International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 13 Issue 2 ǁ February 2025 ǁ PP. 68-79

Design and Production of a Counter on Turnstile for Library Use

*[1] W. A. Akpan,[2] A. E. Oboh ,[3] U. E. Akpan [4] M.S.Etuk[5] N.I. Effeng
[1] Department of Mechanical Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Ikot Abasi, Akwa Ibom State, Nigeria.
[2] *Department of Mechanical and Aerospace Engineering, Faculty of Engineering,University of Uyo, Nigeria.*
[3] *Department of Mechanical Engineering, Faculty of Engineering, Top-faith University, Mkpatak, Akwa Ibom State, Nigeria*
[4,5] *Department of Mechanical and Aerospace Engineering, Faculty of Engineering, University of Uyo, Nigeria.*

Abstract
There is need to know the number of library users within a given period of time, the research is concerned with the design and production of a counter for turnstile for university library to determine the number of users within a given period of time. The counter works through gear reduction and takes its input from the turnstile and the gear reduction is 1:2:3:4:5:6. The counter with the turnstile was designed can count a maximum of 10,000 person before a reset. The introduction of the turnstile at the entrance of the library will help to know the number of users on daily or weekly basis and will also help management in decision making.
Keywords*: Counter, design, turnstile, library, users, university.*

Date of Submission: 02-02-2025 Date of acceptance: 12-02-2025

I. Introduction

A turnstile is a revolving gate that allows one person at a time to enter and leave, example a football ground or museum. According to [1] other public utility establishments like airport security checkpoint and some companies have mounted turnstile at the entrance of their administrative block, ostensibly to restrict in and out movements of staff in the company.

A turnstile could also be termed a baffle gate [2] which allows one person to pass at a time. A turnstile does not move in the reverse direction. For example, if it is manufactured to turn clockwise, it cannot function in the opposite direction and vice versa. It so enforces a one- way traffic of movement of people and so maintains orderliness. Most banks have turnstile at the entrance of their doors, basically to check influx of customers. These brands of turnstile in banks are sophisticated in the sense that it can promptly indicate metallic objects like keys, guns, knives, which are regarded as instruments for violent and conflicts. Communication gadgets can also be sensed by the turnstile. The incorporation of electronic sensors allow for the detection of aforementioned unwanted objects inside the halls of the bank.

The use of turnstile was not common in the African continent in the 2oth century, But in the 21st century its usage has gradually increased, as most public buildings like banks, companies and the corporate buildings now install turnstiles.

Tracing back to 1880's when Bochhacker of Berlin was granted German patent DE18349 on December 22, 1881 for 'Door without draft of air'. Theophilus Van Kannel of Philadelphia was granted patent 387571 on August 7, 1881 for a 'storm door structure'. The patent described it as having 'Three radiating and equivalent wings provided with weather strips or equivalent means to ensure a snug fit'. He also said that the door possesses numerous advantages over a hinged door structure, it is perfectly noiseless, effectively prevents the entrance of wind, snow, rain and dust. Moreover, the door cannot be blown open by wind, there is no possibility of collisions and yet people can pass both in and out at the same time. In 18889, the Franklin Institute of Philadelphia awarded the 'John Scott legacy medal' to Van Kannel for his contribution to the society. In 1899, the World's first wooden revolving door was installed at rectors, a restaurant on time square in Manlathan, located on Broadway West, 43rd and 44th Street.

The Oxford Advanced Learners Dictionary (1980) described a turnstile as a revolving gate that allows one person at a time to enter or leave, for example a football ground or museum. The wings of the turnstile may be constructed using different materials like glasses, so that any entry cab be controlled and recorded. It could be made from bending pipes, It is proper that the wings are transparent.

There is another version of a turnstile and is called a revolving door. A revolving door is used to control traffic or heating and air condition in a building [3]. The revolving door structure consists of individual door panels or wings, a centre structure called a ' rotunda' or 'drum' that is fitted with glass and the ceiling supported by the rotunda, that contains either a Mechanical breaking device that uses a motor to drive the doors automatically. The exact use of revolving doors is unknown. However, it is known that they have been in use since 1970 in Chicago, where they are still widely being used today [4].

Turnstile often use ratchet mechanism to allow the rotation of the stile in one direction, allowing ingress but preventing rotation in the other direction. Some turnstile are designed to operate only after a payment has been made, usually by inserting a coin or token in a slot or by swiping or inserting a paper ticket or electronically encoded card.

Counter are incorporated on turnstile which are often use for counting the numbers of people passing through a gate, even where payment is not involved. They are used extensively in this manner in amusement parks, in order to keep track of how many people enter and exit the park and ride each ride; the first major use of turnstile at a sporting verve was at Hampden Park in Glasgow, Scotland.

There is a difference between a turnstile and a revolving door. The revolving door is always open and closes while a turnstile will only turn when a slight forced is applied on one of the wings and it will cease to do so on removal of the load. A revolving door reduces the amount of heating volume and air conditioning (HVAC) that escapes from the building and these saves energy costs(when using glass wings) whereas a turnstile cannot as the require an applied force.

A revolving door contains an electronic device that uses a motor to drive the doors automatically while a turnstile does not necessarily contain an electronic motor.

A turnstile could be modified or developed to serve the interest of the public in vehicles. For example the entry point of a public commuter as sometimes has a turnstile installed on it. It controls the in and out movements of the commuters. Revolving door systems (in the United States) must be fitted with a panic collapsing mechanism or brisk system that permits the door frames to fold against one another [5]. This book fold position permits an unobstructed exit from the interior to the exterior of the building in the event of a fire or other emergency. The uniform building code (adopted by most municipalities in the United States) require the breakout system together with another manual or automatic swinging or sliding door next to the revolving door for emergency exit and handicap access.

Turnstile can be classified as optical turnstile, full height turnstile and waist high turnstile. In the optical turnstile, it is used in place of traditional arm-style turnstile and is used in location where physical barriers are considered a problem. Optical turnstile generally uses an infra beam to connote patrons and recognize anyone attempting to enter a site without a valid entry pass. Full height turnstile is a larger version of the turnstile commonly about 92,1m high, similar in operation to a revolving door, which eliminates the possibility of anyone jumping over a turnstile unit. Waist high turnstile otherwise known as half high turnstile has been the most popular type of turnstile. They are variants of this type available including one designed to be accompanied by a matching ticket box. Some styles are designed to allow entry only after a payment are inserted.

The basic components of turnstile and counter are: Shaft, wings, ratchet mechanism, Geneva mechanism, gears, bearings, base and counting housing.

The shaft is a rotating machine element which is used to transmit power from one member to another member. The power is delivered to the shaft by some tangential fore and the resulting torque set up within the shaft permits the power to be transferred to various machines linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys, gears etc. are mounted on it.The types of shafts include: Transmission shafts-this shaft transmit power between the source and the machine absorbing power. The counter shafts, overhead shafts and all factory shafts are transmission shafts, since these shafts carry machine parts such as pulleys, gears etc. Therefore they are subjected to bending in addition to twisting.

In machine shafts, these shafts form an integral part of the machine itself, the crank shaft is an example. Materials used for shafts should have high strength, good machinability, low notch sensitivity, good heat treatment properties and high wear resistant properties.

Stresses induced in the shafts include: Bending stress (tensile or compressive) due to force acting upon machine elements like gears, pulleys, etc. as well as due to the weight of the shaft itself; shear stresses due to the transmission of torque; stresses due to combined tensions

Al and bending loads.

In the design of the shaft the following cases may be considered: Is shaft subjected to twisting moment to torque only, shafts subjected to bending moment only or a combination of the two. In additional axial loads present in addition to combined torsion and bending loads.

When shafts are to designed on the basis of rigidity the following types of rigidity are considered-torsional and lateral rigidity. Torsional rigidity is important in case of shaft of an I C engine, where the timing of values would be affected. In lateral rigidity, it is important in case of transmission shafting and shafts running at high speed, where small lateral deflection would cause huge out-of-balance force. The lateral rigidity is also important for maintaining proper bearing clearances and for correct gear teeth alignment.

The turnstile wing is a kind of barrier which is rigidly attached to the shaft. In the case of manually operated turnstile, for the shaft to rotate, force is applied directly on the wing by the individual using the turnstile.

Ratchets are used widely in lifting equipment to lock motion and prevent reverse rotation when the input force is removed. Ratchet can be used to drive a motion in one direction and allow freewheeling in the reverse direction. There are many form of ratchet often requiring some ingenuity in their derivation. Example of ratchet mechanism is a pawl which consists of a wheel with teeth called the ratchet wheel. It receives periodic or intermittent motion from a swinging member called a ratchet or pawl. The pawl ratchet also prevents backward motion. The best example of application is the bicycle chain drive. Types of ratchets included-pawl ratchets, spring blade ratchets, cam driven ratchets, friction ratchets and magnetic ratchets,

The Geneva mechanism is a turning device according to Ferdinand Bear Russell Johnson Jr. ‘It is used in many cutting instruments in order application, where intermittent and in order applications where an intermittent rotary motion is required. Essentially, the Geneva Mechanism consists of a rotating disk and slot into the pin slides.

Geneva mechanism was originally invented by a watch maker. The watch maker only put a limited number of slots in one of the rotating disk so that the system could only go through many rotations. This prevented the spring on then watches to wound to tight, thus giving the mechanism its own name, the Geneva stop. The Geneva stop was incorporated into many of the first film projectors used in theaters. Ray Johnson made many reference to the use of Geneva mechanism to provide an intermittent motion to the conveyors belt of a film recording marching. He also discussed several weak points in the Geneva mechanism. For instance, for each rotation of the Geneva (slotted) gear the drive shaft may start to vibrate, another problem is wear, which is central at the drive pin. Finally, the designer has no control over the acceleration the Geneva mechanism will produce. There are basic types of Geneva motion: eternal Geneva motion (most common), internal Geneva motion and spherical Geneva motion, which is rarely used.

Since the driver wheel in a Geneva motion is always under full control of the driver, there is no problem with overrunning. Impact is still a problem unless the slots of the driver wheel are accurately made and the driving pin enters these slots at the proper angle. For best result, the pin picks up the drivers number as slowly as possible. Impact can also be reduced by leaving the top and bottom of the slot open. However, strength is of primary importance and the slot must be bridged by a web.

The external Geneva and internal Geneva have been used for both light and heavy duties. They are frequently used as inputs to high speed devices such as high speed mechanical counters.

When input and output shafts are being perpendicular few intermittent mechanism are as suitable as the spherical Geneva, but this type is bulky and not practical for significant power levels. Molded or case spherical Geneva is adequate for light duty application [4].

Gears have existed since the invention of rotating machinery. Because of their force-multiplying properties, early Engineers used them for hoisting heavy loads such as building materials. The mechanical advantage of gears was also used for ship anchor horsts and catapult pre-tensioning. Early gears were made from wood cylindrical pegs for cogs and were often lubricated with animal fat grease. Gears were also used in wind and water machinery for decreasing or increasing and providing rotational speed for application to pumps and other powered machine. The rotational speed of a water or horse drawn wheel was typically too slow to use, so a set of wooden gears needed to be used to increase the speed to a usable level.

A gear may be defined as any tooth designed to transmit or receive motion from another member to successively engaging both**.**

Types of gears include: spur, helical, bevel, rack and worm gear. For spur gears both teeth are parallel to the axis of the wheel.

A helical gear has both teeth in form of helix around the gear. The bevel gears are used for transmitting power at a constant velocity station between to shafts whose axis are intersecting at a certain angle, Worm gears are widely used for transmitting power at high velocity ration between non-intersecting shafts that are generally but not necessarily at right angles. It can give velocity ration as high as 300:1. The double helical gear is a cylindrical gear in which a part of the face width is right hand and the other left hand with or without a gap between them. Spiral gears have tooth traces as curved lines other than helices.

Gears can be used to exact velocity ratio, has high efficiency, and is reliable in service. It may be used for small centre distances of shafts, used to transmit power and has compact layout.

It however requires special tools and equipment for manufacture and therefor costly. The error in cutting teeth may cause vibrations and noise during operation. It requires suitable lubricant and reliable method of applying it for the proper operation of gear drives.

The design consideration for gear drive from [6] include:
Power to be transmitted, speed of the driving and driven and center distance.
The following requirements must be met in the design of a gear drive:
(i) The teeth should have sufficient strength so that they will not fail under static loading or dynamic during normal running condition
(ii) The gear teeth should have wear characteristics so that their life is satisfactory
(iii) The use of space and material should be economical
(iv) The alignment of the gears and deflections of the shafts must be considered because they reflect the performance of the gears
(v) The lubrication of the gear must be satisfactory.
The causes of gear tooth failure According to [6] are:
(i) Bending failure- Every gear tooth acts as a cantilever. If the total repetition dynamic load acting on the gear tooth is greater than the beam strength of the gear tooth, then the gear tooth will fail in bending. In order to avoid such failure, the module and free with of the gear is adjusted as that of the beam strength.
(ii) Pitting-It is the surface fatigue failure which occurs due to many repetitions. Hertz contact stresses the failure occur when the surface contact stress are lighter than the endurance limit of the material. The failure starts with formation of pits which continue to grow resulting in the rapture of the tooth surface. In order to avoid the pitting, the dynamic force used between the gear teeth should be less than the wear strength of the gear tooth.
(iii) Scoring- The excessive heat is generated when there is an excessive surface pressure, high speed or supply of lubricant fails. It is a stick-slip phenomenon in which alternate shearing and welding takes place rapidly at high spots. This type of failure can be voided by properly designing the parameters such as speed, pressure and proper flow of the lubricant so that temperature at the rubbing faces is within the permissible limits.
(iv) Abrasive wear-the foreign particles in the lubricants such as dust, dirt or burn enter between the tooth and damage the form of the tooth. This type of fail can be avoided by providing filters for the lubricating oil or by using high viscosity lubricant oil which enables the formation of thicker oil film and thus permit the passage of such particles without damaging the gear surface.
(v) Corrosive wear-the corrosive of tooth surfaces is mainly caused by additive, present in the lubricating oils. In order to avoid this type of wear, proper anti-corrosive additives should be used.

II. Materials and Methods

2.1 Design Criteria

It is required to design and produce a turnstile that can allow one person at a time into the library

2.2 Theory of operation

The machine works on the principle of Geneva mechanism that allows rotation or movement in one direction. It has a four divided member which on rotation allows one person at a time into the library.

2.3 Design Analysis

The torque applied on a given shaft is given in Equation 1

$$T = \frac{Jr}{\tau} \quad \text{Equation 1}$$

Where J is the polar moment of inertia, r is the distance from neutral axis to the outer most fiber and τ is the shear force [7].
For a hollow shaft J is expressed in Equation 2

$$J = \frac{(d_0^2)\pi}{32} \quad \text{Equation 2}$$

where d_0 the outer diameter, d_i is the inner diameter
For a solid shaft, the Equation reduces to Equation 3

$$J = \frac{(d_0^2 - d_i^2)\pi}{32} \quad \text{Equation 3}$$

For a shaft subjected to bending Equation 4 applies

$$M = \frac{I\sigma_b}{Y} \quad \text{Equation 4}$$

Where M is the bending moment, I is the section modulus, Y is the distance ($Y = \frac{d}{2}$) and σ_b is the bending stress.

For a solid round shaft Equation 5 is used

$$I = \frac{\pi d^4}{64} \qquad \text{Equation 5}$$

For a hollow shaft, Equation 6 applies as:

$$I = \frac{\pi(d_0^4 - d_i^4)}{64}$$

There are times that shafts are subjected to a combined twisting moment and bending, various theories have been suggested to account for the elastic failure of the materials [4]. The following two theories are important from the subject point of view:

(i) Maximum shear stress theory or Guest's theory. It is used for ductile materials such as steel

(ii) Maximum normal stress theory of Rankin's theory. It is used for brittle materials such as cast Iron

Let τ is the shear stress induced due to twisting moment and σ_b the bending stress (tensile or compressive) induced due to bending moment, according to maximum shear theory the maximum shear stress in the shaft is:

$$\tau_{\max} = \frac{1}{2}\sqrt{\sigma_b^2 + 4\tau^2} \qquad \text{Equation 7}$$

In dynamic load rating for rolling contact bearings under variable loads, the following Equation in 8 is fundamental:

$$L = \frac{[C]^K x 10^6}{W} \qquad \text{Equation 8}$$

where L is the rating life, C is the basic dynamic loading rating and W is the Equivalent dynamic loads and K= 3 for ball bearings and $10/3$, for roller bearings. The relationship between the life in revolutions (L) and working life is expressed in Equation 9

$$L = 60N.L_H revolutions \qquad \text{Equation 9}$$

The design Equations for spur gears are given in Equations 10, 11 and 12 respectively.

$$W_T = \frac{PC_S}{V} \qquad \text{Equation 10}$$

where W_T is the permissible tangential tooth load, P is the power transmitted, V is the pitch line velocity and D the pitch circle diameter.

$$V = \frac{\pi DN}{60} \qquad \text{Equation 11}$$

The circular pitch is expressed as:

$$P_c = \frac{D\pi = \pi m}{T} \qquad \text{Equation 12}$$

$$m = \frac{D}{T} \qquad \text{Equation 13}$$

where m is the module and T is the number of teeth

The pitch line velocity may be obtained by using the under mentioned expression

$$V = \frac{\pi DN}{60} = \frac{\pi mTN}{60} = \frac{P_c TN}{60} \qquad \text{Equation 14}$$

Research design specifications

Diameter of the shaft= 24mm

Diameter of the smaller shaft= 17.5mm

Diameter of the driven gear (gear attached to turnstile shaft) =24mm

Diameter of counter shafts

Diameter of bigger shaft=6mm

Diameter of smaller shaft=5mm

Diameter of the driven gear=3mm
Since the counter has five gears(the driven is gear 2 and the other four counter gears of which numbers are indicated on each make up gear:3,4,5 and 6 respectively.
Number of teeth of the Turnstile gear (gear 1)
Driver
Number of teeth=45
Number of teeth on the driven gear (gear 2)
Number of teeth =35
Number of teeth of the four remaining teeth is 30 each
Speed
Speed of gear 1, 2,3,4,5 and 6
According to [5], Equation 15 applies

$$i = \frac{z_g}{z_p} = \frac{n_g}{n_p} \quad \text{Equation 15}$$

where z_p is the number of teeth on pinion z_g is the number of teeth on gear, n_p speed of pinion and n_g is the speed of gear.

For gear1 and 2 $\frac{z_2}{z_1} = \frac{n_1}{n_2} = \frac{45}{35} = \frac{360}{n_2}$ (from Equation 15)

$$n_2 = 280rpm$$

For gear 2 and 3 $\frac{z_3}{z_2} = \frac{n_2}{n_3} = \frac{35}{30} = \frac{280}{n_3}$ (from Equation 15)

$$n_3 = 240rpm$$

For gear 3 and 4 $\frac{z_4}{z_3} = \frac{n_3}{n_4} = \frac{30}{30} = \frac{240}{n_4}$ (from Equation 15)

$$n_4 = 240rpm$$

For gear 4 and 5 $\frac{z_5}{z_4} = \frac{n_4}{n_5} = \frac{30}{30} = \frac{240}{n_5}$ (from Equation 15)

$$n_5 = 240rpm$$

For gear 5 and 6 $\frac{z_6}{z_5} = \frac{n_5}{n_6} = \frac{30}{30} = \frac{240}{n_6}$ (from Equation 15)

$$n_6 = 240rpm$$

The torque in each gear shaft (turnstile) is given by Equation 16.

$$T = \frac{60P}{2\pi n_1} \quad \text{Equation 16}$$

Where P is the power and n is the number of revolutions
Torque can further be expressed as:

$$T = W_1 T_n r_n \quad \text{Equation 17}$$

$$r_n = \frac{d_n}{2} \quad \text{Equation 18}$$

$$T_1 = 60x10^6 x3kw/2x3.142x360x2/24 = 6630.6mm$$

$$T_2 = 60x3kwx10^6 / 2x3.142x360x2/17.5 = 9093.4mm$$

Torques in counter shaft $T_2 = 9093.4mm$

Diameter of the bigger shaft=6mm

$T_1 = 60x3kwx10^6 / 2x3.142x360x2/6 = 26522.4mm$

Diameter of the smaller shaft=5mm

$T_2 = 60x3kwx10^6 / 2x3.142x360x2/5 = 31826.9mm$

Torque of the drive gear

Since the diameter of the driver gear=24mm

$T = 60x3kwx10^6 / 2x3.142x360x2/28 = 8525mm$

Gear ratio $= \frac{D_1}{D_2} = \frac{N_1}{N_2}$, Equation 19

Where $D_1 = 24mm$ the diameter of gear is, $D_2 = 17.5mm$ is the diameter of pinion, $N_1 = 360rpm$ is the speed of the turnstile shaft, $N_2 = 240rpm$ and is the speed of the shaft.

From here, gear ratio=1.2

2.4 Design drawings

The design drawings are shown in Figures 1, 2, 3 and 4 respectively.

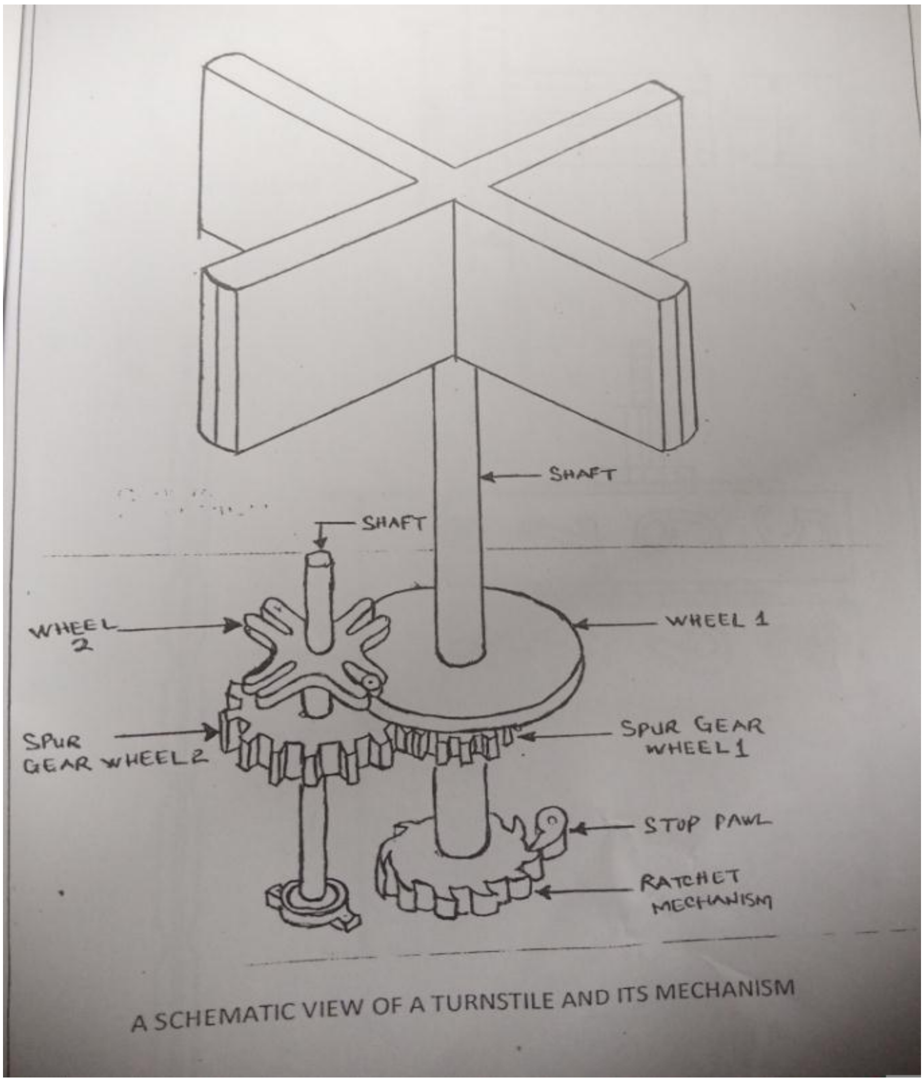


Figure 1: A Schematic View of a Turnstile and its Mechanism

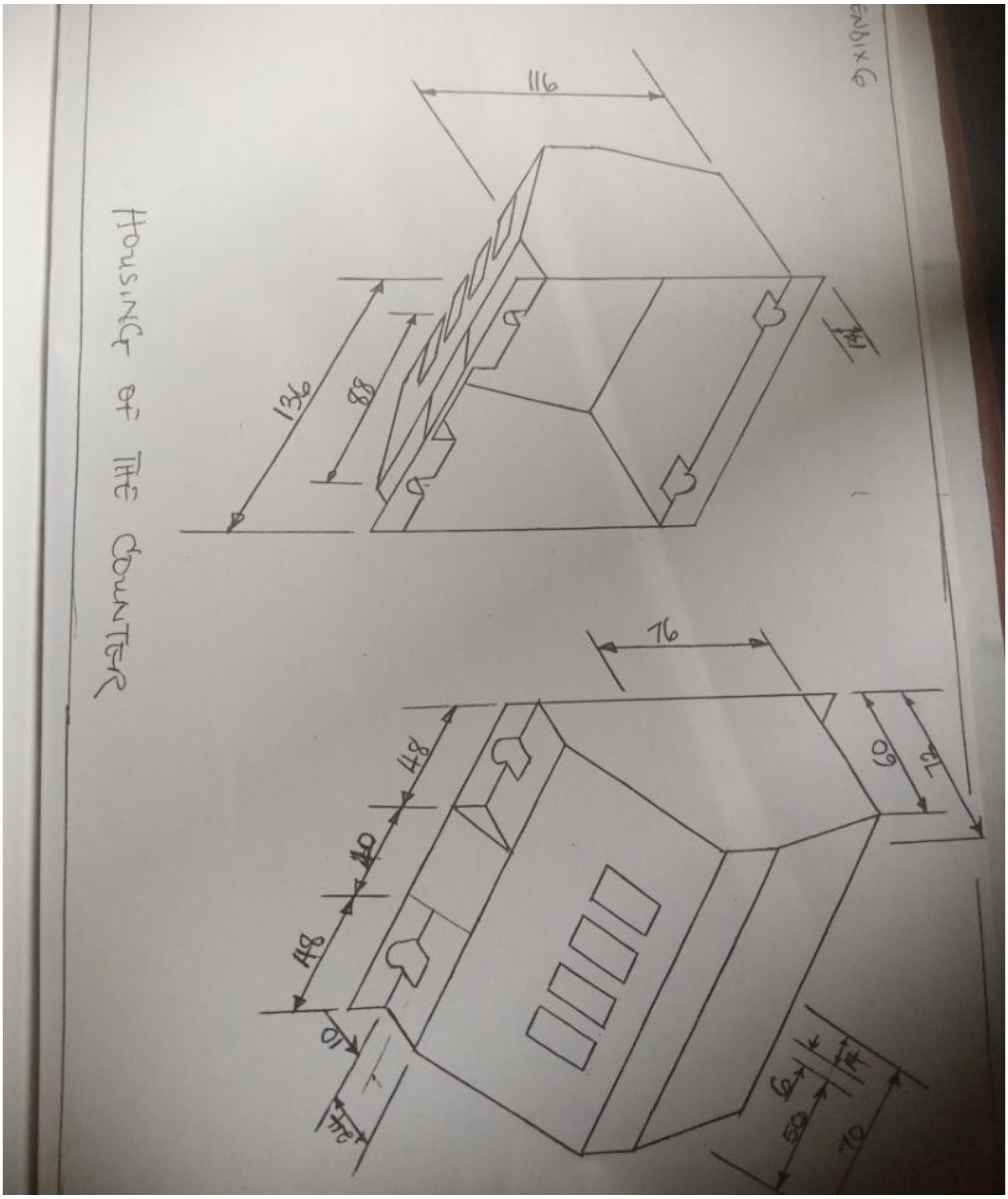


Figure 2: Counter Housing

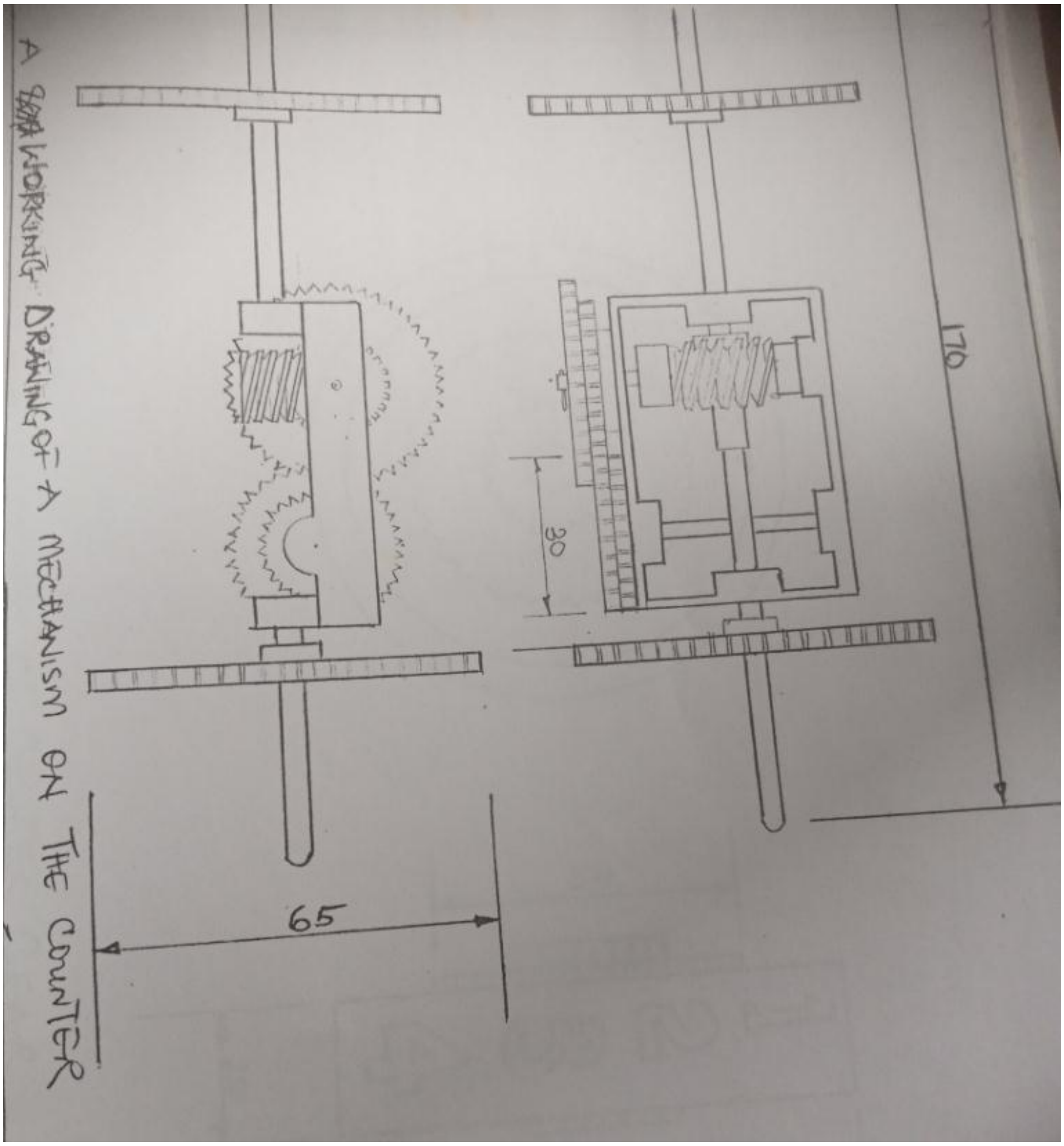


Figure 3: Counter Mechanism

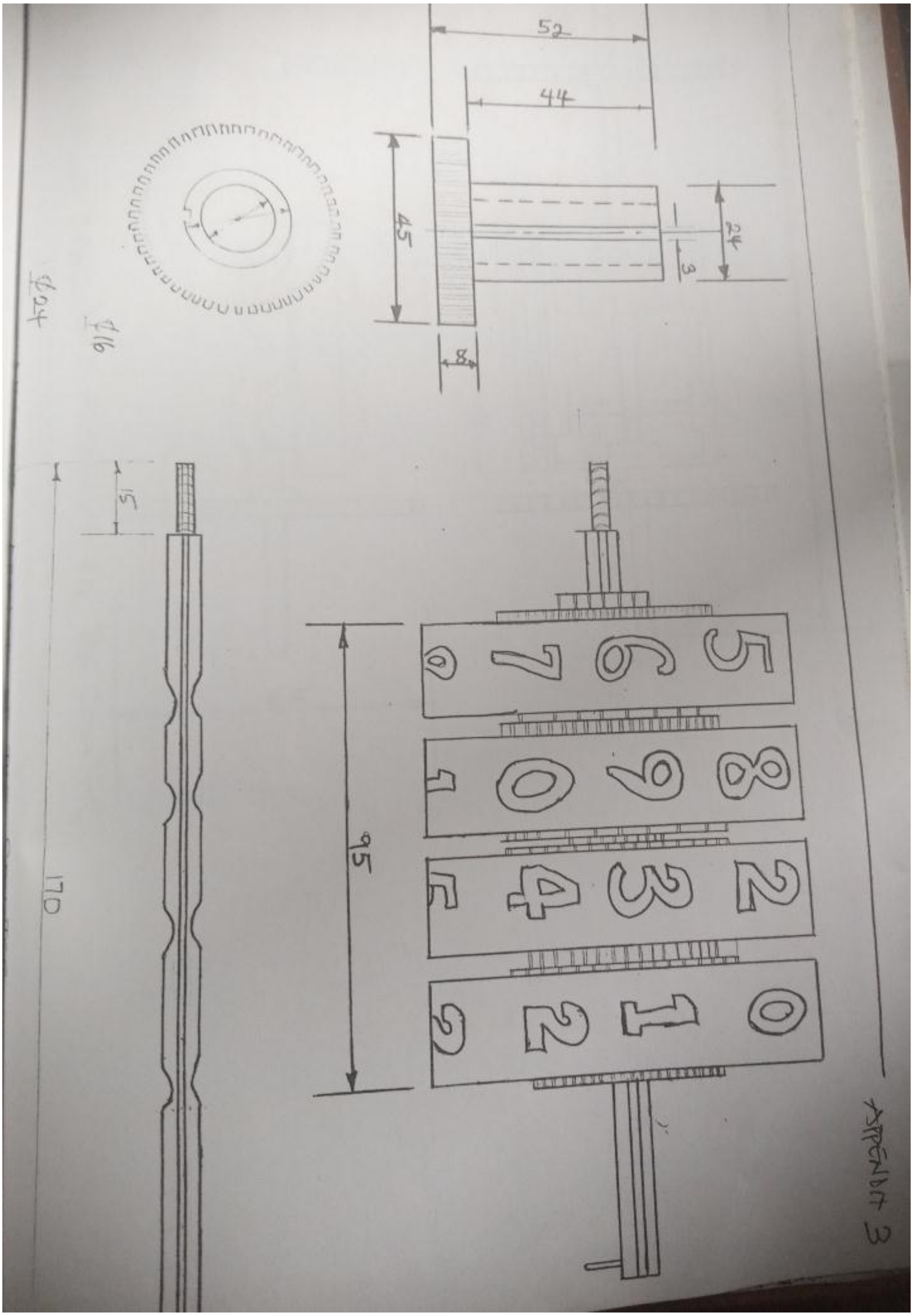


Figure 4: Counter Display

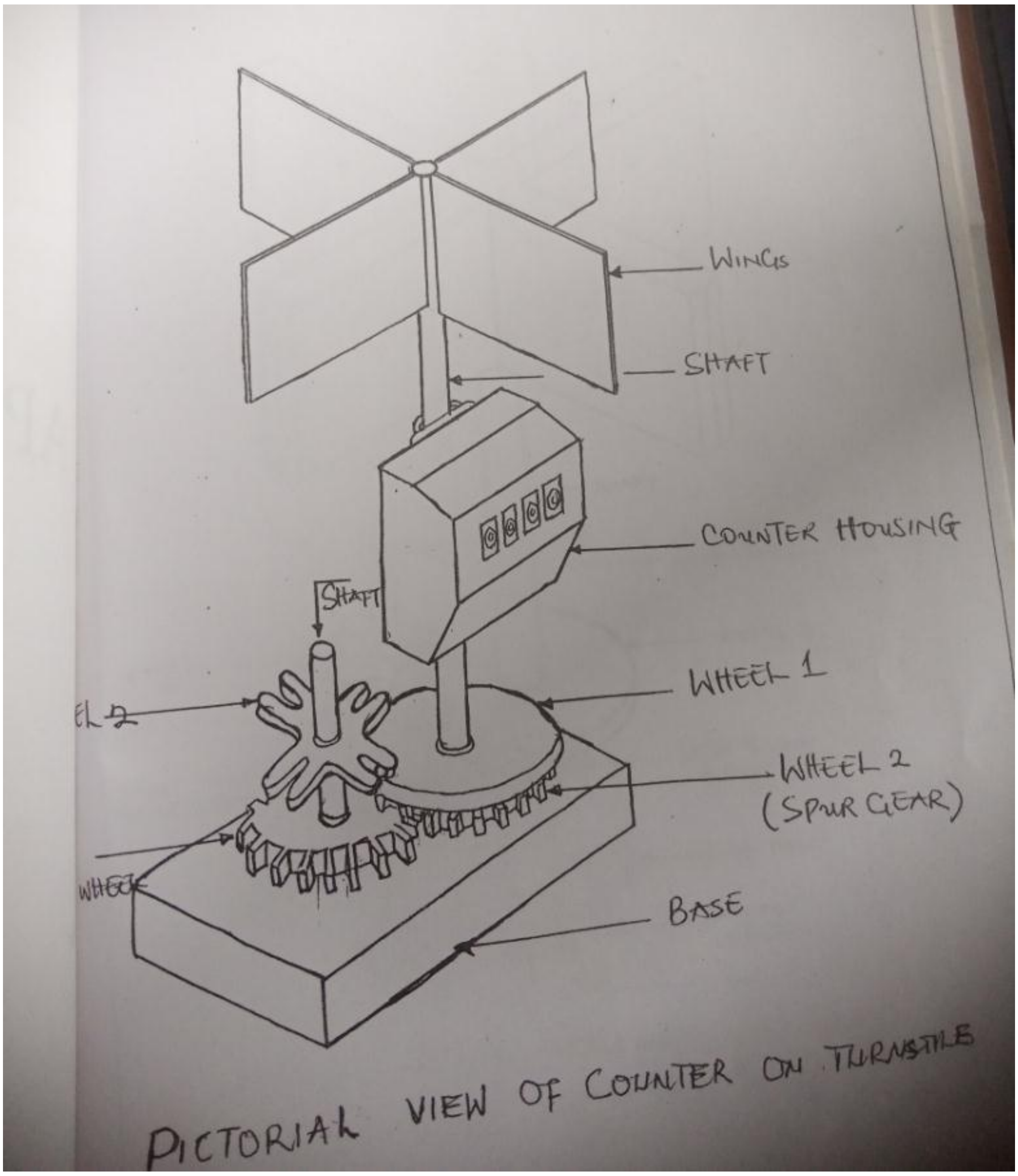
III. Results and Discussion

3.1 Result

After the manufacture the different components of the counter were assembled in their respective positions. The counter incorporated on turnstile consists of two shafts. One is the driver and the other is the driven. The Geneva mechanism consists of two wheels, the driver and the driven. The driver wheel was rigidly fixed to drive the shaft and the driven shaft such the pin on the drive wheels enters the slot in the driven wheel smoothly.

The pawl ratchet consists of the ratchet wheel and the stop pawl was properly positioned. The ratchet wheel was fixed to the base such that it opposes motion in the reverse direction.

The turnstile produced consists of twenty-seven parts. Good surface finish was used to ensure a good finish. The machine was tested and confirmed satisfactory. Figure 5 shows the pictorial view of the counter with the turnstile produced.



3.2 Discussion

The turnstile was mounted and tested for its performance evaluation and it was able to control the entry and exit of library users. The turnstile installed also functions as a counter and could help to record the number of students entering the library. This records can be used by management to know the number of students using the library and could use in management's decisions. The turnstile produced here is manually operated and is very useful where power supply is epileptic as it does not need any form of power supply.

IV. Conclusion

The design objective of designing and producing the counter on the turnstile was archived. It allowed only one person at a time to enter and leave the library and also records the number of students entering the library within a given period. The counter with the turnstile can count a maximum of 10,000 people before a reset. The introduction of the turnstile at the entrance of the library will help to know the number of users on daily or weekly basis and will also help management in decision making. Further work is recommended for digital counter, especially where power supply is not a problem.

References

[1] Hornby, B. Advanced Learners Dictionary (1980)
[2]Okon, E.E.; Ikpe, A.E (2009) Design and Development of a Turnstile, University of Uyo.
[3] Alan, B. The Revolving Door (1881): Architecture in Detail, 200.ISBN 9090 1374-3-3. [4] Boonedam Inc.(200) www. Boonedam. Us(20th August,2010)
[5] Khurmi, R.S. and Gupta, J.K.(2006). Machine Design, Multi-Colour Colour Edition , Ecuresid Publishing House, India.
[6] Khurmi, R.S. and Gupta, J.K.(2004). Theory of Machines, 2 Colour Edition , Ecuresid Publishing House, India.
[7] Shily, S. A. (2004) Machine Desgn two Colour Edition, Eurasid Publishing House, India.