Design and Development of Volley Ball Practice Machine

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Abstract - There are many games played in the world. The Volleyball is one of the popular games in the world. Nowadays the players are trained with the help of practice machine. In volleyball the practice machines are only develops the "Pass" skill to the players. In this project the automated volleyball machine was fabricated to develop the skill set of "Pass, Set, Attack, and Dig," to the players. In Volleyball, the ball motion involves aerodynamic and mechanic principles. It demands superior Bio-mechanical skills acquired by repeated practices. To simulate different varieties of motions, speeds, and trajectories accurately and repeatedly, an automatic volleyball practice machine was designed by iterative design processes (manual calculations) with solid works and AutoCAD. Two counter rotating wheel mechanism imparts both translational and rotational motions with spin. It was portable, flexible, battery powered (suitable for outdoor conditions), operable at various horizontal and vertical planes and desired combinations of both planes. It was fully automatic for the ball feeder mechanism to make it self contained, yet made economical by making the ball shooter mechanism partially automatic/manual. The model was validated. The volleyball practice machine was simple and user friendly, to assist in acquiring the required skills for a trainee independently or for a professional player to enhance his/ her skills.

Keywords – Mintonette, spectator, prototype, ball shooter, ball feeder, etc

I.INTRODUCTION

The purpose of this project is to design an automated ball throwing mechanism for training in the sport of Volleyball. Volleyball is a challenging, point-based competitive team sport that is played both outdoors and indoors. The sport is played by two opponent sides which have a 2.43 meter (max.) high net separating the court.

Mr.William G.Morgan invented volleyball in 1895 at the Holyoke, Massachusetts (USA), YMCA (Young Men's Christian Association) where he served as Director of Physical Education. Morgan originally called his new game of volleyball, "Mintonette". The name volleyball came about after a demonstration game of the sport, when a spectator commended that the game involved much "volleying" and game was renamed volleyball.

Figure 1: Inventor of volleyball: Mr.William G.Morga

Skills in Volleyball

There are six basic skills available in this game. They are

- Serve
- Pass
- Set
- Attack
- Block
- Dig

These skills are shown in Figure 3.

This game begins with the server and the opponent side is then allowed to use only hands to make contact with the ball and throw the ball over the net. The rules of the game allow players to make contact to the ball up to three consecutive times per side. During the volleyball game, both teams will make different powerful moves to the ball to go to the opponent side and fall within the boundary line of the court. See Figure 2 for volleyball court dimensions, as specified by the Federation of International Volleyball (FIVB).

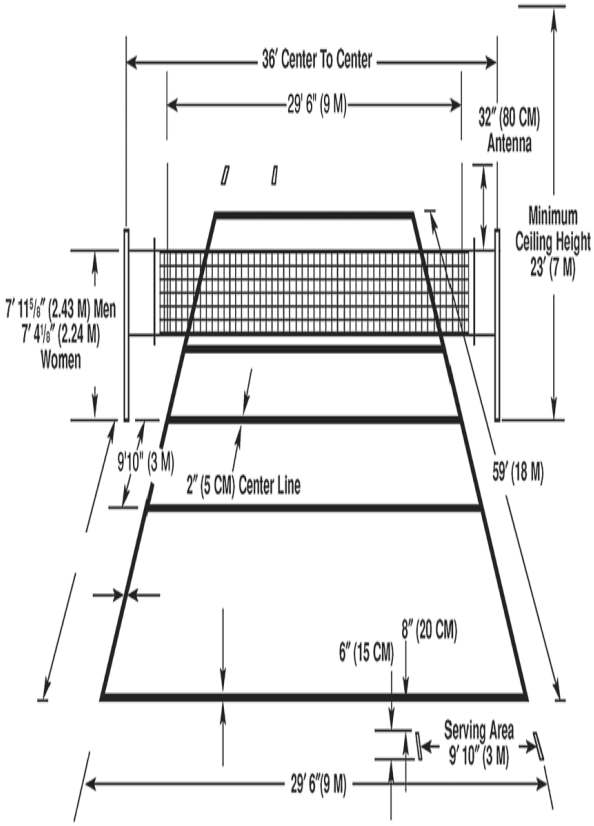


Figure 2: Dimensions of Official Volleyball Court

Figure 3: Basic skills in Volleyball: a) i – Serve (Overhand serve), a) ii – Serve (jump serve), b) Pass, c) Set, d) Attack, e) Block, f) Dig

Although volleyball is a growing sport, there are a limited number of advanced athletes and coaches available to train new players in the world. Since the game requires complex ball control skills, it is important for volleyball players to have sufficient and thorough training. This training can be a time and labour-intensive process. For example, during practice sessions, the team members are trained by coaches who use their labour and manual training techniques to generate a variety of ball motion to train players. Manual training might involve throwing the ball by hand, or hitting the ball with a wooden paddle to athletes for defense and offence drills. It is a difficult and time consuming process because a volley ball coach's arms will get tired after hitting 30 balls consecutively (approx.). For three hours per day of training sessions, a coach may have to hit the ball repeatedly up to 300 times approximately. In addition, the accuracy of human-generated ball motion cannot be controlled, and this can effect development of athlete's throwing skills.

One way to develop ball control, throwing skills and to address the other training problems discussed above is to use an automated mechanism that generates motion of the Volleyball. Although there are ball throwing machines available for other sports, such as baseball, tennis, table tennis, and soccer, none of these machines have been designed to specifically meet the needs of the unique sport of volleyball.

Most volleyball has three levels of construction. The first level is a rubber bladder made from the same material as a bicycle inner tube. The bladder is then attached to a cloth layer made of material similar to cheese cloth and sealed with rubber type glue. The outer layer is made of leather and is glued to the cloth layer.The balls that are used in this game are 0.3-0.35 kg in weight. The ball has a hollow spherical shape 200-225 mm in diameter.

In order to find out what principles are used in other types of ball throwing machines, research on the various types of commercially available ball machines was done as a background of study. There are several ball throwing machines available on the market. The most common principles involved with these machines are rotating lever arm, propulsion system and two counter rotating wheels.

Currently there is no automatic training device for coaching and helping volleyball players to improve their skills commercially available on the market. This study hopes to provide a new educational and training tool for youth and professional volleyball players to practice repeatable drills and a variety of movements to improve their ball control skills.

II. METHODOLOGY

The scope of this project includes gathering kinematic data on the types of ball motion generated in volleyball and using this data and other research in order to design and build a novel automated volleyball throwing mechanism to be used for training athletes. The overall plan for the methodology and design of this study can be described in three main parts:

1. Kinematic Data: Study and measure kinematic data of ball motion in actual performance of volleyball players.
2. Design: Describe design specifications and requirements and generate computer model of a prototype mechanism. Build, assemble and iteratively adjust prototype to ensure mechanism is in working order.
3. Testing Validation: Ensure whether the machine is capable of creating realistic volleyball motion.

III. DESIGN

Most volleyball games are played outdoors and this prototype was designed to meet these conditions. To design a ball throwing mechanism capable of being used for volleyball training it is important that design specifications are identified.

Design Requirements

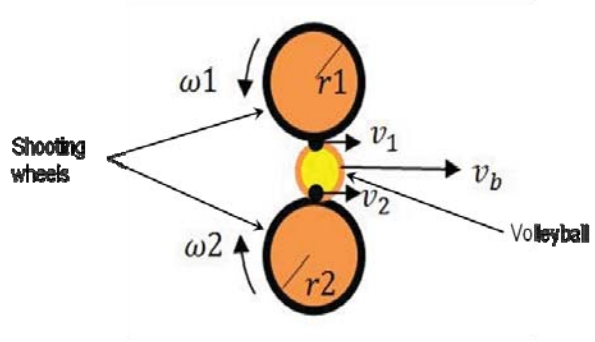
The prototype must be:

1) Portable: Transportable from one location to another location.
2) Easy to take apart and assemble.
3) Partially automatic: operating by itself or by using only a few controls.
4) Sufficient ball capacity: able to contain up to 10 balls.
5) Battery powered: able to run the machine without electrical outlet.
6) Able to generate ball speeds from 10- 30 m/s.[1,5]

7) Able to shoot the ball from 9-18 meter in distance.
8) Able to adjust ball release point from 1-2 meter high from the ground.
9) Able to provide various time intervals of ball release: 6-10 balls/minute.
10) Able to adjust ball launching angle along a vertical plane.
11) Able to adjust ball launching angle along a horizontal plane.

SELECTION OF MOTOR

Diagram:



where,

r1,r2 = radius of shooting wheels
v_1,v_2 = velocity of shooting wheels
v_b = velocity of the ball
ω1, ω2 = angular velocity of shooting wheels

Data:

1. Mass of the ball = 300 gm
2. Shooting Wheel diameter = 200 mm [8]
3. Shooting wheel mass = 1.35 kg [8]
4. Maximum ball velocity = 30 m/s [1,5]

Calculation:

v_b = $(v_1+v_2)/2$
r = r1 = r2
ω = ω1= ω2
v = ωr
r = 100 mm = 0.1 m
ω = v/r = 30/0.1 = 300 rad/s

Convert to RPM :- ω/2Π = 300/2 Π = 47.75 rps
= 47.75 x 60 rpm
= 2865 rpm

Motor without load requires RPM = 2865 rpm

Assume that factor of safety of load acting in motor shaft is = 1.5

Suitable motor speed to generate ball speed at 30 m/s is = 2865 x 1.5
= 4297.5 rpm
= 4300 rpm (or)
= 450.3 rad/s

Calculate the amount of kinetic energy for ejecting the ball at 30 m/s:

KE_b = $mv^2/2$
= $(0.3 \times 30^2) / 2$
KE_b = 135 J

Calculate the amount of energy stored in a shooting wheel:

E_s = $I\omega^2/2$
I = $mr^2/2$
= $(1.35 \times 0.1^2) / 2$
= 6.75×10^{-3} kg.m^2
E_s = $6.75 \times 10^{-3} \times 450.3^2/2$

E_s = 684.4 J

Calculate the total power needed:

Total energy = $Ke_b + E_s$
= 135 + 684.4
E = 819.4 J

Power (P) = E / t
= (10 x 819.4) / 60 (assume 10 balls/minute to be ejected)
P = 136.6 Watts (or) 0.18 hp

Assume that the factor of safety is 3.
Therefore $P_{total} = 3 \times 0.18 = 0.54$ hp

Motor specifications needed for shooting balls at 30 m/s & 10 balls/minute are 0.54 hp with 4300 rpm.

IV. PRINCIPLES AND DESIGN OVERVIEW

Ball Shooter

In reviewing the basic volleyball kinematics, a basic principle that needs to be considered in the design of the volleyball throwing mechanism is projectile motion. After observing volleyball motion in live matches, the ball exhibits both translational and rotational motions. The characteristic of these motions led to the decision to use the principle of the two counter rotating wheels as the main ball shooter component of the mechanism. The two wheels rotate in different directions, generating speed on the wheels' surface which imparts speed on a ball propelled between these wheels. Equation 4.1 is used to calculate velocity of the wheel's surface (v) where ω is angular velocity (rpm) of the wheel and r_w is radius of the wheel.

$$v = \omega r_w \quad (4.1)$$

The following equation can be used to calculate ball linear velocity (v_b) based on the velocities of the two points of contact (v_1 and v_2) between the wheels and the ball:

$$v_b = (v_1 + v_2)/2 \quad (4.2)$$

A spin may also be produced when the two wheels spin at different speeds. This spin is imparted about an axis which is perpendicular to the ball linear velocity vector.

The radius of the volleyball is 100 mm. Several volleyball movements impart spin on the ball, to create this type of spinning ball motion using the volleyball throwing mechanism, the counter rotating wheels need to spin at two different speeds; if the top wheel spins faster than the bottom wheel it will create a top spin on the ball. On the other hand if the bottom wheel spins faster than the top wheel, the ball will produce an under spin.

Since the volleyball is synthetic rubber surface, the two counter rotating wheels need to provide some cushion on the ball to help propel the ball out; furthermore a hard solid wheel could break the ball; thus pneumatic rubber wheels were selected as the wheel type so that the air pressure could cushion the ball and help avoid ball damage. The two rubber wheels selected for the ball shooter were 200 mm in diameter and 50 mm in width. The two wheels should have a gap size between them that is a little less than the diameter of the volley ball (200 mm) to allow for the wheels to press the ball out when it is received in between the two wheels.

Since the mechanism is portable, a 12 volt rechargeable battery can be used as the power source. The two wheels are driven by two separate DC motors. Calculations are made to determine the size of the motor that is suitable to produce the required ball speeds of up to 30 m/s. The revolutions per minute for a suitable motor to generate ball speed at 30 m/s are 4300 RPM.

Because the design requirements specify the need to adjust the launching angle along a vertical plane, the mechanism of a rotating fixed axis between the frame and the ball shooter was applied. Changing the launching angle is important because the different volleyball movements, such as serving and digging, depend on a variety of angles. This mechanism also allows horizontal angle adjustment. This horizontal angle changing feature is mounted to the base which freely moves along a vertical axis.

Ball Feeder

Since the mechanism must provide volleyballs to the ball shooter automatically, a ball feeder component was designed. The ball feeder needed to vary the individual drop rate of balls by set time intervals. The design of

the ball feeder also needed to meet the size requirements of the volleyball, and hold a capacity of 10 balls at the smallest feeder size possible. Based on the principle of uniform rotation, a rotating wheel was used as the mechanism to transport single balls in different time intervals to the ball shooter. This component is automatically rotates and drops the volleyballs at regular intervals (i.e. every 6 seconds) to the ball shooter.

The ball feeder also consists of a ball hopper where the balls are inserted into a basket, to allow the balls to drop into the wheel one at a time. The rotating wheel is driven by DC Motor. The ball feeder can be taken apart from the ball shooter for ease of transportation of the mechanism and for flexibility in using the mechanism.

Control box

Controllers are needed to switch the motors on, change the speed, and set ball release time intervals. The mechanism design should be as simple as possible using only a few controls. Three DC motor speed controls were selected for the mechanism – two to control the ball shooter motor and one to control the ball feeder motor. In order to vary the time interval of the ball release from the ball feeder, the DC motor speed controller is used to modify time intervals of dropping balls in the ball feeder. Similarly the controllers for the ball shooter are used to change the motor speed of the ball shooter and in turn impact the launch speed of the ball. The three speed controllers are housed in a control box. Refer figure 4 for a block diagram of the motor speed controllers for the volleyball throwing mechanism.

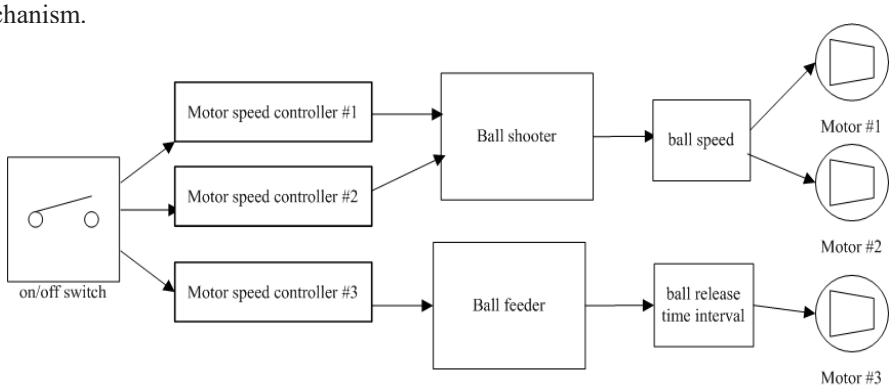


Figure 4: Controllers for ball throwing

Base

Since the mechanism must be portable and needs to hold steady while the balls are released, the base was designed with four lockable caster wheels that can swivel at full 360 degrees of rotation. The height can be adjusted by lifting and placing a telescopic pole into the tube and inserting a bolt into the hole to support the bottom of the telescopic pole. The telescopic adjustable pole is attached to the base to further adjust the height of the mechanism, allowing for the range of required ball releasing heights.

A computer model of the prototype mechanism was designed using Solid works, Education Edition software which provides 3D design functions.

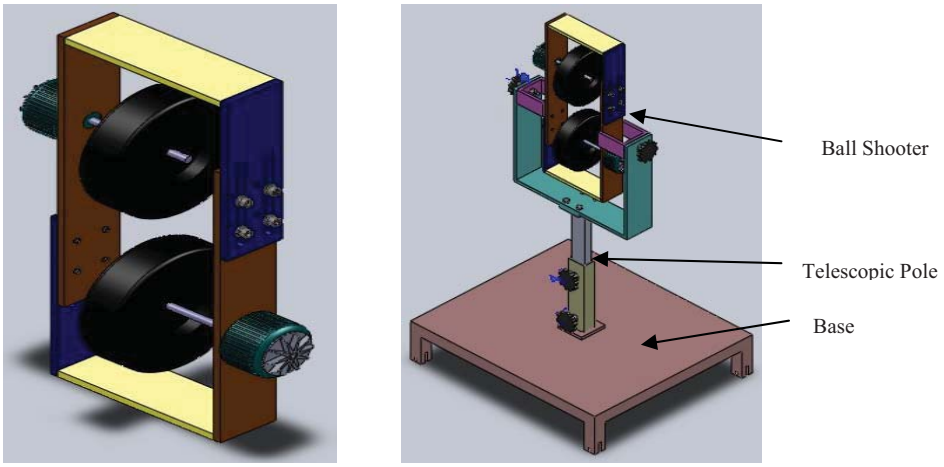


Figure 5: Computer model of volleyball throwing machine prototype

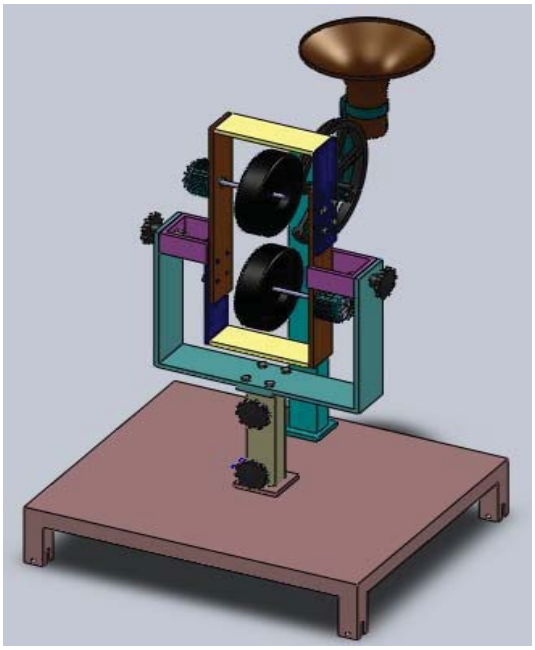


Figure 6: Computer model of volleyball throwing machine prototype showing ball shooter and ball feeder

Design Requirements

The design requirements were reviewed and showed that the volleyball throwing machine is capable of meeting 10 out of 11 design requirements. See Table for details on how the mechanism met the requirements.

Table 1: Comparison of design and actual

S.No.	Design Requirements	Design	How did the mechanism meet the requirements
1	Portable: Transportable from one location to another location by vehicle.	✓	It can be Transport from one place to another
2	Easy to take apart and assemble.	✗	Did not meet because the weight is high.
3	Partially Automatic: operating by itself or by using only a few controls.	✓	Partially automatic ball feeder.
4	Sufficient Ball Capacity: Able to contain up to 10 balls.	✓	Able to hold 10 balls at a time.
5	Battery powered: able to run the machine without electrical.	✓	Rechargeable battery power can be used.
6	Able to generate ball speeds from 10- 30 m/s.	✓	Speeds up to 30 m/s can be obtained by using the selected motor.
7	Able to shoot the ball from 9-18 meter in distance.	✓	Ball distances up to 18 meter can be obtained by using the selected motor.
8	Able to adjust ball release point from 1-2 meter high from the ground.	✓	Ball release points found at these heights using telescopic adjustable pole.
9	ball launching angle adjustable along a horizontal plane	✓	Used four swivel wheels to adjust horizontal rotation.
10	Ball launching angle adjustable along a vertical plane.	✓	Tilted ball shooter to adjust vertical angles.
11	Able to generate various time intervals of ball release.	✓	Ball release time intervals of 6 seconds and 10 seconds can be obtained.

The only one design requirement that wasn't met was easy to apart and assembles. This requirement wasn't met because the weight of the machine is high. In the future, more lightweight materials such as aluminum might be

considered for the ball shooter to minimize weight. Also some of the steel parts could be cut into smaller, lighter sizes with more time and availability of the machine shop. In future designs, plastic could be used to decrease weight of the ball feeder.

During the manufacturing process, the design was iteratively adapted to ensure the machine worked in the desired way. For example, connecting the motor shaft to the counter rotating wheels of the ball shooter and getting the wheels to spin without vibration was a big challenge because the shaft was designed to be supported on one side of the wheel. For future designs, the motor axis support must be more balanced with the wheels and the shaft should be supported on both sides of the wheels to ensure stability and increase performance and accuracy of the mechanism.

Overall the mechanism meets the needs of volleyball players. The volleyball throwing mechanism as designed can generate the serving and train the players for passing, setting, blocking and digging skills which are needed to practice the unique sport of volleyball.

VI. CONCLUSION

In most of the games, players are trained with the help of practice machines. In volleyball, the available practice machines develop only the "Pass" skill to the players. If the practice machine trains the players in the skill set of "Pass, Set, Attack, and Dig" that can produce skilled players. So the automated volleyball practice machine was designed and fabricated to develop the skill set of "Pass, Set, Attack, and Dig" by changing the ball launching angle along vertical and horizontal plane. This new machine has additional features such as portable, battery operated; generate different ball speeds at different heights and automatic ball feeding at a specified time interval.

The objective to build the first prototype for a volleyball throwing mechanism has been met and tested. The new volleyball throwing mechanism is capable of recreating realistic volleyball motion and can even be used by one person. This work can be used as base standard information for future reference for others interested in this kind of ball motion, ball mechanism and the study of developing skills in other games.

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