DESIGN AND FABRICATION OF THROWER MECHANISM FOR TENNIS BALL MACHINE

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"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive)."

Signature: …….

Supervisor: …….

Date: ...……..

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This report submitted in partial fulfillment of
the requirement for the award of
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DECLARATION

"I hereby declare that the work in this report is my own except for the summaries and quotations which have been duly acknowledged."

Signature: …….

Author: …….

Date: ...……..

DEDICATION

This report is specially dedicated to my

beloved family, lecturers and friends.

ACKNOWLEDGEMENT

This thesis is the culmination of four years studying Bachelor of Mechanical Engineering (Automotive) at Universiti Teknikal Malaysia Melaka. I have survived four years here to finish my study with help and cooperation of many people. I would like to thank them here. First of all, Alhamdulillah, praise to Allah S.W.T. for giving me a chance and opportunity to accomplish this Projek Sarjana Muda. I would like to express the most appreciation to my project's supervisor, Mr. Herdy Rusnandi, who has giving me a great support and encouragement throughout the project. Without him, it would be difficult for me to complete this project successfully.

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ABSTRACT

There are three main objectives in producing the thrower mechanism of the tennis ball machine. The first objective is to design a prototype of thrower mechanism for tennis ball machine. While for the second objective is to fabricate a prototype of thrower mechanism for tennis ball machine. Last but not least is to reduce the production cost of this machinery by using low cost materials.

For this project, there are three different concept designs generated. Each design has its own characteristics. One of them needs to be chosen to pursue this project. So Pugh Concept Selection Method is used to select the best concept design for this project. Then concept design which used rotating wheels is selected as the best concept design.

The fabrication of this tennis ball machine is using materials which are easily available in markets. The materials selection is based on the lower price because one of the project's objectives is to reduce the production cost. Furthermore, local and recycles products are used as the machine's components.

This project not only focuses on the thrower mechanism, but generally the whole tennis ball machine is constructed. So when the construction finished, this machine can benefit many people especially Malaysian tennis players.

ABSTRAK

Terdapat tiga objektif utama dalam menghasilkan mekanisma pelontar pada mesin bola tenis ini. Objektif pertama adalah untuk mereka bentuk prototaip mekanisme pelontar untuk mesin bola tenis. Manakala bagi objektif kedua adalah untuk memfabrikasi prototaip mekanisme pelontar untuk mesin bola tenis. Dan yang terakhir adalah untuk mengurangkan kos pengeluaran jentera ini dengan menggunakan bahan-bahan berkos rendah.

Untuk projek ini, terdapat tiga konsep reka bentuk yang berbeza dihasilkan. Setiap reka bentuk mempunyai cirri-ciri tersendiri. Salah satu daripada reka bentuk tersebut perlu dipilih bagi meneruskan projek ini. Konsep Pemilihan Kaedah Pugh digunakan untuk memilih konsep reka bentuk yang terbaik untuk projek ini. Kemudian konsep reka bentuk yang menggunakan roda berputar dipilih sebagai konsep reka bentuk yang terbaik.

Fabrikasi mesin bola tenis ini menggunakan bahan-bahan yang mudah didapati di pasaran. Pemilihan bahan berdasarkan harga yang lebih rendah adalah diutamakan kerana salah satu objektif projek ini adalah untuk mengurangkan kos pengeluaran. Tambahan pula, produk tempatan dan kitar semula juga digunakan sebagai komponen mesin.

Selain itu, projek ini bukan sahaja memberi tumpuan kepada mekanisme pelontar, tetapi secara umumnya keseluruhan mesin bola tenis dibina. Jadi apabila pembinaan selesai, mesin ini boleh memberi manfaat kepada orang ramai terutamanya pemain tenis di Malaysia.

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θ	=	Elevation angle
L	=	Length
F	=	Force
T	=	Torque
W	=	Weight
V	=	Linear speed of ball
V_0	=	Initial speed of ball
V_1	=	Circumferential speed of first wheel
V_2	=	Circumferential speed of second wheel
r_w	=	Wheel radius
r_l	=	Ball radius after deformation
ω	=	Rotational speed of ball
ω_1	=	Rotational speed of first wheel
ω_2	=	Rotational speed of second wheel
m	=	Mass of ball
$\int$	=	Integration
Δt	=	Time difference
Δl	=	Ball deformation due to wheel pressure

LIST OF ABBREVIATION

ATP	=	The Association of Tennis Professionals
ITF	=	International Tennis Federation
RPM	=	Revolution per minute
RM	=	Ringgit Malaysia
MITC	=	Malacca International Trade Centre
MPHTJ	=	Majlis Perbandaran Hang Tuah Jaya

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Tennis ball machines are popular all over the world and especially with ATP tour professionals and those who enjoy playing tennis but who travel a lot. The machine operates by containing a large number of tennis balls and pitching them through a shoot over the tennis net to the player waiting on the other side of the net. They are used primarily for training exercises to include basic shot making either at the baseline or up at the net. These are several advantages of using the tennis ball machines.

The first advantage is that the machine will keep players focused whilst training. The portable ball machine does the pitching of the ball for players accurately and the way they want it. Consequently, this will keep players focus on their swing and helps them to hit the balls the right way without having to worry about what their training partner is doing. Furthermore, players can set their portable ball machine to feed and pitch the tennis balls according to their level of expertise. Players can gradually increase the speed, set the direction and the trajectory of the tennis balls that come at them and the manner that they are delivered for players to hit. Therefore, the machine is suitable for players of all abilities. The final advantage of having a ball machine is that players can use it anytime they like and anywhere. They are easy to travel with and mean that players do not have to rely on anybody else to get a decent training session when the time suits them.

1.2 PROBLEM STATEMENT

Tennis sport is growing exponentially in this period. With the emergence of champions such as Roger Ferderer, Novak Djokovic and Rafael Nadal, Malaysia would also want to produce world class tennis players comparable to those champions. To realize that dream, the talent can be further from the start by providing intensive training. But, these little things stunted due to the lack of local trainers. To overcome this problem, a tennis ball machine is used to replace the services of a coach. With the participation of many players, this machine can help them. Tennis ball machines already in the market. But the cost is very high due to importation from other countries. So, a tennis ball machine innovation has been created. It is produced with the use of local and recycles products. This can save the cost of production of machinery. With a much cheaper cost compared with imported machineries, this innovation can be commercialized with a broader perspective. If tennis players used this machine, certainly their skills and the quality of the game can be improved. So, tennis sport can be promoted widely in this country and Malaysia is in track to produce world class champions.

1.3 OBJECTIVE

There are three main objectives in producing this tennis ball machine. The first objective is to design a prototype of thrower mechanism for tennis ball machine. While for the second objective is to fabricate a prototype of thrower mechanism for tennis ball machine. Last but not least is to reduce the production cost of this machinery.

1.4 SCOPE

The scope of this project is to study and analyze the thrower mechanism of the tennis ball machine. In conjunction to analyze the thrower mechanism, this machine is designed by using CATIA V5R20. Finally, it is fabricated using low cost materials.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY

The tennis ball machine has a relatively short history. In 1920s, the first machine was introduced and the concept has steadily gained interest from tennis professionals, competing amateurs, coaches and instructors. The features, conveniences and technology around tennis ball machines have continued to evolve throughout the years.

Rene LaCoste was a famous French tennis player from the 1920s who is most notably recognized for the crocodile logo on LaCoste polo shirts. However, he is also credited with creating the first hand-crank tennis ball machine, which he called “lance-balle.” LaCoste was known as a perfectionist whose own coach criticized him for overtraining. His rigor during training was tiring for partners, so he decided to create a ball-throwing machine to keep his edge. This machine was hand-cranked by someone on the opposite side of the court [Prescott, 2008].

Fifty years later, Bob McClure introduced the first electronic tennis ball machine. McClure made the discovery in his garage in Princeton, New Jersey, with a tennis partner, Jerry Sweeten, by reversing the motor on his vacuum cleaner. The machine works by using pressure from the vacuum cleaner to propel a tennis ball out of a connected tube. McClure named his invention the "Little Prince,” and later built Prince Manufacturing Company upon the machine’s success [Blessing, 2012].

Throughout the 1990s and 2000s, tennis ball machines gained popularity, and many other companies began to manufacture them. As technology continued to advance, so did the features and options on the machines. Some of the current features include portability, range of motion, arc control, feed and ejection speed, oscillation, ball capacity, spin, increased battery life and durability.

2.2 TENNIS BALL LAUNCHER

Tennis ball launcher is quite popular among tennis players. It is used to help them practice their strokes skills based on different conditions of ball speeds, ball rotations, types of spin and trajectory angles. Generally there are two types of tennis ball launcher available in market today. They are pneumatics launcher and mechanical launcher.

2.2.1 Pneumatics Ball Launcher

Pneumatics launcher basically uses compressed air to throw the tennis ball. The air is compressed using compressor and stored in a chamber. The pressure of this compressed air is very important to ensure good trajectory of tennis ball. This is because the initial velocity of the ball depending on the compressed air pressure. While the tennis ball is stored in a tube and this tube's elevation angles can be adjusted to get certain types of trajectory mechanisms. The elevation angles can be set manually or automatically using electronic system.

This pneumatic launcher can produce spin ball trajectory by installing adaptor at the end of the outlet tube. This adaptor slowing down one side of the ball and makes the ball rotates at required axis. The adaptor needs to be relocated about the tube's axis to get different types of ball spins such as top spin, back spin and slice ball. However, the spin velocity cannot be set separately as it depends on the initial velocity of the throwing ball.

Usually the pneumatics launcher is powered by 230/110 V mains voltage. The advantages of pneumatics launcher are high durability, reliability and resistance to various weather conditions. But this type of machine only promotes basic strokes to the users and no complex training can be performed. It is most suitable to beginners and not for armature and professional players [Wojcicki et. al. 2004].

2.2.2 Mechanical Ball Launcher

Mechanical ball launcher basically uses two counters rotating rollers or wheels to throw the tennis ball. These wheels are usually powered by electrical motors to rotate. The initial velocity of the ball depends on the rotating velocity of the wheels. The wheels have small opening between them where they affect the incoming ball. The tennis ball coming from ball feeder is then squeezed under tremendous speed and pressure exerted by the wheels. Then the tennis ball is launched via immense speed and pressure of the wheels.

The heading and elevation angles can be changed by yawing (move wheels left and right) and pitching (move wheels up and down) its launching mechanisms. Spin ball trajectory can be performed by this machine by altering the rotating speeds of both wheels. If the upper wheel is spinning faster than lower wheel, it will produce top spin ball. While if the lower rotating wheel is spinning faster than upper wheel, the ball ejects with back spin.

Usually mechanical launcher is powered by accumulators as it can be used at courts with no electrical supply or in case of its malfunction. But there is also disadvantage of using accumulators because they restricts the usage time although there is no uninterruptible operation. However, when compared to pneumatics launcher, mechanical launcher can perform better as it provides high accuracy and wider range of the possible strokes. So it can be used in advanced training and suitable for armature and professional tennis players [Wojcicki et. al. 2004].

After both types of tennis launcher are analyzed, it shows that mechanical launcher gives better parameters and greater control potential compare to pneumatics

launcher. As the advantages, mechanical launcher provides launching mechanism with great repeatability, increases initial velocity and the ball is flying with smooth and accurate velocity. Moreover, it can control the throw better and spin the ball in a required manner. The disadvantage of using pneumatics launcher is the tennis ball hits by the compressed air rolls inside the outlet tube in an unpredictable manner. As it is difficult to control, this will cause many problems such as worse accuracy and repeatability.

CHAPTER 3

METHODOLOGY

3.1 OVERVIEW

Generally, various kinds of tennis ball machines are already available in markets. But their prices are too expensive due to the importation from other countries. So this new innovation of tennis ball machine can overcome this problem. To make this tennis ball machine comes into reality, several criteria and procedures need to be taken. The procedures ensure the machine is well constructed within time according to certain specifications. This project starts with idea generation, and then continues with technical specification and lastly fabrication process.

3.2 IDEA GENERATION

3.2.1 Tennis Ball Machine Available in Market

There are a lot of tennis ball machines available in market today. Basically they are divided into two groups which are beginner range machine and advance range machine. Both of them have different criteria and features. Different machine suits different tennis players. Tennis players choose tennis ball machine which have certain specifications that tally with their training program. Table 3.1 shows the comparison between three different advance tennis ball machines. Some of these

criteria and specifications are taken as reference guide when constructing this new tennis ball machine project.

Table 3.1: Comparison between three advance tennis ball machines

[Tennis Warehouse Australia, 2012]

Model	**Sam-SP1**	**Lobster Elite**	**Tutor Plus**
Image			
Top Speed	140 km/h	130 km/h	140 km/h
Slowest Speed	32 km/h	32 km/h	16 km/h
Ball Feeds	2-13 seconds	2-10 seconds	1.5-12 seconds
Ball Capacity	300	150	150
Spin	Yes	Yes	Yes
Electronic Elevation	No	Yes	Yes
Elevation Degree	55	60	N/A
Horizontal Oscillation	Yes	Yes	Yes
Vertical Oscillation	No	No	No
Electric Option	Yes	Yes	Yes
Battery	Yes	Yes	Yes
Battery Size	14.4 A/h	18 A/h	14.4 A/h
Battery Life	4-6 hours	4-8 hours	4-6 hours
Charge Time	8	18	20
Portable	Yes	Yes	Yes
Weight	20 kg	18 kg	18 kg
Remote Control	Yes	Yes	No
Price	AUD 2,695.00	AUD 2,149.00	AUD 2,530.00

3.2.2 Concept Evaluation and Selection

Concept evaluation and selection is the most crucial part in constructing a new product. It is used to choose the best concept design that follows company ability and fulfill customer's requirements. For this project, there are three different concept designs generated. Each design has its own characteristics. Figure 3.1 shows Concept Design A which used rotating wheels, Figure 3.2 shows Concept Design B which used compressed air and Figure 3.3 shows Concept Design C which used spring. One of them needs to be chosen to pursue this project. So Pugh Concept Selection Method is used to select the best concept design for this project. This method compares each concept relative to a reference or datum concept by following certain procedures. Table 3.2 shows the Pugh Concept Selection Method to choose the best concept design.

Table 3.2: Pugh Concept Selection Method

NO	CRITERIA		CONCEPT		
			B	A	C
1	Cost		+	DATUM	=
2	Suits Armature/Professionals		-		-
3	Availability of Spin Ball		-		-
4	Availability of Materials		=		-
5	Ease of Manufacturing		+		-
6	Simplicity of Design		=		=
7	Ability to Prototype		=		-
8	Ease of Assembly		+		-
9	Portable		=		=
10	Weight		+		+
		PLUSES	4	0	1
		MINUSES	2	0	6

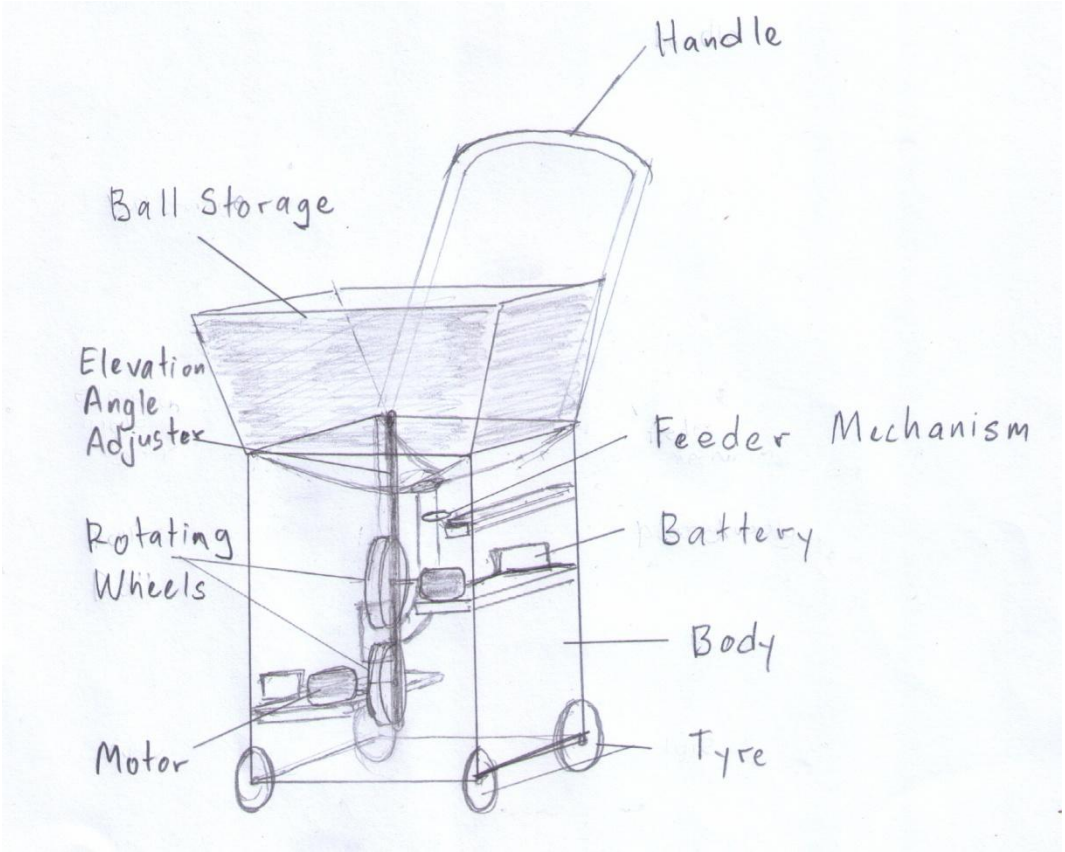

Figure 3.1: Concept Design A

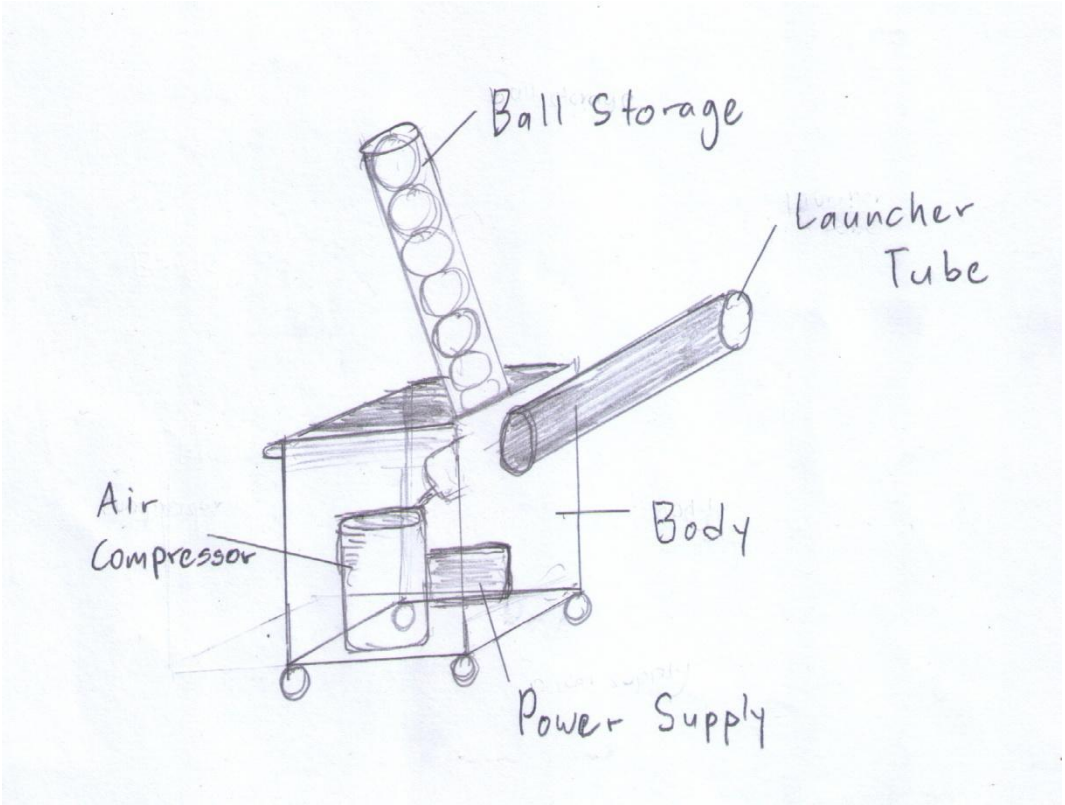

Figure 3.2: Concept Design B

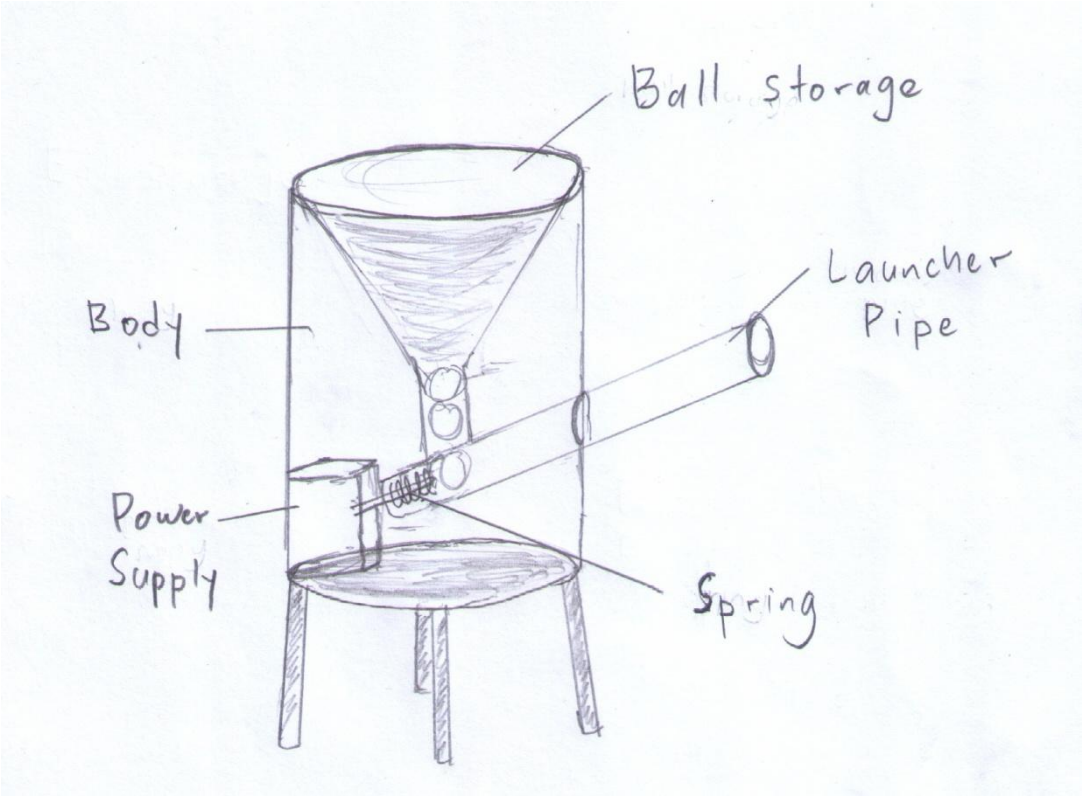

Figure 3.3: Concept Design C

3.3 FINALIZED DESIGN

After Concept Design A has been chosen as the final design, it is designed by using CATIA V5R20 software as shown in Figure 3.4. The dimension is 0.68 m height, 0.47 m width and 0.47 m length.

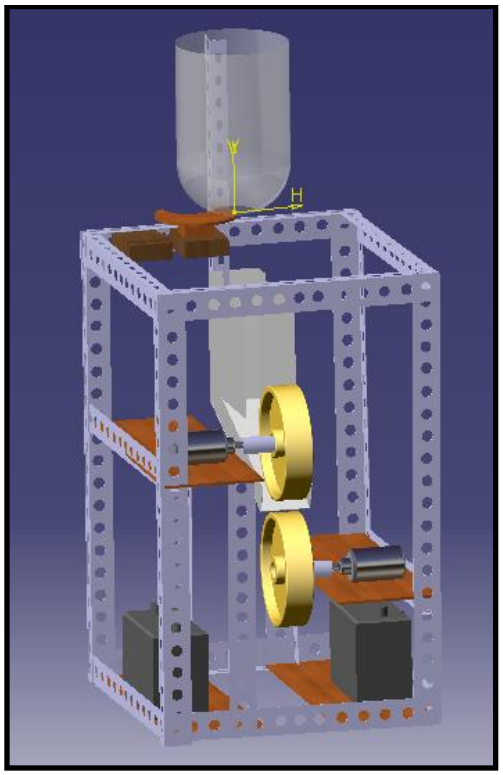

Figure 3.4: Final concept design in Catia

3.4 TECHNICAL SPECIFICATIONS

Based on the study and analysis, three main specifications must be set up in order to produce a tennis ball machine. They are height of the trajectory ball, distance travelled by the ball and trajectory speed of the ball. These specifications are very important to be followed so that they can meet the standards released by International Tennis Federation (ITF).

3.4.1 ITF Standards

The International Tennis Federation (ITF) is the world-wide governing body of tennis and has following broad areas of responsibility. ITF functioned in administrating and regulating tennis game, organizing international competitions, structuring the game, developing the game and last but not least promoting tennis game.

The ITF Technical Commission is responsible for monitoring developments in equipment technology in order to protect the nature of the game of tennis at all levels. As custodians of the Rules of Tennis, ITF sometimes has difficult task of judging whether innovations in tennis equipment may bring about a benefit to those who play, or whether such developments constitute a threat to the nature of the game [ITF Standards, 2012].

So, in developing a new tennis ball machine, the standards and specifications published by ITF must be followed. Certain important parameters are taken from the ITF specifications to build this new tennis ball machine. The parameters are very crucial in order to produce a well-perform tennis ball machine. Examples of the parameters are stated in Table 3.3.

3.4.1.1 Tennis Ball Specifications

ITF have already published the specifications of tennis ball. The specifications include mass, size, rebound, forward deformation and return deformation. Refer Table 3.3.

Table 3.3: Tennis Ball Specifications published by ITF [ITF Standards, 2012]

	TYPE 1 (FAST)	TYPE 2 (MEDIUM)[1]	TYPE 3 (SLOW)[2]	HIGH ALTITUDE[3]
MASS (WEIGHT)	56.0-59.4 grams (1.975-2.095 ounces)	56.0-59.4 grams (1.975-2.095 ounces)	56.0-59.4 grams (1.975-2.095 ounces)	56.0-59.4 grams (1.975-2.095 ounces)
SIZE	6.54-6.86 cm (2.57-2.70 inches)	6.54-6.86 cm (2.57-2.70 inches)	7.00-7.30 cm (2.76-2.87 inches)	6.54-6.86 cm (2.57-2.70 inches)
REBOUND	135-147 cm (53-58 inches)	135-147 cm (53-58 inches)	135-147 cm (53-58 inches)	122-135 cm (48-53 inches)
FORWARD DEFORMATION[4]	0.50-0.60 cm (0.197-0.236 inches)	0.56-0.74 cm (0.220-0.291 inches)	0.56-0.74 cm (0.220-0.291 inches)	0.56-0.74 cm (0.220-0.291 inches)
RETURN DEFORMATION[4]	0.67-0.91 cm (0.264-0.358 inches)	0.80-1.08 cm (0.315-0.425 inches)	0.80-1.08 cm (0.315-0.425 inches)	0.80-1.08 cm (0.315-0.425 inches)

3.4.1.2 Tennis Court Specifications

ITF also published the specifications of tennis court dimension. The specifications include the dimension of base line, service line, side line and centre mark. These dimensions are shown in Figure 3.5.

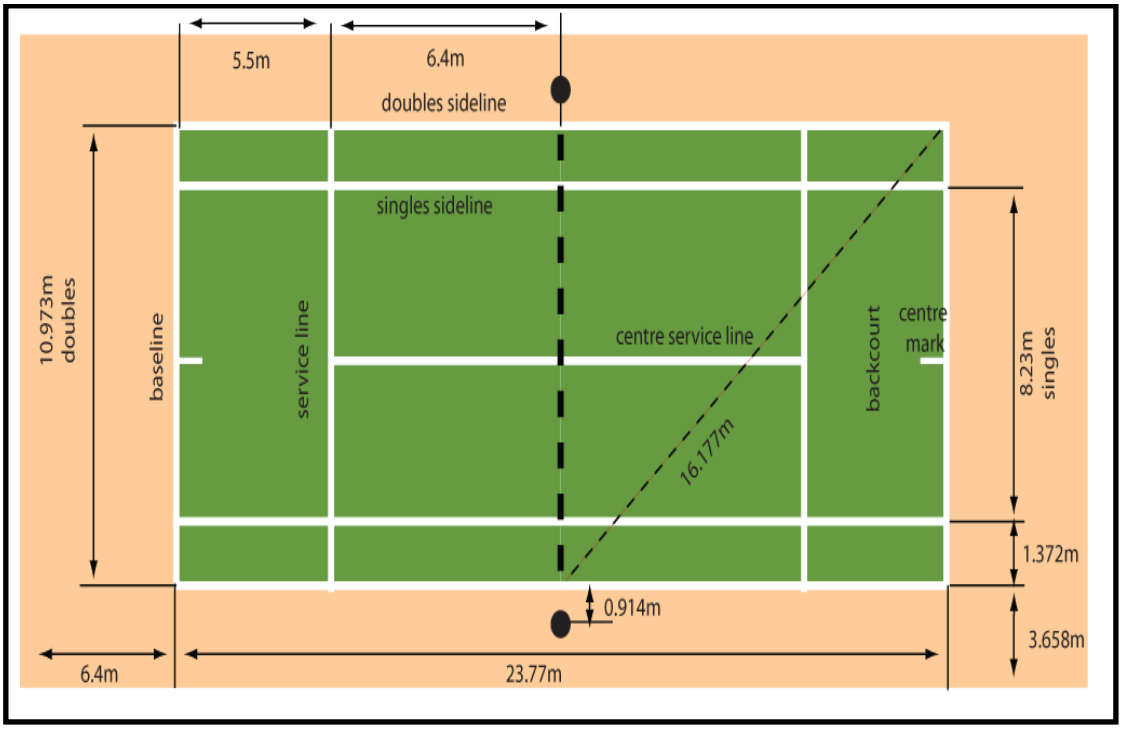

Figure 3.5: Tennis court dimensions published by ITF [ITF Standards, 2012]

3.4.2 Summary of Technical Specifications

After summarizing all the standards and parameters that must be followed, the height of the trajectory ball must be launched at minimum height of 1.1 meter. This is because the net is 1.07 meter high as the standard requirement issued by ITF. While the distance travelled by the ball must be at least 12.0 meter long and maximum of 23.8 meter if the tennis ball machine is place right behind the baseline. Refer Figure 3.5. For the trajectory speed of the ball, it is set to be 100 km/h as the average speed.

3.5 BILL OF MATERIALS

Materials that need to be bought to construct the tennis ball machine are listed. All the quantity and cost of the materials are listed in Table 3.4.

Table 3.4: Bill of materials

NO	MATERIAL	PRICE (RM)	QUANTITY	NET PRICE (RM)
1	Angle Bar with Holes (10 m)	25.00	4	100.00
2	Screws & Nuts	0.20	80	16.00
3	Modenas Jaguh Motor Starter	72.00	1	72.00
4	Lathe Polyurethane (PU) Wheels	15.00	2	30.00
5	Lathe Aluminum Rods	65.00	2	130.00
6	12V Battery	27.00	2	54.00
7	Wire (2m)	5.00	1	5.00
8	Wooden Block	FREE	-	-
9	Plywood	FREE	-	-
			TOTAL	407.00

3.6 FABRICATION PROCEDURES

1) Angle bar is measured and marked using marker and meter rule according to specified dimension as shown in Figure 3.6.

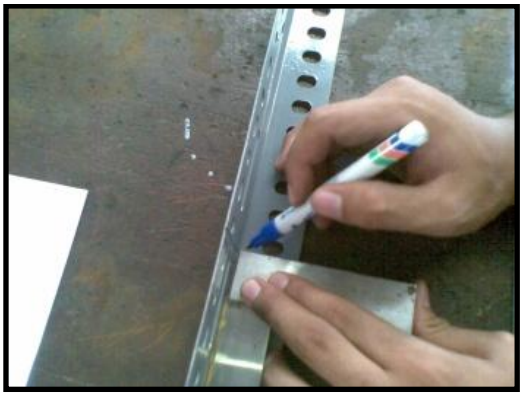

Figure 3.6: Measured and marking

2) The angle bar is cut using high-speed cutting machine. See Figure 3.7.

Figure 3.7: Cutting

3) The angle bars that have been cut are joined together using bolts and nuts to produce the body frame of the tennis ball machine. Refer Figure 3.8. The size of the body frame is 0.68 m height, 0.47 m width and 0.47 m length.

Figure 3.8: Joining for body frame

4) Plywood is measured and cut according to specified dimensions to make a basement to place motor starter. Then, finishing process of the plywood is conducted as shown in Figure 3.9.

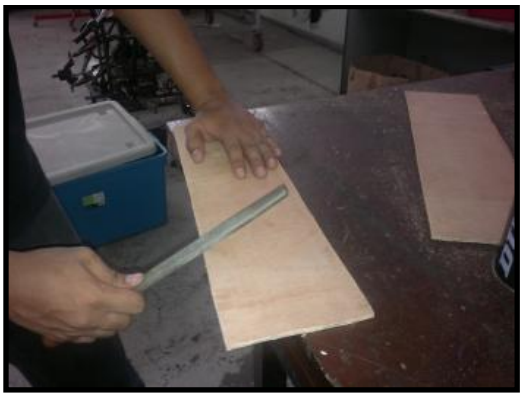

Figure 3.9: Finishing the plywood

5) The plywood is drilled and screwed to the machine body frame. See Figure 3.10.

Figure 3.10: Motor starter basement

6) Then a wooden block is measured and cut according to specified dimension. This wooden block is used as a holder to grip the motor starter. Figure 3.11 shows the finished wooden block.

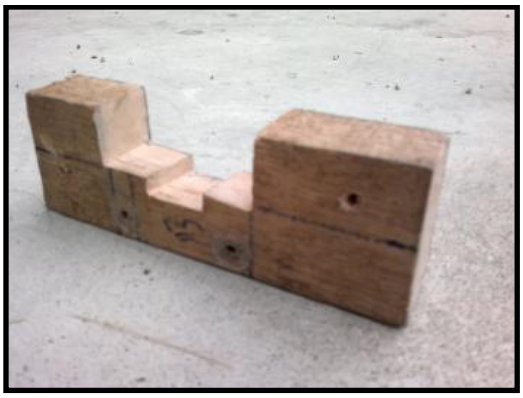

Figure 3.11: Finished wooden block

7) The wooden block is drilled and screwed to the basement of the machine as shown in Figure 3.12.

Figure 3.12: Motor starter holder

8) Then the aluminum rods and rollers that have been lathe are joined and screwed together with rollers to produce the rotating rollers assembly. Refer Figure 3.13.

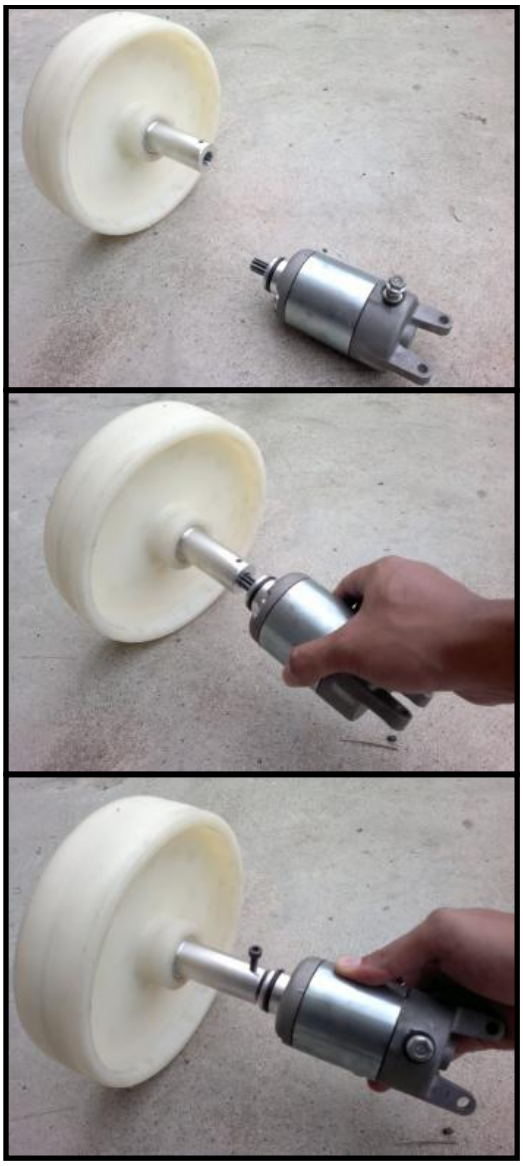

Figure 3.13: Assembly of aluminum rods, rollers and motor starter

9) These assembled parts are fixed to the basement of the machine as shown in Figure 3.14 and functioned as thrower mechanism soon.

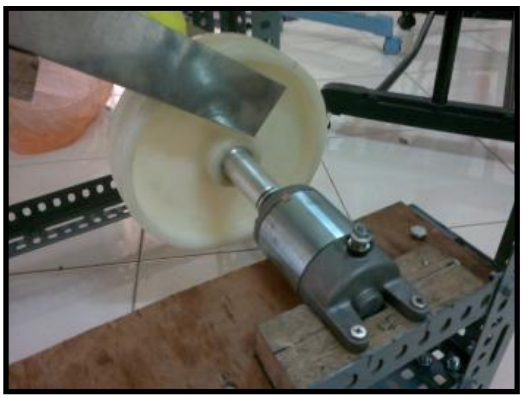

Figure 3.14: Rotating roller assembly

10) Then the motor starter is connected to the 12V battery using set of wires. Refer Figure 3.15.

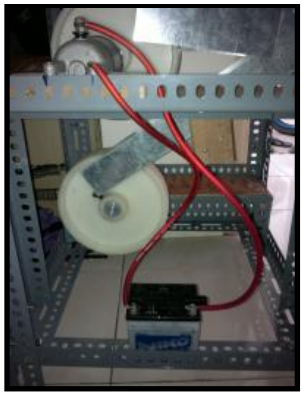

Figure 3.15: Power supply connection

3.7 THE THROWER MECHANISM

The thrower mechanism is functioned to throw the tennis ball while the machine operates. Figure 3.16 and Figure 3.17 shows the side and front views of thrower mechanism that has been assembled together with the machine body frame.

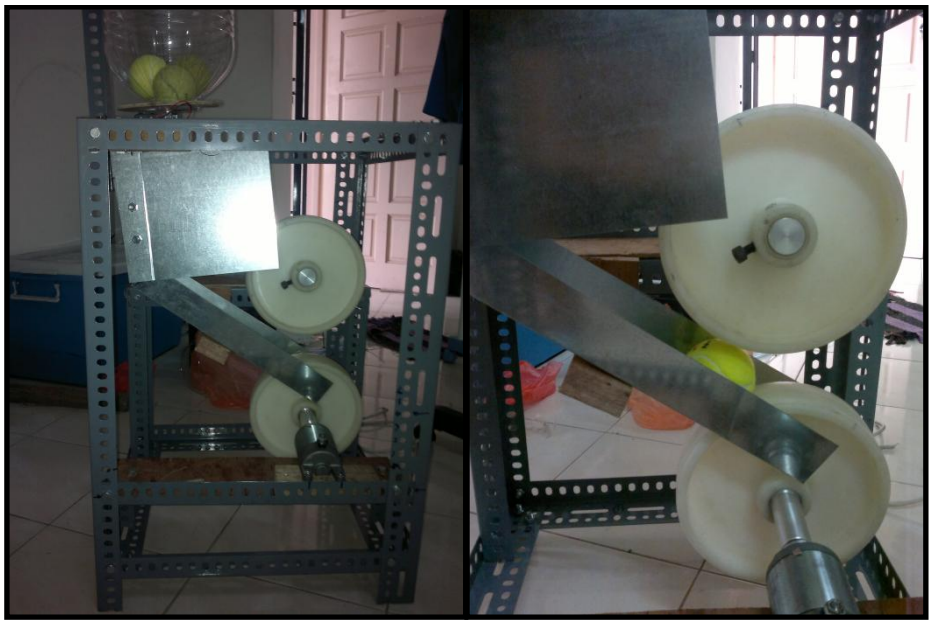

Figure 3.16: Side view of thrower mechanism

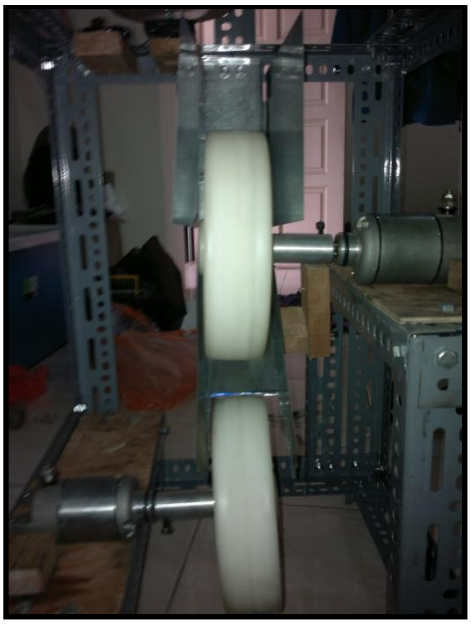

Figure 3.17: Front view of thrower mechanism

3.8 THE TENNIS BALL MACHINE

After assemble the thrower mechanism with the machine body frame, the whole tennis ball machine construction are finished and ready to be used. The finished machine is shown in Figure 3.18.

Figure 3.18: Tennis ball machine ready for testing

3.9 FLOW CHART

Every construction project must have its own flow chart. The flow chart is very important to show the working steps of the project. For this tennis ball machine project, the flow chart is shown in Figure 3.19.

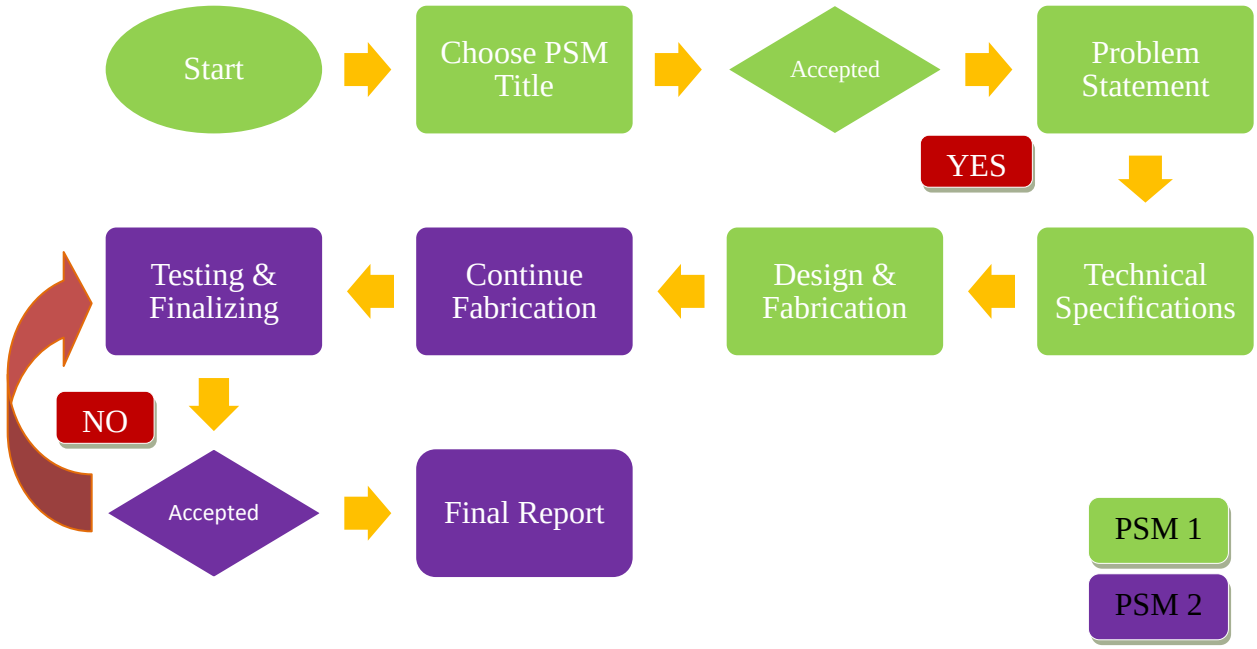

Figure 3.19: Project flow chart

CHAPTER 4

RESULTS

4.1 OVERVIEW

Generally, the thrower mechanism of this tennis ball machine performs very well. It can throw the tennis ball according to the technical specifications stated before. In order to ensure the thrower mechanism runs smoothly, three main factors are taken into account. The factors are throwing distance of the ball, rotating speed of the wheels and power of the motor

4.2 THROWING DISTANCE OF THE BALL

The first factor that must be considered when constructing a thrower mechanism is the throwing distance of the ball. The distance consists of length and height travelled by the ball. This mechanism used the concept of projectile motion. Refer Figure 4.1. In order to analyze the travelling distance of the ball ejected from the rotating wheels, the theoretical calculation of projectile motion is considered.

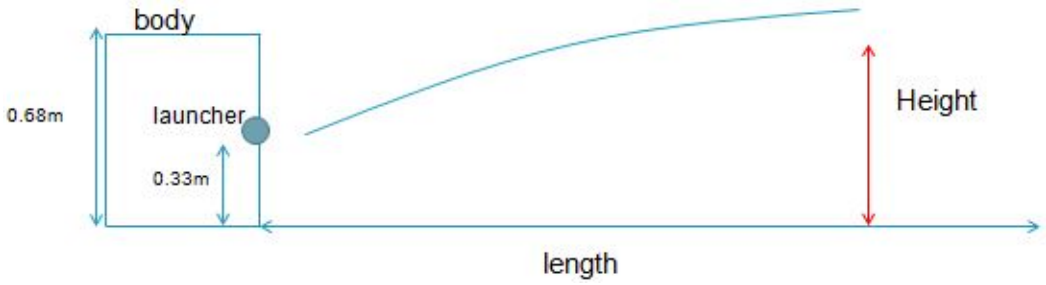

Figure 4.1: Projectile motion diagram for this project

4.2.1 Theoretical Calculation

From previous study and analysis, the ball speed range of tennis ball machine available in market is in between 20 km/h to 150 km/h. So for this project, the ball speed ejected from the launcher is assumed to be 100 km/h as the average speed. The position of the ball launcher is located 0.33 meter from the ground. So the height travelled by the ball must be combined with this value to get the total height travelled by the ball. The thrower mechanism of this tennis ball machine is designed with six elevation angles that can be adjusted. The elevation angles are 2.5°, 5.0°, 7.5°, 10.0°, 12.5° and 15°. The calculations are such below.

a) Length travelled by the ball;

- Length, $L = (V_0^2 \sin 2\theta) / g$ (4.1)
- $V_0 = 100$ km/h and $g = 9.81$ m/s

Table 4.1: Length travelled by ball

Elevation Angle (°)	Thrown Length (m)
2.5	6.86
5.0	13.66
7.5	20.36
10.0	26.91
12.5	33.25
15.0	39.33

The total length of tennis court is 23.77 meter. From this calculation, it shows that the ball can pass through beyond the net of the tennis court starting from 5.0° elevation angle if the tennis ball machine is placed right behind the baseline. The distance between the baseline and the net is about 12 meter. Although the thrown length at 15.0° elevation angle exceeds the total length of the tennis court, it does not affect this project as long as the tennis ball machine can be adjusted to be placed further behind the baseline. This can make the ball ejected falls right into the opposite side.

b) Height travelled by the ball;

- Height, $H = [(V_0^2 \sin^2 \theta) / 2g] + 0.33$ (4.2)
- $V_0 = 100$ km/h and $g = 9.81$ m/s

Table 4.2: Height travelled by ball

Elevation Angle (°)	Thrown Height (m)
2.5	0.41
5.0	0.63
7.5	1.00
10.0	1.52
12.5	2.17
15.0	2.96

The height of tennis net from the ground is 1.07 meter. From this calculation, it shows that the ball can pass through beyond the net of the tennis court starting from 10.0° elevation angle if the tennis ball machine is placed right behind the baseline. Although the thrown height at 15.0° elevation angle quite high, it does not affect this project because there is no height limitation at the tennis court. No problem if the ball is ejected higher as long as it falls right into the opposite side.

4.2.2 Experimental Calculation

After finish constructing the tennis ball machine, it has been tested at MPHTJ Tennis Court, MITC. The ball ejected from the thrower mechanism travels at minimum 4 meter and maximum 18 meter in length. While for the height, the ball travels up to 2.0 meter high. Both length and height are not reaching their maximum distance due to some errors. These errors are discussed in discussion section.

4.3 ROTATING SPEED OF THE WHEELS

In order to eject the tennis ball from the launcher, two counter rotating wheels are used. The ball from the feeder is passing through between these two wheels. Two forces of the wheels act on the ball to be push at high speed. The linear and angular speeds of the ball depend on the circumferential speeds of the wheels.

$$V = \frac{V_1 + V_2}{2} \tag{4.3}$$

$$\omega r_1 = \frac{V_2 - V_1}{2} \tag{4.4}$$

Where; V_1, V_2 = circumferential speeds of the first and the second wheels

r_l = ball radius after deformation. Refer Figure 4.2

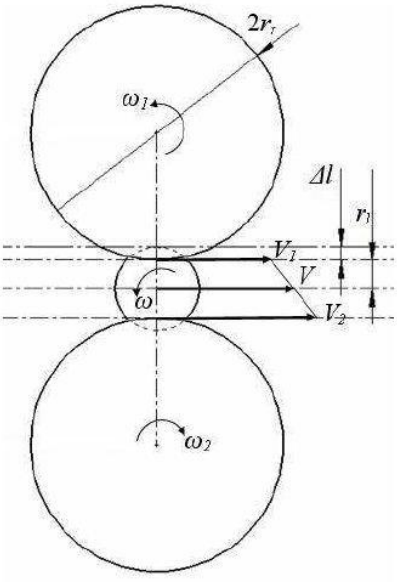

Figure 4.2: Velocities during the throw: V, ω – linear and rotational speeds of the ball, V_1, V_2, ω_1, ω_2 – circumferential and rotational speeds of the wheels, r_w – wheels radius, r_l – radius of deformed ball, Δl – ball deformation due to the wheels pressure