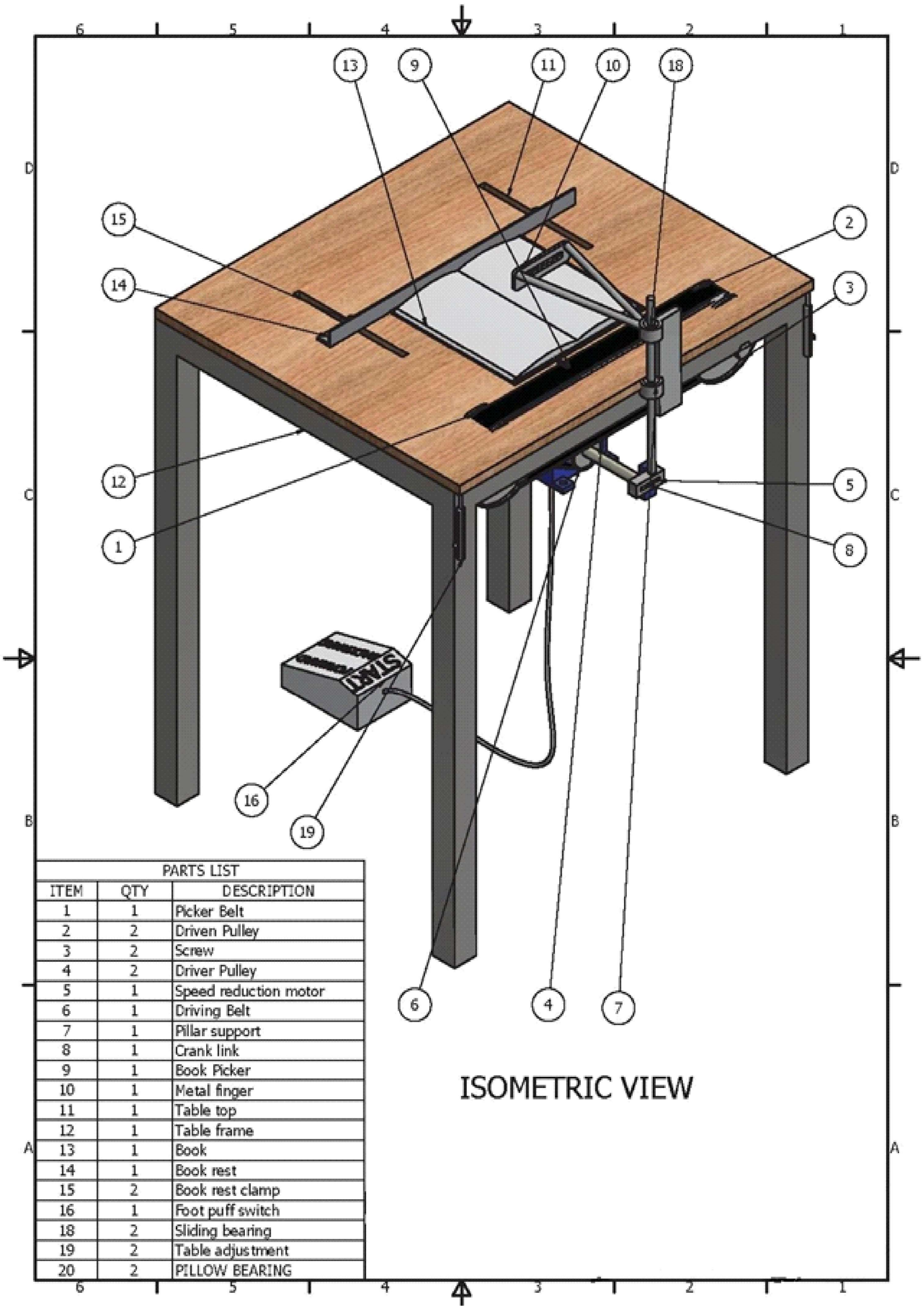
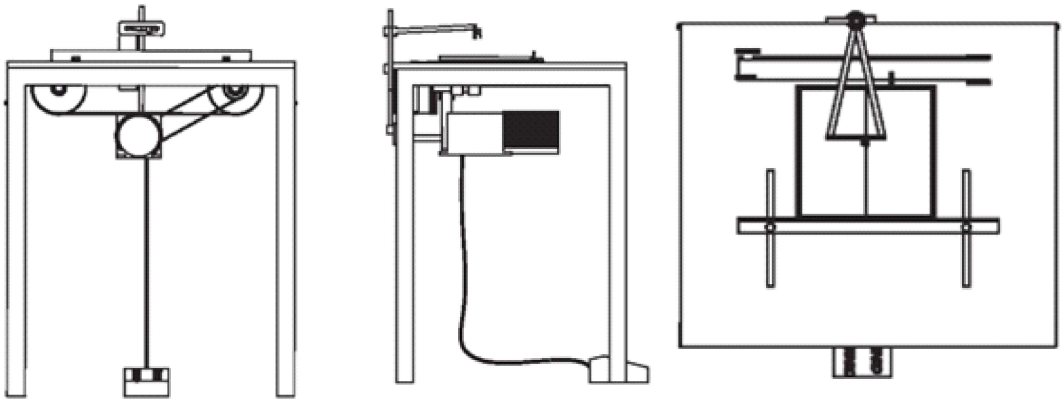
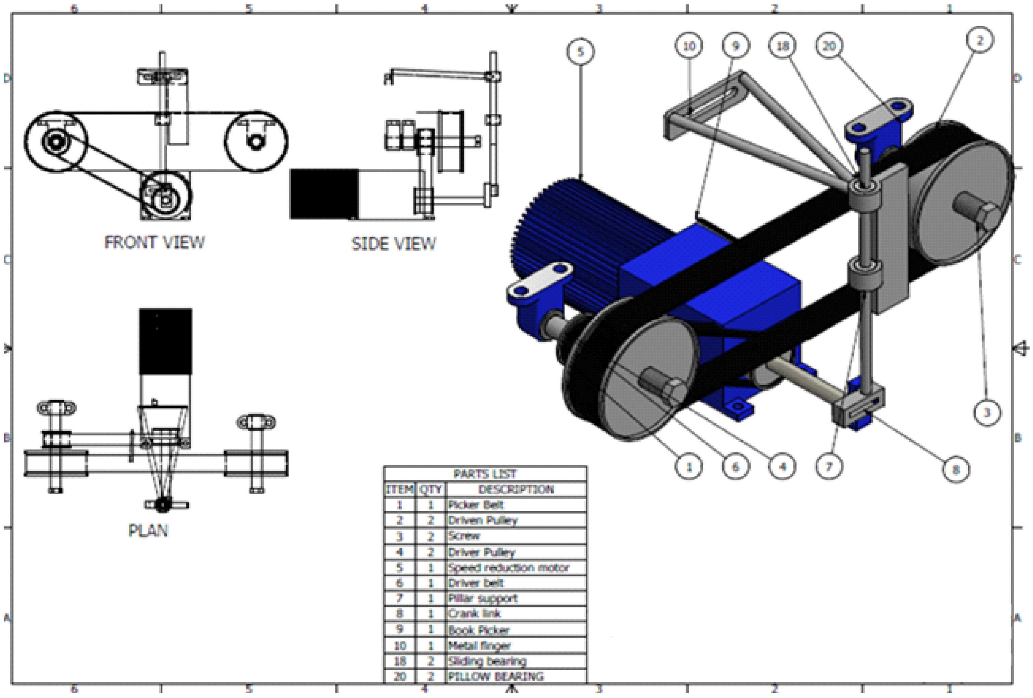



**Figure 2: Assembled Drawing of the Machine**



Front Elevation Side Plan

**Figure 3: Orthographic View of the Design**




| PARTS LIST | | |
|---|---|---|
| ITEM | QTY | DESCRIPTION |
| 1 | 1 | Picker Belt |
| 2 | 2 | Driven Pulley |
| 3 | 2 | Screw |
| 4 | 2 | Driver Pulley |
| 5 | 1 | Speed reduction motor |
| 6 | 1 | Driver belt |
| 7 | 1 | Pillar support |
| 8 | 1 | Crank link |
| 9 | 1 | Book Picker |
| 10 | 1 | Metal finger |
| 18 | 2 | Sliding bearing |
| 20 | 2 | PILLOW BEARING |

**Figure 4: Components View of the Machine**

**Fabrication Procedure**

The fabrication and assembling of the instrument was carried out at the Don- Bosco Technical workshop, Ondo, Ondo State, Nigeria. The processes involved in the fabrication of the page turner are as discussed below:

i. Belt: Flat Belt was bought and joined together to get desired size and length.

ii. Book Rest: 25.4 mm (1 inch) angle iron was cut into required length using hacksaw, drilled out two holes, nut was welded into it as well as the adjustment nut.

iii. Driver/Driven pulleys: Two 50 mm and two 120 mm diameter pulleys were turned on the lathe machine using turning tool, grooved out the space to accommodate flat belt using grooving tool.

iv. Stand: Square pipe was cut to required sizes for the stands and brazes using hacksaw, the stands were assembled together using arc welding process with gauge 12 mild steel electrode.

v. Table adjuster: Bushing was turned on the lathe machine by turning out the external diameter to 20mm diameter, drill out 10mm diameter hole through the bush. The bushing was removed on the lathe, mount it on the drilling machine vice, drill out the hole, later mount on the bench vice for tapping operation using taps.

vi. Adjusting shaft: Adjusting shaft was turned on the lather machine to 10 mm diameter.

vii. Table: The table is made up of 25.4 mm (1 inch) hard wood, which was cut to the required rectangular size. The surface was planned on wood planning machine. Slots were cut out to accommodate the pulley and the picker/detacher.

viii. Crank link mechanism: Flat bars were cut with hacksaw, taken to milling machine to produce slots and the attachment rods welded to it. Two bushes and adjustment rods were machined out on the lathe machine, the two bushes were welded to a pillar flat bar, then assembled the parts together to form the crank link mechanism.

ix. Rod/shaft: The rods or shaft to accommodate the driver and driven pulley were turned on the lathe machine to 20 mm. The shafts were assembled with the aids of four pillow bearings two at both sides.

x. Electric Motor: The electric motor was mounted under the wooden table using bolt and nut, driver pulley was mounted on the spindle of the electric motor, the pulleys were connected together using flat belts and the book rest was mounted on the table.

xi. Finishing: All the sharp edges were chamfered using grinder, smoothen surface with emery cloth in order to remove the corroded surface. The metal parts were painted with silver colour paint while the wooden parts were polished.

**Technical Description and Working Principle of the Page Turner**

The page turner works by grabbing and lifting a single page of reading material. A metal "finger" with adhesive at its tip enclosed inside a two bar mechanism is attached to a reciprocating rod through a metal linkage that stands over the centre of the book in the "ready" position. The reciprocating rod is been powered by a low speed reduction motor with the help of a belt drive, as it moves up and down it reach and lift each page. Another principal component is the belt drive attached with a fibre picker at the centre. The two pulleys of the belt drive are mounted within the plane of the table extending little inches out from the loop created within the table. This mechanism is driven by the right pulley which is powered by the same low-speed reduction motor that powers the crank link mechanism at the same speed. After the metal finger lifts the page, the belt mechanism advances the page by sweeping the pulleys in the appropriate direction. For forward movement, the member sweep left to right and for backward movement the members sweep right to left.

The device can be used with books of a wide range of sizes. The maximum open-book size is 266.7 mm (10.5 inches) high and 431.8 mm (17 inches) wide. The minimum open-book size is 5.5 inches high and 279.4 mm (11 inches) wide. Also the book can be up to 25.4 mm (1 inch) thick.

## RESULTS AND DISCUSSION

An automated page turner has been developed using locally sort raw materials. This page turner can repeatedly turn only a single page that is the next page in sequence both forward and backward. The machine through its design enables a person with limited use of hands or arms to read without the assistance of others. The machine is shown in Plate 1.

**Performance Evaluation and Discussion**

The developed book page turner was evaluated by carrying out some reliability and performance test. This test was to determine the response time of turning a page of book. A stop watch was use to ascertain the response time. The performance test was carried out on various putties, gels and tapes on a variety of paper weights and textures applied over a range of settings for contact pressure and time. An average of 4 seconds was deduced as the response time of turning a page at around 15 pages/min and was promising for a precise book page turner.

The result of the response time of the device over a trial with 30 pages of an A4 paper of weight 4g, 4.5g and 5g respectively as shown in Table 2.

**Plate 1: The Fabricated Page Turner**

**Table 2: Result of the Response Time on the Page Turner**

| Weight of an A4 Paper | | 4 g of an A4 Paper ($70\ g/m^2$) | | 4.5 g of an A4 Paper ($75\ g/m^2$) | | 5 g of an A4 Paper ($80\ g/m^2$) | |
|---|---|---|---|---|---|---|---|
| S/N | Page Loaded (PL) | Page Turned (PL) | Response Time (RT) (Sec.) | Page Turned (PT) | Response Time (RT) (Sec.) | Page Turned (PT) | Response Time (RT) (Sec.) |
| 1 | 30 | 29 | 101 | 28 | 112 | 27 | 135 |
| 2 | 30 | 29 | 116 | 27 | 108 | 27 | 136 |
| 3 | 30 | 28 | 112 | 27 | 108 | 26 | 130 |
| 4 | 30 | 28 | 110 | 26 | 104 | 26 | 130 |
| 5 | 30 | 28 | 112 | 27 | 135 | 25 | 102 |
| TOTAL | 150 | 142 | 551 | 135 | 567 | 131 | 633 |
| AVERAGE | 30 | 28.4 | 110.2 | 27 | 113.4 | 26.2 | 126.6 |

**Determination of Response Time, Efficiency and Reliability of the Device with an A4 Paper of weight 4 g**

Average no of pages turned $= \frac{\sum Pt}{n}$ (9)

where:

$\sum Pt$ is 142 pages, and n is 5

Therefore, average number of pages turned = 28.4 =28 Pages

Also, Average Response Time = $\frac{\sum Rt}{n}$ (10)

where:

$\sum Rt$ is 551 Pages

Hence, Average response time = 110.2 Sec.

Moreover, Response Time Per Page = $\frac{\text{Pt}}{\text{Rt}}$ (11)

= 3.88 = 4 Sec.

$Efficiency \frac{No. of\ pages\ turned}{No. of\ pages\ loaded}\ x\ 100$ (12)

where:

No of pages loaded is 30,

No of pages turned is 28.4,

Therefore, efficiency of the machine = 94.66 %

Reliability = Probability that there is no failure (Probability of turning a page)

= 1 - Probability that there is failure (Probability of not turning a page)

$= 1 - \frac{No. of\ pages\ unturned}{No. of\ pages\ loaded}\ x\ 100$ (13)

where:

No of pages left unturned = 1.6 Pages

No of pages loaded = 30 Pages

Therefore, Reliability of the machine = 90%

**Determination of Response Time, Efficiency and Reliability of the Device with an A4 Paper of Weight 4.5 g**

Applying equations 9 to 13 and using the results in table 2 under 4.5 g of A4 paper, Average no of pages turned was found to be 27 Pages, Average Response Time calculated to be 113.4 seconds, Response Time Per Page found to be 4.2 seconds, Efficiency of machine 90% and Reliability of the machine 90%.

**Determination of Response Time, Efficiency and Reliability of the Device with an A4 Paper of weight 5 g**

By applying equations 9 to 13, and using the results in table 2 under 5 g of A4 paper, average no of pages turned was found to be 26.2 Pages, average response time was calculated to be 126.6 seconds, response time per page was found to be 4.8 seconds, efficiency of machine 87.33% and reliability of the machine 87.33%.

**Summary of the Performance Evaluation Result**

The summary of the performance evaluation results showing the relationship between the weight of the papers, response time, efficiency and reliability of the device is shown in Table 3.

**Discussion of the Performance Evaluation**

The performance test was carried out on the developed page turner machine using 30 pages of A4 Paper of weight 4 g, 4.5 g and 5 g respectively. The test carried out was to determine the response time, efficiency and the reliability of the device with different weights of paper. The device was allowed to turn independently both forward and backward and a stop watch was used to ascertain the response time of turning a page of a book.

Table 2 shows the relationship between the weight of the paper, number of page turned and the response time of the machine. It was established that the higher the weight of the paper, the higher the response time of the machine and the lower the numbers of pages successfully turned.

Table 3 shows the summary of the performance test, it presents the relationship between the weights of the paper, the response time, efficiency and the reliability of the machine. An A4 paper of weight 4 g, 4.5 g and 5 g gave a response time of 4.08 seconds, 4.2 seconds and 4.8 seconds as well as efficiency and reliability of 95%, 90% and 87% respectively. It was deduced that the lower the weight of the paper, the lower the response time, the higher the

**Table 3: Summary of the Performance Evaluation Result**

| S/N | Weight of a Paper (g) | Response Time (Secs) | Efficiency (%) | Reliability (%) |
|---|---|---|---|---|
| 1. | 4.0 | 4.08 | 94.7 | 95 |
| 2. | 4.5 | 4.20 | 90 | 90 |
| 3. | 5.0 | 4.80 | 87 | 87 |

efficiency and the reliability of the machine and vice versa.
However, it was observed that at each of the performance test carried out, few pages were left unturned, this was due to the variation in the adhesive properties of the adhesive used. This also contributed to the disparities observed in the response time of the device. As a result of this, it is required that the adhesive should be replaced after turning about 25 pages.
Generally, the aim of this work was achieved, an average of 4 seconds was deducted as the response time of turning a page at 15 pages per minute with 90% efficiency and reliability respectively.

## CONCLUSION

In this study, the design and development as well as performance evaluation of an electromechanical page turner that could independently turn pages of book both forward and backward was carried out. This device will be useful for anyone with severe upper limb dysfunction. The machine performance was evaluated using an adhesive on A4 paper of weight 4 g, 4.5 g, and 5 g respectively. The results show that the average response time of turning a page of the paper was 4 seconds and the machine achieved 90% success rate of turning pages of a book at 15 pages/minute.

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