Continued research, development and construction of a state of the art impact testing lab for eyewear: Instrument calibration portion

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Pacific University

Aqil Habib  
Pacific University

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Abstract
The purpose of this thesis is to calibrate a pre-existing high-velocity ballistic firing device capable of projecting various sized sports balls with variable velocities at eyewear mounted on a head form. Four sports balls have been tested and calibrated with the results displayed in a table format for easily accessible findings. A laser timer linked to the Datasource computer program was used to make precise measurements of time and speed.

Degree Type
Thesis

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CONTINUED RESEARCH, DEVELOPMENT AND CONSTRUCTION OF A STATE OF THE ART IMPACT TESTING LAB FOR EYEWEAR:
INSTRUMENT CALIBRATION PORTION

BY
IAN FORD
AQIL HABIB

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
For the degree of
Doctor of Optometry
December 2006

Advisors:
Karl Citek, OD
Alan Reichow, OD
Biographies

Ian Ford has attended Pacific University College of Optometry since 2003. He received his undergraduate education at Pacific University, Montana State University – Bozeman, and the University of Mary in Bismarck, North Dakota, earning his undergraduate degree with a B.S. in Biology with a Chemistry minor. Upon receiving his doctorate of optometry degree, he plans on returning to Montana to practice optometry.

Aqil Habib has attended Pacific University College of Optometry since 2003. He received his undergraduate education at the University of Washington in Seattle and Pacific University earning his undergraduate degree with a B.S. in Vision Science. Upon receiving his doctorate of optometry degree, he plans on returning to Seattle, Washington to practice optometry.
Abstract

ABSTRACT

The purpose of this thesis is to calibrate a pre-existing high-velocity ballistic firing device capable of projecting various sized sports balls with variable velocities at eyewear mounted on a head form. Four sports balls have been tested and calibrated with the results displayed in a table format for easily accessible findings. A laser timer linked to the Datasource computer program was used to make precise measurements of time and speed.

Key Words: Nike, Ballistics, Lenses, Impact, Sports
Acknowledgements

We would like to thank Nike, Inc. for grant support for this thesis project. We would also like to thank Shawn Tsai and Richard Baird for their assistance during testing.
Introduction

In the year 2000, Chad Roberts and Stephen Reigstad began a thesis project aimed at giving Pacific University College of Optometry a "State of the Art" impact testing lab for eyewear. The first part of this project, completed in 2001, dealt with the research, development, and construction of a drop ball apparatus consisting of variable sized and weighted objects that could be dropped from chosen heights onto selected eyewear or lens blanks. The second part of this project, completed by Dustin Bodman, Ryan Hogan, and David Biggar in 2004, dealt with the research, development, and construction of a high-velocity ballistic firing device capable of projecting various sized sports balls with variable velocities at eyewear mounted on a head form. The third part of this project, running from 2005 thru 2006, dealt with the calibration of this machine as well as making improvements to the design. The advisors for all portions of the lab design are Dr. Alan Reichow and Dr. Karl Citek, who are both professors at Pacific University College of Optometry.

Methods

The first improvement for the ballistics machine was to investigate the possibility of high-speed imaging. With high-speed imaging, videos and still images could be examined, showing the entire impact process during testing. This would allow for better interpretation of the results, as well as offering some awfully interesting photographs. The camera would be mounted outside of the machine and cover a 30 cm x 30 cm area, centered on head form. Questions arose regarding a degraded image through the ½" polycarbonate, but it was determined that for the safety of the camera, this would be the best choice.

Calculations for the speed and resolution needed for this camera were based on a maximum testing speed of 80 mph, or 35.8 m/s, and a necessary field of view of 30 x 30 cm. This meant a ball would travel through our field of view in 8.4 ms. In order to capture 20 frames during this span, a camera with a speed of at least 2384 frames per second (fps) would be necessary. As for the resolution needed for this camera, the area needed to capture in the field of view was 900 cm². In order to have high enough quality of resolution over this area, a camera with at least 3 megapixel (2048 horizontal x 1536 vertical pixels) capability would be necessary. This would allow for 68 pixels per 1 cm².
horizontally and 51 pixels per 1 cm vertically. Two different companies, Photron and Itronix, were contacted regarding pricing for cameras with such capabilities, and it was determined that the cost ($10,000 - $50,000) definitely outweighed the benefit at this current phase of the project.

The next goal of the project was to calibrate the instrument using a laser timer linked to the Datasource computer program for numerous different sports balls. Included in this phase of the project were the tennis ball, baseball, softball, and volleyball. Being that the Juggs machine had been calibrated for a specific ball with a specific spacing, its calibration was no longer accurate, and therefore could only be used as an estimate.

The initial set-up of this laser gate consisted of a laser mounted to a tripod aimed through a hole in the polycarbonate casing at a mirror on the other side. This mirror reflected the laser beam to another mirror, which in turn reflected the beam to a sensor. When the ball passed through the first beam, the switch would be shut off, then turned on again when the ball cleared the beam. The same thing would occur when the ball passed through the second laser (see Figure 1). These four times were captured by the Datasource program, then transferred to a Microsoft Excel spreadsheet to determine the true velocities of the projected balls.

Figure 1.
In order to make the machine more aesthetically pleasing, an attempt was made to mount the laser, the mirrors, and the sensor to the frame of the machine. Not only would this would get rid of the cinder blocks and tripods, but it should have also made the alignment process much easier. Using pipe fittings, test-tube holders, and corrugated metal rods, the instruments needed for the laser gate were mounted to the machine’s base. A new laser was purchased that ran on AA batteries instead of the previous button battery variety in order to make for easier replacement. This improvement worked until the Juggs machine was turned over its 60 mph indicator. Anything at this speed or higher caused too much vibration of the base, which caused the laser to shift loose, which made it impossible to gather any recordings because the sensor no longer had contact with the laser. Therefore, in order to gather the calculations for this project, the old laser gate setup was utilized.

The methods used to calibrate the Juggs machine for different sports balls were fairly straight-forward. A metal spacer was inserted between the two wheels of the Juggs machine to provide proper spacing for the ball being tested (see Table 1). The speed indicator on the Juggs machine was then turned to an increment of 10, and then 20 trials were run at that speed. Four times were recorded for each ball (when the first switch went off, when it turned back on, when the second switch went off, when it turned back on) and were entered into a spreadsheet. The velocity of the ball was then calculated in both miles per hour and meters per second. An average of the 20 runs as well as the standard deviation was also calculated.

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<th>Ball</th>
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<td>Baseball</td>
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<td>Softball</td>
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<td>Volley Ball</td>
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### Results

- **Average**: 0.946
- **Standard Dev.**: 0.007
- **Minimum**: 0.928
- **Maximum**: 0.970
- **Median**: 0.951

---

### Additional Data

- **Table Values**: Various physical measurements related to the tennis ball, including mass, diameter, and other properties.
- **Graphs**: Visual representations of performance metrics over different conditions.
- **Equations**: Mathematical formulas used to calculate various properties of the tennis ball.

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**Note**: The table and data are presented in a structured format, ensuring clarity and ease of understanding.
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Table 4 - Softball

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Average:

- Standard Dev: 0.25150137
- Average: 0.8962

Table 5 - Baseball

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<th>Break 2</th>
<th>Recovery 2</th>
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Average:

- Standard Dev: 0.25150137
- Average: 0.8962
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*Table 5 - Volleyball*
Summary of Results

Tennis Ball
With a Jugg speed of 20:
Avg ball speed was 30.15 mph with a standard deviation of 0.2252
With a Jugg speed of 30:
Avg ball speed was 43.28 mph with a standard deviation of 0.7514
With a Jugg speed of 50:
Avg ball speed was 62.345 mph with a standard deviation of 0.1.579
With a Jugg speed of 70:
Avg ball speed was 76.06 mph with a standard deviation of 3.161
With a Jugg speed of 80:
Avg ball speed was 88.31 mph with a standard deviation of 2.430

Baseball
With a Jugg speed of 40:
Avg ball speed was 51.54 mph with a standard deviation of 0.4748
With a Jugg speed of 60:
Avg ball speed was 61.43 mph with a standard deviation of 0.6280

Softball
With a Jugg speed of 60:
Avg ball speed was 65.025 mph with a standard deviation of 3.157
With a Jugg speed of 70:
Avg ball speed was 71.71 mph with a standard deviation of 2.803
With a Jugg speed of 80:
Avg ball speed was 75.633 mph with a standard deviation of 1.789

Volleyball
With a Jugg speed of 40:
Avg ball speed was 27.46 mph with a standard deviation of 1.648
With a Jugg speed of 60:
Avg ball speed was 35.04 mph with a standard deviation of 0.8259
With a Jugg speed of 80:
Avg ball speed was 39.37 mph with a standard deviation of 1.001
Conclusions

The Nike ballistics testing instrument is an excellent way to test the impact resistance of different eyewear at different controlled velocities using different balls from different sports. Due to the modifications of the Juggs machine, the speeds recorded on the dial were no longer accurate. Also, different balls have different variables including size, diameter, mass, and material, meaning that when the instrument is calibrated for one sport, the speeds will not carry over to another sport. The research completed here provided actual speeds of balls traveling at speeds recorded on the dial of a Juggs machine. For smaller balls, the Juggs machine tended to slightly underestimate the true speed; however, the opposite was true for the larger ball tested in this project. The results showed consistency, with the greatest standard deviation coming for a tennis ball with a Juggs recorded speed of 70 (actual value 76.06 ± 3.161 mph).

Throughout the testing, a few ideas arose that call for further testing. The first involves the variability of revolutions per minute (RPM) of the Juggs' wheels. If there is a great difference between trials, this could make the standard deviation greater. Also, if there is a difference between testing on different days, then the results of our calibration findings here would not be valid. We propose that this issue be investigated in the ongoing phases of this study in order to improve the validity of our research.

A second issue that arose during testing was the variability of conditions of the ball we were testing. On the first trial, the ball used was in superb condition. However, after 20 trials, the ball was beginning to get scuffed up and lose its consistency. It would be interesting to note whether or not using an old ball instead of a fresh ball does in fact contribute to any significant differences in the speeds measured during this experiment.

The third and final issue that needs to be investigated is whether or not there is a difference in the measured speed depending on how the ball is placed in the ramp. Sometimes, as was the case with the larger volleyball, the ball needed a gentle nudge to begin its descent down the ramp. We cannot say with certainty whether or not it was nudged with the same amount of force between trials, and therefore cannot say with certainty whether or not our variability between measured speeds is truly representative of the Nike ballistics machine or our methods. This needs to be explored not only for the
larger volleyball, but also for the other balls that intend to be tested using this instrument in case of tester variability.

Follow-up regarding the high-speed camera system should also be completed at a later date when the instrument is ready for trials. To be able to see the way the eyewear reacts at impact would be beneficial not only for frame design, but also to see how much inconsistency there is between the location at which the ball strikes the eyewear. The calculations for the specifications needed for this camera are included in the methods section of this write-up, as well as two companies who were willing to assist in any way they could.

As far as making the device more aesthetically pleasing, this may be difficult without radical reconstruction. At certain RPMs, the Juggs machine causes the entire base of the ballistics machine to vibrate. These vibrations cause the laser, the mirrors, and the sensor to all vibrate, too. The problem with this is that they do not vibrate in unison, which causes the beam to not strike the sensor and therefore lead to an incomplete laser gate. A couple of ways that this could possibly be remedied include the separation of the Juggs machine from the enclosed impact zone or to set up two laser-sensor switches. However, each of these comes with added disadvantages as well. By separating the Juggs machine from the rest of the ballistics testing device, we are increasing the need for perfect alignment of the entire device. If the angle at which the ball is expelled is off by a minimal amount, it runs the risk of striking the head-form at an oblique angle and giving invalid results. Also, it increases the risk of the ball missing the pre-constructed opening through which it needs to travel to strike the head-form, thereby increasing the chances of operator injury. By mounting two laser-sensor switches, we would eliminate the need for precision in the alignment of the mirrors. However, we would still have to have the lasers striking the sensor without any interruption, and with the shaking of the ballistics device, this may pose quite the challenge.