Design and Development of a Bowling Machine for Effective and Efficient Cricket Batting Training

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ABSTRACT

Cricket is one of the most popular sports in the world. For the batters to practice, there could be a requirement for an effective and efficient device to mimic different bowling variations to enhance the training sessions. This research consists of computer aided design, simulation, and fabrication of a robust cricket bowling machine to achieve target bowling for effective training of cricket batters. A novel ball propelling mechanism was designed with two degrees of freedom movements of a pair of rotating wheels. Mechanisms for sudden speed changes were also tested with prototypes during this design. However, for acceptable product compactness and cost, the design was prototyped without the sudden speed changing concept. The base is maintained on a bi-axial precise tilting gyroscopic mechanism. This tilting mechanism accurately adjusts the delivery point of the ball with respect to a two-axis system, which helps to control the line and length of the ball. The novel ball propelling mechanism enhances the stability of controlling in pitching position, ball rotation axis, and ball speed. Controlling these parameters effectively creates an environment for efficient practice sessions for batsmen. Target bowling is the main objective of this study and the machine intends to mimic the vast bowling variations.

Keywords: *Dimpled Ball; Ball Propelling; Pitching; Spin; Swing*

ISSN 1823-5514, eISSN 2550-164X
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Universiti Teknologi MARA (UiTM), Malaysia.
https://doi.org/10.24191/jmeche.v21i1.25360

Received for review: 2023-02-06
Accepted for publication: 2023-09-13
Published: 2024-01-15

Introduction

Cricket is a game played between two teams which includes 11 players in each team. This game is played on a ground with a 22-yard pitch in its center with 3 stumps (as the wicket) on either side of the pitch [1]. One team is nominated as the batting team by a toss of a coin while the other team is selected for fielding. The batting team attempts to score runs as much as possible to post a score for the other team to chase. One of the main activities of cricket is batting. It requires skill and practice to master the art of batting. However, it is difficult for a batter to practice without the help of skilled bowlers as batters need to be prepared under different bawling patterns and conditions [2]. In cricket, the intention of the bowlers is to get the batters out as soon as possible without allowing them to score. Therefore, knowing the parameters of bowling, such as the speed, is essential to continue batting. The variations in bowling include the pace of the ball [3], swing [4]-[6], spin [7]-[8], pitching position, ball releasing height [9]-[10], bowling position, bowling arm action [9], pitch conditions [11], and the environmental conditions [12]. The batters need to prepare for variations in these parameters in order to play against skilled players. However, in practice sessions, it is impossible to depend solely on human bowlers to provide the required training for the batters, since the consistency of human bowlers is lower in long training sessions and specially it costs more bowling machines are developed as an effective and efficient solution for the above issue in practice sessions. There are plenty of different designs of machines that can handle a limited set of variations. In addition, the currently available bowling machines have limitations such as being bulky, low-cost effectiveness with inadequate flight characteristics, low accuracy and precision of target bowling, and limited variations [13]-[14]. Overcoming the aforementioned limitations is a requirement to enhance the training sessions in an effective and efficient manner. Therefore, this study intends to design and develop a semi-automated cricket bowling machine with target bowling capability.

Study of existing ball propelling mechanisms

The literature reveals that batters struggle during practice sessions and also at cricket matches due to a lack of practice with different bowling variations [4]-[8]. There are different kinds of commercially available cricket bowling machines [15]-[17]. Most of these machines have similar features and only produce some basic variations with manual operation. There are also other similar sports that use ball throwing machines for training purposes such as badminton [18], tennis [19], football [20], volleyball [21], and baseball [22]. When considering these machines with respect to propelling a ball, there are main 4 mechanisms that can be used for ejecting a ball such as pneumatic powered [23], rotary wheel [18]-[22], spring actuate [24], and pitching arm [24].

Pneumatic mechanism

In the most basic stage of a cricket bowling machine of the prior art designs, pneumatic power has been used to throw the ball. When compressed air passes through a barrel, the balls are sucked in from a container of balls due to the velocity head [23]. In this type of machine, there is no contact of moving parts with the ball and damages to the ball are low. However, they produce low variations with higher ball speeds (Figure 1(a)).

Rotary wheel mechanism

This mechanism involves wheels to obtain the speed and variations of the cricket ball (Figure 1(b)). As per the literature, there are wheel arrangements for the required speed and variations. Single-wheel [16], two-wheel [19], [21], [22], and three-wheel [25] mechanisms are few of them.

Spring mechanism

This mechanism is used to propel the ball manually or using any other means. During the first phase of the cycle, the tension spring is stressed, and in the second phase, the spring is released to propel the ball [24]. This mechanism has more drawbacks than the previous two mechanisms. Shocks during the operation, inability to obtain a high number of ball variations, and limited speed variation are some of such drawbacks (Figure 1(c)).

Pitching arm mechanism

This mechanism mimics a bowler's arm using spring actuated, or motorized means to execute the bowling action (Figure 1 (d)). The pitching arm is only capable of changing the pace of bowling and limitations are present when it comes to executing spin and swing bowling variations [23].

(a) (b) (c) (d)

Figure 1: Existing ball propelling mechanisms; (a) pneumatic mechanism. figure extracted from ref. [22], (b) rotary wheel mechanism-figure extracted from ref. [25], (c) spring mechanism-figure extracted from ref. [26], and (d) pitching arm mechanism-figure extracted from ref. [24]

Each mechanism has its own set of disadvantages. The pneumatic-powered mechanism is more complex than the other mechanisms and its controllability in variations is lower [23] and the operating cost is higher. The pitching arm mechanism and spring actuation have limited bowling variations [24]. Based on the above discussion, it is evident that target bowling technique and bowling variations are critical factors to consider when designing a cricket bowling machine. It is further evident that there are limitations in every mechanism being used. Comparatively, the drawbacks are less in rotary wheel mechanism since it can change the rotational axis orientation and speed to achieve different bowling variations [16], [19]-[22], [25]. Hence, the objective is to use a rotary wheel mechanism in an effective and efficient way with a focus on variations of bowling techniques, target bowling, and variations of bowling speeds. According to the literature and feedback from professional players and coaches, the apparatus was planned to perform under the following variations. Maximum bawling speed, pitching angle range, and rolling angle range are 12 kmph, -10 to +10 degrees, and -30 to +30 degrees, respectively. Here "-" indicates an anticlockwise direction while "+" indicates a clockwise direction. The use of stepper motors with sufficient torque will overcome the back force generated when the ball is propelling from the machine. This ensures the repeatability of the ball pitching position for the same bowling parameters fed to the machine and enables it as a bowling machine with a target bowling technique with different bowling variations. Exceeding the aforementioned range of pitching and rolling angles will enable the machine to mimic all the bowling variations effectively.

Methodology

In the development process, initially, trials were carried out using two means for ball propelling. Ball variation using conical Constantly Variable Transmission (CVT) wheel mechanism (mechanism A) and innovative ball propelling mechanism (mechanism B) are introduced in this study.

Mechanism A

CVT (Figure 2) can be used to change the tire speed quickly without changing the speed of the motor. This method changes the speed of the wheels by changing the belt position along the pulley. In mechanism A, the trials were conducted by fabricating a conical wheel CVT as shown in Figure 3 to implement sudden speed variations of the ball propelling mechanism (propelling the ball through two rotating tires).

CVT system is an effective method when using conical rollers, a belt can be used for moves along the slope of the cone, creating variations between the narrow and wide diameters of the cone [27]. By moving the cones of the CVT along the axes, different torques can be transmitted. It will be smoother in operation and can achieve more variations in a short period of time.

However, a belt-driven design reduces the efficiency because of slipping and creep [27]. Furthermore, due to the shape of the standard belt, conical wheels were unable to maintain firm contact with the belt surface. Therefore, it affects target bowling, and its torque handling capability is limited. The development of the ball propelling mechanism was achieved in two stages. Ball propelling was achieved with quick ball variation using the conical wheel CVT mechanism as seen in the model (Figure 3(a)) according to the design of "mechanism A" (Figure 2). In order to perform quick ball variations, a prototype was fabricated based on the model as seen in Figure 3(b) to investigate the effectiveness of changing speed ratios in quick speed variation for rotary wheels as illustrated in Figure 3.

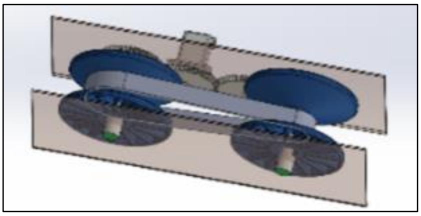
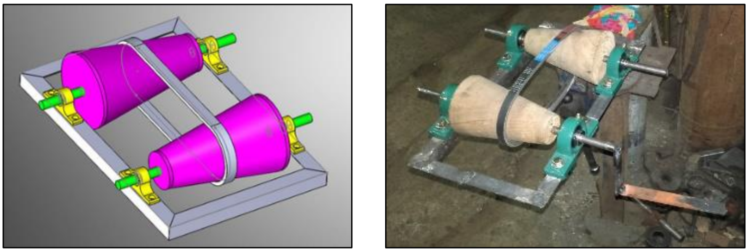


Figure 2: CVT system



(a) (b)

Figure 3: Developed conical wheel CVT system; (a) CVT design, and (b) fabricated conical wheel CVT

The final design of mechanism A consists of two (02) independent CVT-operated wheels which are powered by a DC servo motor. Both wheel assemblies are mounted on a common frame, which can be tilted in the longitudinal axis through a rack and pinion mechanism. During the design stage of "mechanism A", a few drawbacks were observed which are affecting the controllability of the machine. After assigning material properties to the model in SolidWorks 2017, it showed that "mechanism A" carries a significant weight of 57.48 kg approximately. Hence, to perform the rolling effect (to rotate the complete structure in a clockwise and anti-clockwise direction along the rack as shown in Figure 4), it requires stepper motors with high torque capacity. Also, the rolling angle is highly dependent on the selection of the circular rack.

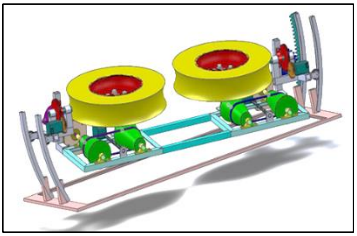


Figure 4: CVT-based bowling machine design (mechanism A)

Thus, in order to develop a proper ball propelling mechanism while addressing the issues in the CVT model, "mechanism B" was introduced without using the conical CVT mechanism.

Mechanism B

Mechanism B was derived as per the results gained from mechanism A by eliminating the drawbacks. The mechanism depicted in Figure 5 is a compact and accurate design in terms of pitching position (target bowling) in comparison to the method described in "mechanism A". In "mechanism B", the force required to propel the ball is obtained by rotating two tires which are actuated by two Independent Servo Motors (WSM1 and WSM2). The fundamental theory behind the ball propelling is transferring the momentum from rotating wheels to the ball. Therefore, the required inertia of the wheels is calculated under extreme cases and the control system was developed to control the speeds of the wheels, according to the required variations. The ball pitching position is changed by rotating Frame B with tires using the side stepper motors as shown in Figure 5.

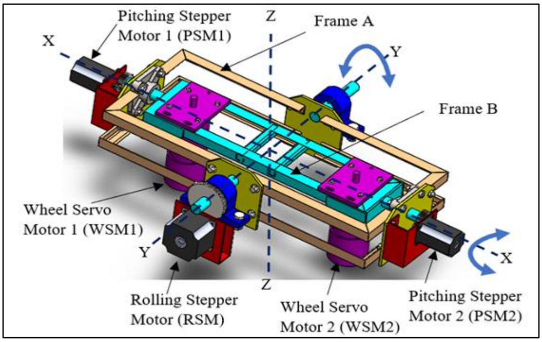


Figure 5: Gyroscope ball propelling (mechanism B)

Spin variation of the ball is obtained by changing the rolling angle (rotation around the Y-Y axis) with respect to the horizontal. Thus, frame A should be rotated in the clockwise and anticlockwise directions based on the spin variation type (leg spin or off-spin). Therefore, the rolling mechanism was obtained using a stepper motor with a gear reduction. The stepper motor selection was based on a combination of theoretical torque calculations and SolidWorks motion analysis results on different pitching and rolling angles. The process of final design can be summarized as shown in Figure 6.

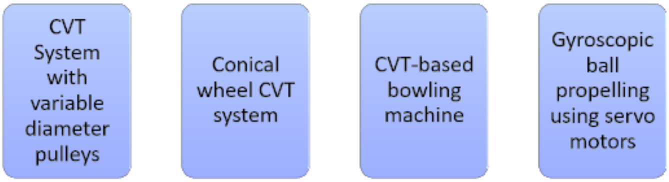


Figure 6: Design process

The final machine with gyroscopic ball propelling mechanism was designed using SolidWorks 2017 design software and motor torque requirement was generated via motion simulations. The back force generated when the ball is propelling is directly affecting the precision of the target bowling. When the two tires rotate at an angular speed of 234.35 rads $^{-1}$, the angular speed of the tires will reduce to 227.08 rads $^{-1}$. Hence, as a percentage, there is a 3.1% speed reduction due to the friction and change of momentum of the entire assembly. According to the block diagram and algorithm depicted in Figure 7 and Figure 8, Arduino microcontroller boards were used to operate the machine. An IR sensor was used to detect the presence of the dimpled ball before it pushed through the rotating wheels. The sensor sends a signal to the microcontroller and accordingly, a bulb and a buzzer are activated to provide an instantaneous signal to the batsman to ready before the ball releases. Whereas two types of motor controllers were used to control the rotation angle of stepper motors and the speed of servo motors. Users can use the input features such as push buttons (for Rolling Stepper Motor (RSM) and Pitching Stepper Motor (PSM), and potentiometers (for Wheel Servo Motors (WSM); WSM1 and WSM2) to control the angle and speed of the motors respectively while Liquid-Crystal Display (LCD) displays the real-time angle and speed of relevant motors.

Pitching and rolling operation needs to be executed by selecting a proper motor and adequate torque in order to eliminate the effect on stepper motor step positions due to vibration and back force. Hence, the "mechanism B" design was subjected to a motion analysis in SolidWorks 2017 software, and results were obtained in Figures 9(a) and 9(b). The Center of Gravity (COG) of the proposed "mechanism B" depicted in Figure 5 is approximately positioned on the XY plane. The simulation was done with the constraints of maximum pitch angle: +10°, minimum pitch angle: 0°, the maximum angular speed of the WSM1 and WSM2 is 2300 RPM, and pitch frequency is 0.5 Hz. According to the simulation results, the maximum torque in PSM was 1.657 Nm. The factor of Safety (FOS) is approximately considered as 1.8 [28]. Thus, the torque of PSM1 and PSM2 was selected as 1.5 Nm. A FOS value was considered to compensate for the back force and vibration effect when the ball is propelling from the machine. It is shown that there is a sudden inertia change of the system when the PSM1 and PSM2 velocity reaches zero and the pitch angle reaches 10°.

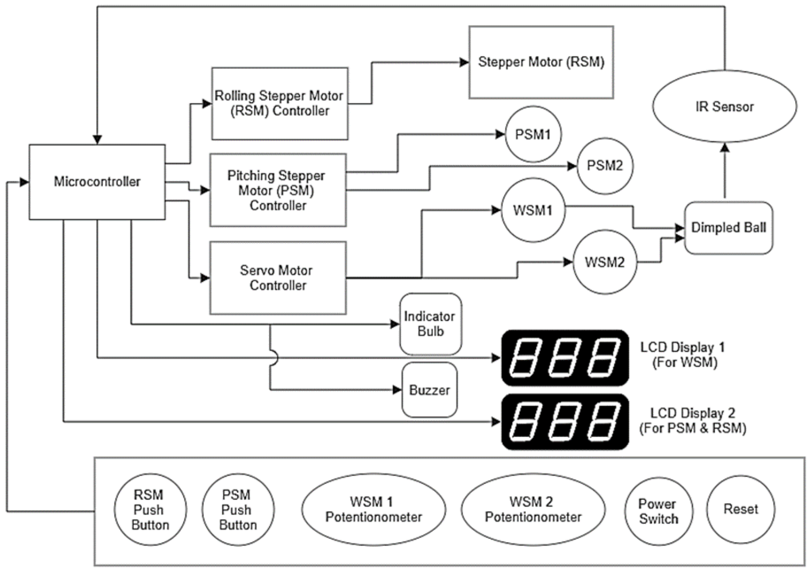


Figure 7: Block diagram of the “mechanism B”

To calculate the torque required for the rolling operation of the CBM, the same procedure was followed as pitching using SolidWorks software. According to the simulation results depicted in Figure 9, maximum torque is observed when the rolling angle and angular velocity are zero. This is due to the inertia of the entire assembly illustrated in Figure 5 with wheels. The maximum torque observed is 1.027 Nm, which should be provided by RSM. This torque is less than the pitching torque. The reason for having less torque is due to the balanced COG positioned on the YZ plane. Hence, the entire assembly is balanced along the Y-Y axis.

Considering the FOS with a value of 2 to compensate for the vibration and back force same as the pitching operation, RSM torque is taken as 2 Nm. Hence, “mechanism B” shown in Figure 10 gives a more compact and cost-efficient design in terms of the controllability of the machine with the target bowling technique. To validate the effectiveness of “mechanism B”, experimental and theoretical values of the ball pitching positions were compared in the experiments and results section of this article.

The overall height and width of the fabricated apparatus were 620 mm and 300 mm, respectively to achieve the ball release of 2000 mm.

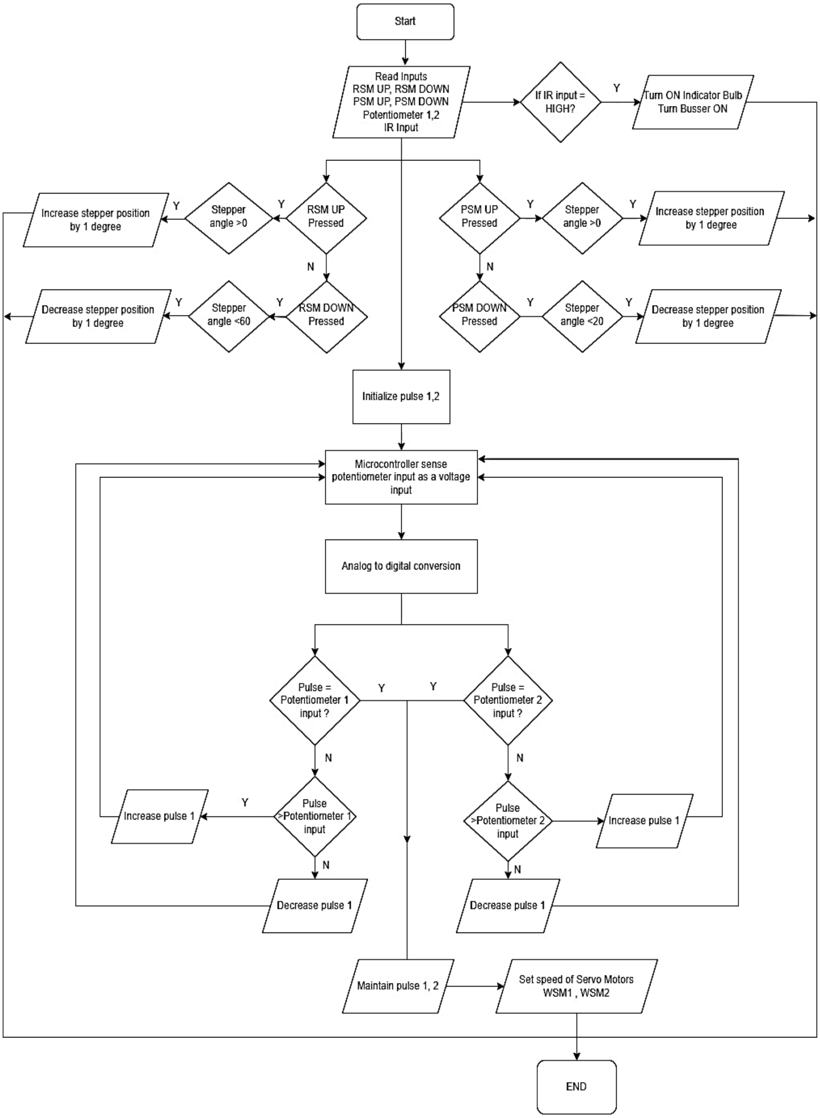
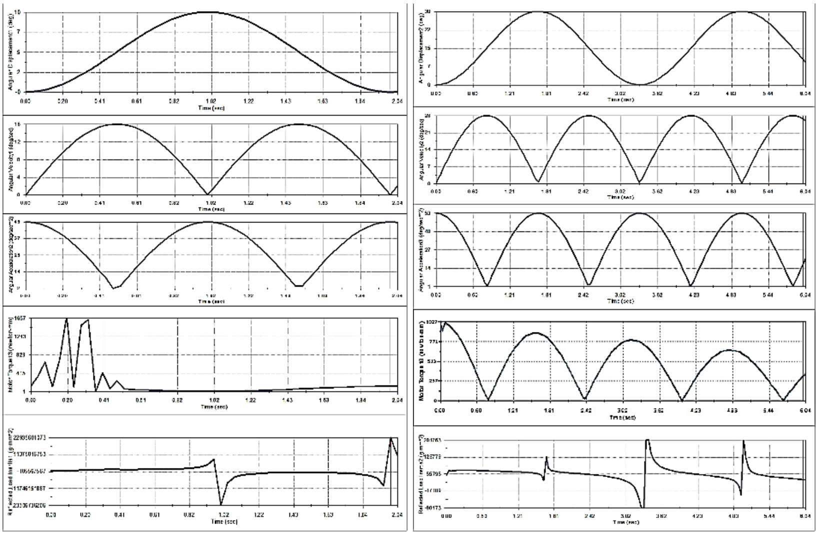
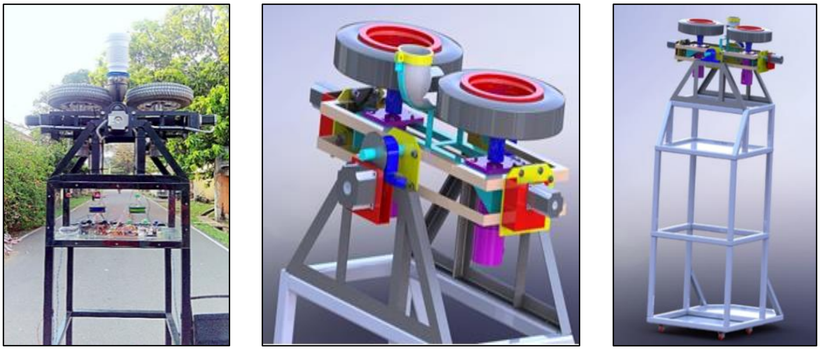


Figure 8: Algorithm of the "mechanism B"



(a) (b)

Figure 9: Motion simulation results; (a) X-X axis, and (b) Y-Y axis



(a) (b) (c)

Figure 10: Developed cricket bowling machine; (a) complete machine design, (b) wheel assembly, and (c) fabricated cricket bowling machine

Ball trajectory path calculations

The trajectory path of the dimpled cricket ball mainly depends on a few parameters such as ball propelling speed (speed of the two tires), pitch angle, rolling angle, and the different speeds of the two tires. In order to analyze the ball pitching positions on the pitch, common equations for projectiles were used. As the first stage of development, in the calculation, wind conditions and the Magnus effect of the ball are neglected.

$$S = ut + \frac{1}{2}at^2 \tag{1}$$

Equations (2) and (3) are obtained from Equation (1) where the height for the ball propelling position from the floor level is 2 m.

$$R = V \times \cos\theta \times T \;\; (2) \tag{2}$$

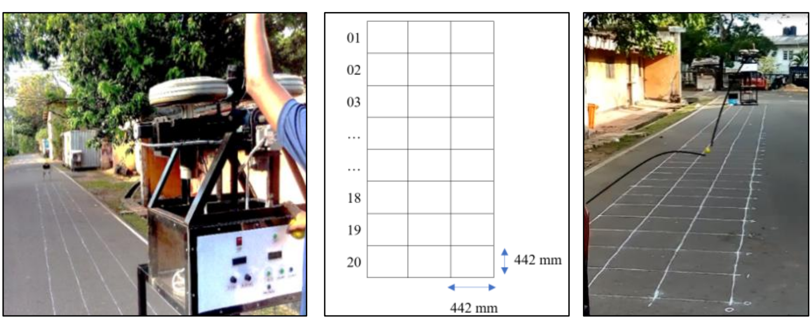
$$2 = V \times \sin\theta \times T + \frac{1}{2}gT^2 \tag{3}$$

$$0 = R^2 \times g \times \tan\theta^2 + 2 \times R \times V^2 \times \tan\theta + (R^2 \times g - 4V^2) \tag{4}$$

where R is projectile range, V is propelling velocity, T is projectile time, θ is pitching angle, and g is gravitational acceleration.

Experiments and Results

The designed machine was fabricated as shown in Figure 10(c) and a few experiments were carried out to validate the target bowling technique and ball variation. Ball variation refers to bowling speed changes, pitching position changes, swing variations, and spin variations. Hence, the pitch was divided into 60 equal squares in a grid with an area of 0.195 square meters (A square with a side dimension of 442 mm) as shown in Figures 11(a), 11(b), and 11(c) [29]. The experimental pitching position is accurately determined by pitching 5 times using the same speed, rolling angle, and pitching angle. Then, an average pitching distance was calculated to compare the deviations with the theoretical pitching distance.



(a) (b) (c)

Figure 11: Validation of cricket bowling machine: (a) testing of bowling variation on the grid, (b) grid dimensions, and (c) target bowling for 13, 2 grids

Straight bowl target bowling validation

The theoretical projectile calculations were made as shown in Table 1. For example, 13, 2 grid parameters were set to the machine (pitching angle, rolling angle, and speed of the tires). The pitching position was observed as shown in Figure 9(c). Pitching angles 1 and 2 are the solutions for Equation (4). The minus figure of pitching angle 2 indicates the actual machine pitching angle. Minus indicates the angle measured downwards direction of the horizontal plane. The machine parameters for this experiment were selected as Left servo motor RPM scale: 100 (equivalent to 1750 rpm) and Right servo motor RPM scale: 100 (equivalent to 1750 rpm). To perform a straight bowling, motor speed should be equal on both wheels [30]-[31]. The maximum speed of the ball was 120 kmph.

Table 1: Fast-straight bowling validation results

Grid no.	Distance from the machine (m)-theoretical	Pitching angle 1 (degree)	Pitching angle 2 (degree)	Average measured distance from the machine (m)-experimental
1, 2	17.46	85.43	-2.42	17.68
2, 2	17.02	85.55	-2.72	17.68
3, 2	16.58	85.67	-3.02	16.89
4, 2	16.13	85.78	-3.34	16.89
5, 2	15.69	85.90	-3.67	16.12
6, 2	15.25	86.02	-4.00	16.12
7, 2	14.81	86.13	-4.36	15.45
8, 2	14.37	86.25	-4.72	15.45
9, 2	13.92	86.36	-5.10	14.01
10, 2	13.48	86.48	-5.50	14.01
11, 2	13.04	86.60	-5.92	12.49
12, 2	12.60	86.71	-6.35	12.49
13, 2	12.16	86.83	-6.81	12.20
14, 2	11.71	86.94	-7.30	12.20
15, 2	11.27	87.06	-7.81	10.92
16, 2	10.83	87.18	-8.35	10.92
17, 2	10.39	87.29	-8.93	10.90
18, 2	9.95	87.41	-9.55	10.90
19, 2	9.50	87.52	-10.21	9.51
20, 2	9.06	87.64	-10.93	9.51

As shown in Table 1 and Figure 12, there is no significant deviation of the experimental pitching position against the theoretical pitching position when the parameters set for the machine are the same as the parameters used in theoretical calculations which was done using Equations (1) to (3).

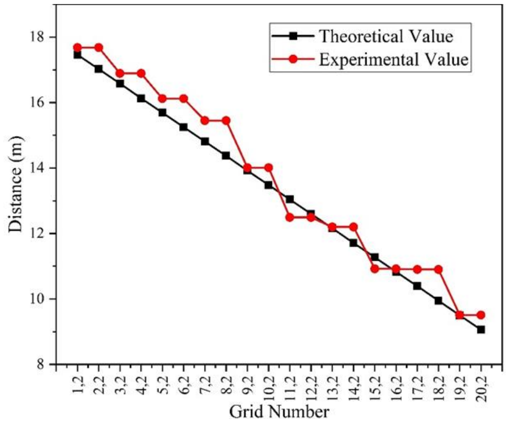


Figure 12: Grid number vs. pitching position for straight bowling

Slow bowling without variation validation results

The machine parameters for this experiment were selected as left servo motor RPM scale: 50 and Right servo motor RPM scale: 50. As shown in Table 2, theoretical pitching position and experimental pitching positions are compared. The maximum speed of the ball is 60 kmph. The scale was 50, thus the angular velocity of the motor was about 875 rpm. In order to maintain the ball in a straight direction aligning with the machine propelling velocity vector, the speed of the two wheels was kept equal [30]-[31]. Figure 13 illustrates the low deviation of the theoretical and experimental pitching positions even in the slow bowl criterion.

Out-swing bowling validation results

The maximum speed of the ball was 110 kmph. There was a little deviation in the ball propelling direction. The ball was moved towards the outside of the wicket as the left-side wheel was slower than the right-side wheel [31]. Machine parameters for this experiment were selected as Left servo motor RPM scale: 90 and Right servo motor RPM scale: 100. As shown in Table 3, theoretical pitching position and experimental pitching positions are compared. However, there were no significant deviations in the pitching distance from the bowling machine as shown in Figure 14.

Table 2: Slow-straight bowling validation results

Grid no.	Distance from the machine (m)-theoretical	Pitching angle 1 (degree)	Pitching angle 2 (degree)	Average measured distance from the machine (m)-experimental
1, 2	17.46	71.83	11.18	17.29
2, 2	17.02	72.36	10.47	17.29
3, 2	16.58	72.88	9.77	16.18
4, 2	16.13	73.39	9.05	16.18
5, 2	15.69	73.90	8.34	15.75
6, 2	15.25	74.40	7.61	15.75
7, 2	14.81	74.90	6.88	14.62
8, 2	14.37	75.39	6.14	14.62
9, 2	13.92	75.88	5.38	14.03
10, 2	13.48	76.36	4.62	14.03
11, 2	13.04	76.84	3.84	13.46
12, 2	12.6	77.32	3.04	13.46
13, 2	12.16	77.79	2.22	12.2
14, 2	11.71	78.26	1.38	12.2
15, 2	11.27	78.73	0.52	11.3
16, 2	10.83	79.19	-0.37	11.3
17, 2	10.39	79.65	-1.29	10.29
18, 2	9.95	80.11	-2.25	10.29
19, 2	9.5	80.57	-3.26	9.09
20, 2	9.06	81.02	-4.31	9.0

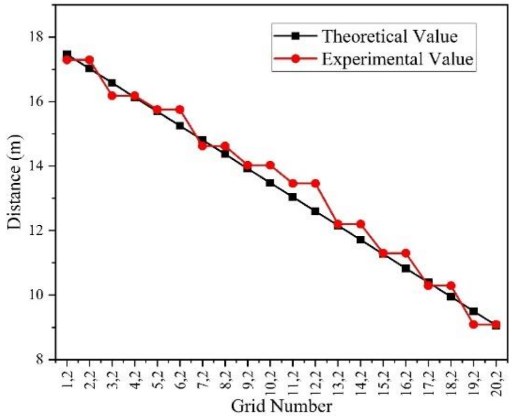


Figure 13: Grid number vs. pitching position for slow bowling without variation

Table 3: Out-swing bowling validation results

Grid no.	Distance from the machine (m)-theoretical	Pitching angle 1 (degree)	Pitching angle 2 (degree)	Average measured distance from the machine (m)-experimental
1, 1	17.46	84.77	-1.76	17.54
2, 1	17.02	84.91	-2.07	17.25
3, 1	16.58	85.04	-2.40	16.58
4, 1	16.13	85.17	-2.73	16.14
5, 1	15.69	85.31	-3.07	15.9
6, 1	15.25	85.44	-3.43	15.27
7, 1	14.81	85.57	-3.79	14.94
8, 1	14.37	85.71	-4.18	14.48
9, 1	13.92	85.84	-4.57	13.35
10, 1	13.48	85.97	-4.99	13.48

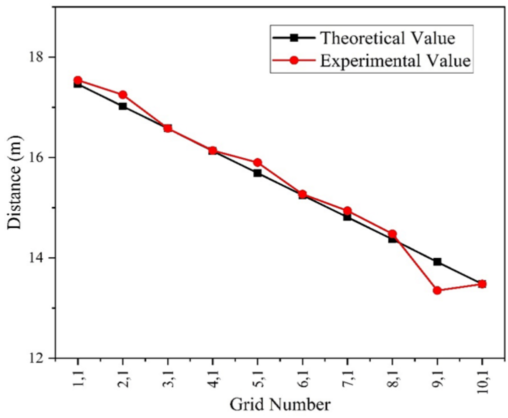


Figure 14: Grid number vs. pitching position for out-swing bowling

In-swing bowling validation results

This was similar to the out-swing delivery mechanism. The only difference was the bowl deviating to the right-hand side with respect to the bowler. The left-side wheel was kept faster than the right-side wheel. As shown in Table 4, theoretical pitching positions and experimental pitching positions are compared. Machine parameters for this experiment were selected as Left servo motor RPM scale: 100 and Right servo motor RPM scale: 90 and ball speed: 110 kmph. However, there were no significant deviations in the pitching distance from the bowling machine as shown in Figure 15.

Table 4: In-swing bowling validation results

Grid no.	Distance from the machine (m)-theoretical	Pitching angle 1 (degree)	Pitching angle 2 (degree)	Average measured distance from the machine (m)-experimental
1, 3	17.46	84.77	-1.76	17.58
2, 3	17.02	84.91	-2.07	17.2
3, 3	16.58	85.04	-2.40	16.89
4, 3	16.13	85.17	-2.73	16.22
5, 3	15.69	85.31	-3.07	15.51
6, 3	15.25	85.44	-3.43	15.48
7, 3	14.81	85.57	-3.79	14.93
8, 3	14.37	85.71	-4.18	14.4
9, 3	13.92	85.84	-4.57	13.53
10, 3	13.48	85.97	-4.99	13.5

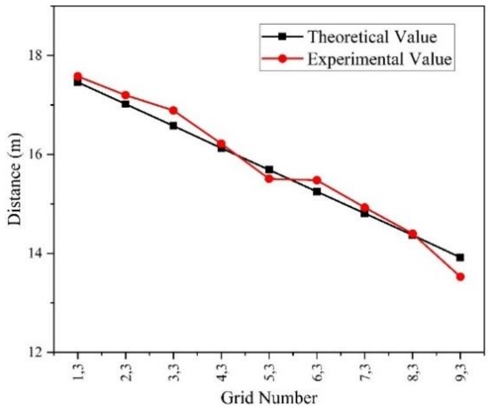


Figure 15: Grid number vs. pitching position for in-swinging bowling

Off-spin bowling validation results

Machine parameters for this experiment were selected as Left servo motor RPM scale: 67 and Right servo motor RPM scale: 60 and ball speed: 80 kmph. The rolling angle is 30 degrees in the anticlockwise direction to the horizontal as shown in Figure 16. The left-side motor was a little faster than the right-side motor [31] so the ball spun towards the right-handed batsman. As shown in Table 5, the pitch angle is positive for most of the off-spin bowling grids. In order to have a spin bowl, there should be more flight height than slow, medium, and fast bowling. The graph mentioned in Figure 17 shows almost the same as the theoretical pitching position and experimental pitching position.

Table 5: Off-spin bowling validation results

Grid no.	Distance from the machine (m)-theoretical	Pitching angle 1 (degree)	Pitching angle 2 (degree)	Average measured distance from the machine (m)-experimental
1, 1	17.46	80.07	2.94	30
2, 1	17.02	80.33	2.50	30
3, 1	16.58	80.59	2.05	30
4, 1	16.13	80.85	1.59	30
5, 1	15.69	81.11	1.12	30
6, 1	15.25	81.37	0.64	30
7, 1	14.81	81.63	0.15	30
8, 1	14.37	81.89	-0.36	30
9, 1	13.92	82.14	-0.88	30
10, 1	13.48	82.40	-1.42	30

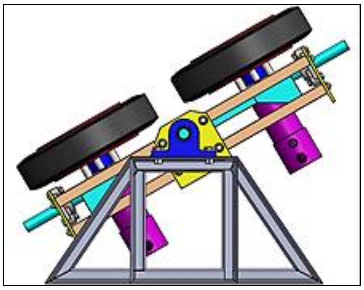


Figure 16: Machine orientation for off-spin bowling

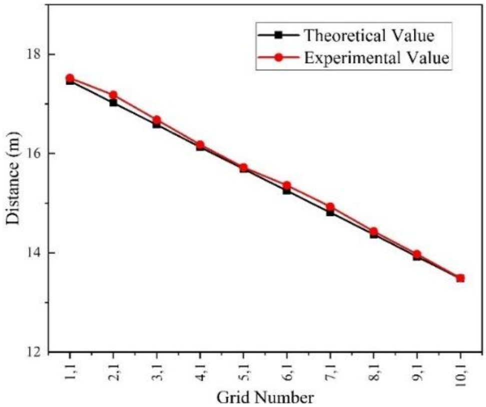


Figure 17: Grid number vs. pitching position for off-spinning bowling

Conclusion

At the beginning of this study, extensive research was carried out in order to investigate the existing cricket bowling machines and identify their major drawbacks. A few prototypes and conceptual designs were made to develop an improved cricket bowling machine by eliminating the discussed drawbacks according to the literature survey. However, the identified major drawbacks were the lack of automation of the machine with high variation and the difficulty of achieving target bowling. Thus, according to the different experiments carried out during the study resulted in a fully automated machine with a high degree of variation of the ball.

Experiments were carried out to validate the effectiveness of the target bowling technique using the fabricated novel cricket bowling machine and according to the analyses of specific bowling techniques, the experimental platform is capable of performing bowling variations with respect to major techniques accurately. And the results showed that this machine is capable of pitching the ball precisely at a given target and theoretical calculations have validated those variations. Further, the developed platform performs more accurately for the in-spin bawling technique, where all mechanisms collectively contribute to executing the particular technique. Therefore, it can be guaranteed that the selected mechanisms are validated for this application. Quick ball variation depends on the coache's practice schedule and thus it will be independent of the batsman.

The conceptually designed CVT system for the bowling machine will make automation difficult, and it will create undesired issues like vibration, back force, and lack of controllability of the machine. Thus, based on the study, a novel ball-propelling mechanism has been introduced that enhances the batsmen's training sessions by having target bowling capability. The mechanisms and the structural design were finalized targeting the accuracy and the compactness of the apparatus. Therefore, coaches can use this machine to pitch the cricket ball at a predetermined place with the desired variation (swing, spin, and speed change) accurately. If the coaches know the speed, pitching position, and variation. it is possible to mimic the variations of any major bowling techniques from this machine. This machine can implement numerous cricket bowling variations by changing the rolling angle, pitching angle, and speed of the ball. The introduced gyroscope mechanism enhances the stability of these variations with less vibration.

Contributions of Authors

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

Funding

This work received no specific grant from any funding agency.

Conflict of Interests

All authors declare that they have no conflicts of interest

Acknowledgment

We thank all the supporting staff in the welding section and machine shop in the Department of Mechanical Engineering in the University of Moratuwa for their equipment and support services in building this machine.

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