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A Study of Ball Velocity Measuring Device

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Introduction

The use of throwing performance has been made in various kinds of experiments. In measuring the velocity of a thrown ball as a performance measure, the more difficulty would be encountered as compared with the other measures. So there has been movement toward solution of this problem. One procedure, reported by Rowland (14), involved timing by stopwatch the flight of the ball for a distance of 100 ft. However, the use of stopwatches for timing purposes reduced the precision markedly. So far, many investigators (1, 4, 8, 9, 15,) has determined the velocity of a thrown ball using a high-speed camera. Filming permits to measure accurately the velocity and the other mechanical elements, but it takes a considerable time to obtain all data needed from the film. On the other hand, an attempt has been made to measure the ball velocity with improvement of the electric apparatus. Hubbard (6) developed an instrument in which a timer was triggered to start and stop by the removal of two plugs attached by strings to the ball. The velocity was calculated from dividing the specified distance by the time interval between the removal of the first and second plug. In this respect, Nelson (12) stated that this method of timing was apparently satisfactory except for the restriction of the throwing movement of the subject by means of strings on the ball. Slater-Hammel and Andres (16) developed an instrument so that an electric clock was started by the release of a ball in pitching and stopped by a sound wave created in catching the ball. In order that the grasp and release of the ball would act as a switch, a regulation baseball was partially coated with conducting silver, and small copper electrodes were designed for finger tips. A speaker unit detecting the sound wave was placed within two feet of home base. The timer was used to measure the duration of ball flight from pitcher's hand to home base. The similar method of measuring the ball velocity was reported by Van-Huss et al. (21) The clock was actuated by

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a finger release and stopped by microswitch when the ball contacted the target. Miller and Shay (11) also designed the similar device in which the clock started as the ball left the hand and stopped as the ball hit the mitt, causing two parts of the double pad to contact each other. The wire attached to the subject might be still considered an insufficient method, although somewhat lessening the restriction of the throwing movement.

A principle different from the one above has been utilized for solution of this problem, that is to say, the use of photoelectric cell detecting the change in light intensity. The velocity was calculated from the elapsed time and the specified distance between two frames of photocell circuits. An equipment for measuring the velocity, reported by Straub (17), was constructed using a photocell circuit and a vibration detector system connected to a timer. The timer was triggered to start when the thrown ball interrupted the rays of light falling upon the photocells and to stop when the ball contacted the target. A device, developed by Nelson et al. (12), consisted of two identical light fields and photocell circuits that were connected to a timer. The thrown ball passed over the photocells and blocked out a portion of the light entering one of the cells. This change in light intensity causes a slight change in voltage within the photocell circuit that is magnified and transmitted to the timer. Toyoshima and Miyashita (20) constructed the similar and possibly improved device. By the use of CdS photocell responding to the ray of sunlight in addition to spotlight, a light field was removed from this device, in other words, the device became smaller. An equipment for measurement of ball speed, reported by Hoshikawa et al. (7) and Toyoshima et al. (19), consisted of two sets of phototransistors connected to a minicomputer. In these instances the free throwing movement could be not quite performed.

Recently, an instrument called "Speed Gun" for measuring the ball speed has been spreading rapidly throughout baseball world. For the ball speed could be measured simply and immediately by means of this instrument. The principle used is called the Doppler effect. The instrument transmits a microwave radio signal going out in a pattern much like a flashlight beam. Objects that pass through this beam cause the signal to be reflected back to the radar unit where this echo is processed electronically to determine the object's speed. This appears to allow subjects to throw freely a ball, but not to be satisfactory to the accuracy of speed measurement.

In this study, a device for measurement of the ball velocity was constructed using the photocell circuit. In two throwing tests the ball velocity was related to the distance of throw.

Description of Ball Velocity Measuring Device

The device for measuring the velocity of a thrown ball consisted of two frames of cadmium sulfide photocells, as shown in Figure 1 and 2. In order to concentrate the light on the photocells, each of the cells was placed in the edge of a bamboo tube, with a length of 18 cm and inside diameter of 13 mm. Ten tubes with the photocell circuits were set equidistant vertically at intervals circuits were set equidistant vertically at intervals of 5 cm in a wooden frame, 75 cm long, 15 cm wide and 6 cm thick. The first frame stands exactly 1.5 m ahead from

the second frame. A variable resistance with the change of light intensity is the significant peculiarity of photocell; the resistance gets less and less as increment of the light intensity incident upon the cells. Current was provided to the photocell circuits by a 9-volt battery.

The thrown ball passes by the first frame interrupting the light entering the photocells. This change in light intensity causes a slight change in voltage within the photocell circuit. The same change occurs as the ball passes by the second frame. The change is amplified and transmitted to a Rectigraph (Figure 3). Under the conditions of this experiment the paper speed of the Rectigraph was 500 mm / sec. The distance from the first to second signal on the paper, as shown in Figure 4, was measured to the nearest half of a millimeter and converted into the time interval because 0.5 mm was equal to 0.001 sec. The ball velocity was calculated from dividing the specified distance (1.5 m) by the recorded time.

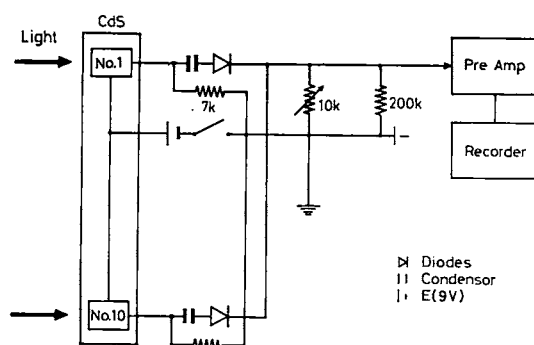


Figure 1. Block diagram of velocity measuring circuit.

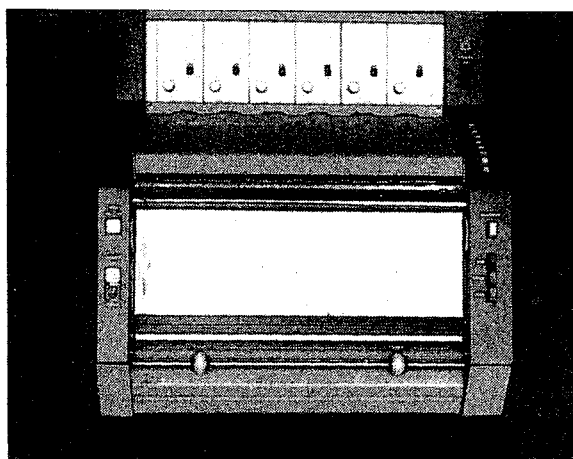


Figure 2. Photograph of ball velocity measuring device.

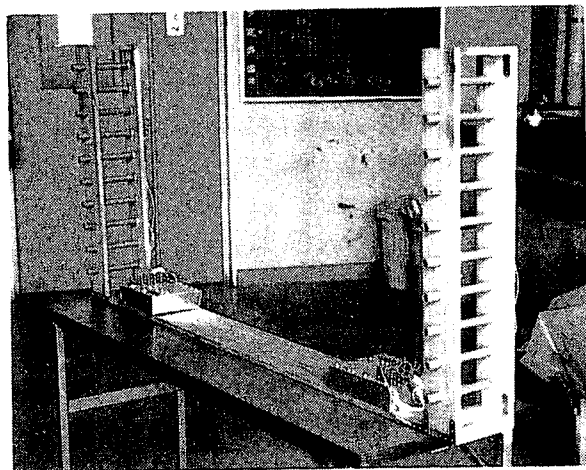


Figure 3. Photograph of Rectigraph for measurement of time interval.

Tests of Throwing

Methods: Seventy-five male and thirty-three female students majoring in physical education in University of Kanazawa participated in this experiment. Each of the subjects was given two tests for measuring the distance and velocity of ball throwing. The subjects were asked to throw a regulation baseball with a diameter of 7 cm and weight of 150 g.

A throwing test for distance was administered outdoors, on ground surfaces marked at 50 cm

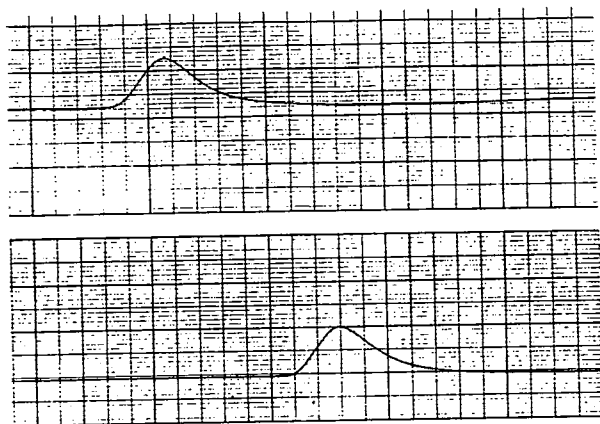


Figure 4. Timing record showing first and second signals.

intervals with chalk lines. Each of subjects was allowed to throw the ball by overarm throw with taking a short run. The distance of throw was measured to the nearest half of a meter.

An indoor test was administered for measurement of the ball velocity. The subjects were told to throw the ball horizontally by overarm throw with their maximum efforts. The ball was released just in front of the first frame of photocells. For each test the best score out of 3 trials was used for analysis.

Results

The mean velocity and distance of a baseball throwing obtained at indoor and outdoor tests are shown in Table 1. The mean ball velocity for male group was 28.5 m/sec with a range of 23.1 to 34.6 m/sec and for female group 16.9 m/sec with a range of 10.9 to 21.1 m/sec. The difference in velocity between both groups ranged from 2.0 to 23.7 m/sec. The mean distance of throw for male group was 71.6 m with a range of 58.0 to 96.0 m and for female group 36.5 m with a range of 24.5 to 51.5 m. The difference in distance between both groups ranged from 6.5 to 71.5 m. In both throwing tests the male group was exceedingly superior to the female group.

The regression equations relating distance and velocity are shown in Table 2. The correlation coefficients for relationship between distance and velocity were .857 for male group and .680 for female group. The statistical significance at .001 level was found in both groups. The regression equation for male group was $Y = 2.781 X - 7.745$ and for female group $Y = 1.846 X + 5.276$, as shown graphically in Figure 5.

Sources of Error and Recommended Improvements

Table 1. Mean distance and velocity of baseball throwing obtained at outdoor and indoor tests.

	N	DISTANCE OF THROW (m)	BALL VELOCITY (m/sec)
Male	75	71.6 ± 9.0 (58.0 - 96.0)	28.5 ± 2.8 (23.1 - 34.6)
Female	33	36.5 ± 7.1 (24.5 - 51.5)	16.9 ± 2.6 (10.9 - 21.1)
All	108	60.9 ± 18.3	25.0 ± 6.0

In terms of the distance and time elements out of which the velocity is formed, three main sources of error are found in the presently reported device. Firstly, an error of the distance element is always caused by a constructive defect of this device in which ten photocells (diameter: 13 mm) are set every interval of 52 mm in a wooden frame. In this experiment, the calculated error for the specified distance is 150.0 ± 0.9 cm when the thrown baseball (diameter: 7 cm) passes vertically in front of the first and second frames.

Therefore, a smaller ball would be unsuitable for the device while the less error could be given by a bigger ball. This problem ought to be eliminated by reducing an interval at which the photocells were placed equidistantly in a frame or using a lense to fill a gap in photocells that are fixed in the frame. Secondly, there also occurs an error of the distance element when the trajectory of ball is not perpendicular to both frames. This deviation would cause the ball to travel a distance of more than 1.5 m, that is, an underestimation of the ball velocity. This, as noted by Nelson (12), is controlled if a ball is

Table 2. Regression equations relating distance and velocity of a baseball throwing.

	REGRESSION EQUATION	r
Male	$Y = 2.781X - 7.745$.857
Female	$Y = 1.846X + 5.276$.680
All	$Y = 2.920X - 12.061$.961

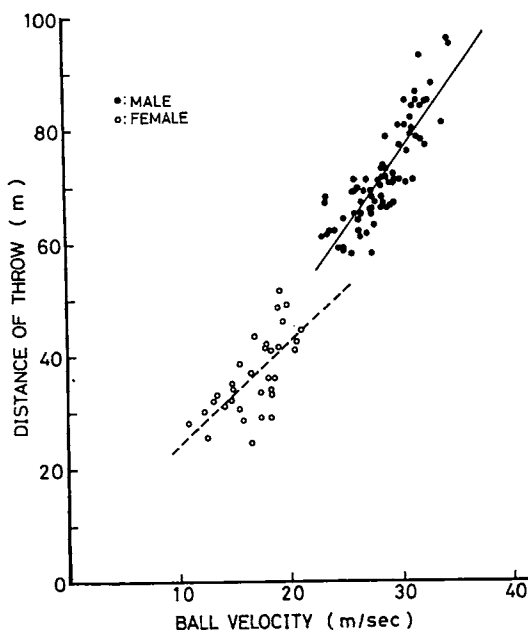


Figure 5. Relationship between distance and of baseball velocity throwing obtained at outdoor and indoor tests.

thrown at a distant target since any marked deviation from a perpendicular trajectory would probably result in missing the target completely. Thirdly, there is a possible error of time element because, by means of a Rectigraph whose paper speed is 500 mm/sec, the time interval is measured only to .001 sec. The velocity is calculated from dividing a specified distance (1.5 m) by a recorded time; the velocity is in inverse proportion to the time. Consequently, the shorter the recorded time, the more the velocity is calculated roughly. It is desirable that a recorder or timer should be capable of measuring the time interval to at least .0001 sec since up to now the highest velocity of a pitched ball, is approximately 45 m/sec. Besides, a timer ought to be used to measure the velocity more simply.

The other improvements in the device would be needed for measuring the velocity everywhere. In this experiment, a change in voltage within the photocell circuit was recorded much better when the ray of sunlight was used as the source of light compared with that of spotlight. It follows that there would be difference in light intensity or characteristics between the sunlight and spotlight. This problem should be solved at once since an investigator cannot but use the spotlight as the source of light during indoor test. In addition, it seems likely that a frame of wood

would be warped by environmental conditions; e. g., hot sun, temperature, humidity and so forth. For this reason it is advisable to improve using a solid and ingenious metal frame. More improvement in the device is required for a wide application to various kinds of experiments.

In summary, a principle of photocell detecting the change in light intensity was applied to measurement of the ball velocity. A device for this purpose consisted of two frames of the CdS photocells connected to a Rectigraph. By the use of this device, the ball velocity was significantly related to the distance of throw. In this experiment, error of the calculated velocity would occur from 1) the constructive defect of the device, 2) the trajectory unperpendicular to both frames, and 3) the limitation in time measurement.

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