

Effectiveness of Grips at Minimizing Vibrations During Field Hockey Hits

by

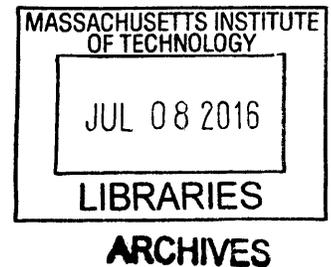
Morgan Gulliver

Submitted to the
Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science in Mechanical Engineering

at the

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ABSTRACT

An experiment was carried out in order to determine the frequencies experienced in two locations on the stick during two different field hockey hits, the push and the strike. The results from these experiments showed that the top hand during a hit experiences a higher resonant frequency. During the push the top hand experienced an average resonant frequency of 349.1 Hz, compared to the lower hand which experienced an average resonant frequency of 43.95 Hz. During the strike the top hand experienced an average resonant frequency of 197.8 Hz, compared to the lower hand which experienced an average resonant frequency of 24.41 Hz.

A second experiment was carried out in order to determine how effective the grip was at dissipating frequencies. The results determined that the grip is most effective over the frequencies of 117 Hz-470 Hz. Both an old and new grip were tested. The new grip was slightly more effective over the frequencies of 117 Hz – 235 Hz, and similar over the frequencies 250 Hz – 470 Hz.

From these experiments it was concluded that field hockey grips are most needed and effective on the shaft of the field hockey stick.

Thesis Supervisor: Anette Hosoi
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1. Introduction

Field Hockey is a stick and ball sport played on a field. There are 11 players on each side, including a goalie. Forms of the game originated as early as 2000 BC in Persia.¹ In its original form field hockey was played on a grass field with wooden sticks, as seen in Figure 1.



Figure 1: Original wooden field hockey sticks.²

Field hockey has developed into a highly competitive game played at the Olympic, collegiate, high school, and primary school levels. As the game of field hockey has developed, the equipment it uses has as well. Field hockey has followed in the trend of adapting the composite stick, as seen in Figure 2. These sticks are a combination of multiple materials in order to produce light and powerful play. A lot of research has been done on the frequencies in composites involved in many other sports such as ice hockey and baseball.



Figure 2: Composite field hockey sticks.²

In a game of field hockey a player will strike a plastic ball numerous times in order to pass to players on their team or shoot the ball into the opposing teams net. Often times the impact of a hit can be sensed by the player's hands by the vibrations through the stick after the hit. It has been determined that a person's hands are most sensitive to frequencies between 200-400 Hz. When vibrations of this magnitude are experienced at the hands a player often undergoes the unpleasant sensation of a "sting." Frequencies above 800 Hz are more likely to go unnoticed.⁶ Some vibration in the stick is important for players so that they can feel the ball on their stick and are not required to be constantly looking down. It is important to understand the vibrations experienced by each hand during a hit so that sticks can be best designed for the comfort of the players.

2. Background

2.1 Parts of the Field Hockey Stick

Figure 3 below depicts a typical field hockey stick and labels its key parts. The stick is typically held with one hand, generally the left, remaining on the top of the shaft/grip. The other hand, depending on the hit, moves from the shaft/grip to the lower stick. The ball is kept and hit on the face of the stick.



Figure 3: Field hockey stick with face, lower stick, and shaft/grip labeled.

2.2 Composition of Composite Field Hockey Stick

Composite sticks became a necessity in the 1970's because the wooden sticks could not withstand the increased pressure from the change in grass to artificial turf.³ Composite sticks provide the benefits of being lighter and stiffer than wooden sticks. This allows for a more efficient transfer of energy along the shaft of the stick, and thus an increase in the amount of power that can be transferred to the ball.

Composite sticks are comprised of fine fibres woven together in a two dimensional matrix enclosed in resin, which binds the structure into a coherent mass. Typically composite field hockey sticks are composed of fibreglass, carbon, and aramid. These materials are layered in order to build up the strength of the material and combine their material properties.³

Fibreglass is made from strands of glass that are woven into a lattice and set within resin. It is a strong material that is lightweight and flexible. Carbon fibre has a high strength to weight ratio, also providing a strong material to the composite while maintaining its light weight. Finally, aramid has impact resistant properties. By combining all of these, composite sticks are strong, lightweight, and able to absorb high impact without shattering or causing strong vibrations to travel up the shaft. Different composite sticks have different percentages of each of these materials. Sticks with higher concentrations of carbon have a "stronger" feeling and allow a player to hit the ball harder. Sticks with more aramid give the player a greater feeling of control while ball handling because of its increase in impact absorption.³

Composite field hockey sticks are manufactured by wrapping the several layers of composite material around a mold in the shape of the finished shaft. They are then heated and pressed. There are three methods in which they can be pressed. The first method is a traditional hydraulic press in which the mold is placed inside another split mold of its mirror image. The mold is then closed, and the hydraulic pressure compacts the composite material. The second method uses vacuum pressure to force the composite against its mold. The third method uses an

inflatable bladder as the inside mold and the composite wrapped bladder is placed into an outer mold and inflated to force the material into the proper shape. After the stick is finished with the pressing process, the blade of the stick is fit into the open end of the shaft by a peg on the blade that is coated with hot glue. Once the peg is inserted, the pieces are clamped and left to dry. To complete the stick a rubber plug is inserted on the other end (at the top of the stick) of the shaft for grip and safety.⁴

2.3 The Field Hockey Grip

A typical field hockey grip is shown below in Figure 4.



Figure 4: On top is an image of a field hockey grip wrapped on the shaft of a stick. Below is an image of a field hockey grip prior to adhering to a shaft.⁵

Field hockey grips are adhered to the shaft of the field hockey stick. Sticks come with a grip already attached. Over time the grip may wear and a player can purchase a new grip and replace it themselves. Grips are primarily marketed for their increase in grip traction, allowing for fingertip control. The grip begins when the stick bottlenecks to a fixed circumference depicted in Figure 3. Grips are a rubber like material which helps in their aid of traction with hands. During various

hits a player's top hand will remain on the grip, while their lower hand will move from grip to lower stick area depending on the skill they are carrying out.

2.4 Field Hockey Strike vs Push

In field hockey there are two primary ways in which a player interacts with the ball. There is the strike, which is a more powerful hit, and a push which is commonly used to cover shorter distances.

During a strike a player has both hands on the shaft of the stick as depicted in Figure 5. They swing the stick backwards and use their entire body, including legs, to deliver as much power as they can to the ball. Strikes are used for passes that are far apart, as well as shots at the goal.



Figure 5: Hand positioning during a field hockey strike.⁷

During a push a player has one hand on the shaft of the stick and one hand placed below the grip as depicted in Figure 6. A player does not always swing backwards to deliver power to the ball during a push. Often players use only their body to transfer the energy to the ball. Players are also often in this position when they are carrying out small moves to get around a defender and dribbling down the field.



Figure 6: Hand positioning during a push.⁷

2.5 Vibrations in Field Hockey Sticks

When a player strikes a ball, they can sense the vibrations of the hit in their wrists and arms. The hands act as nodes and cause bending modes in the stick. This bending about the nodes is oscillatory and is what causes the vibrations in the stick. The ball is impacted with the face of the stick, further away from the bending nodes, resulting in almost all vibrations at the handle. When a player pushes the ball, the impact force is less and there is a node significantly closer to the face of the stick where the ball is hit. Vibrations can be observed by both hands during both kinds of hits in field hockey.

3. Experimental Design

Four experiments were carried out. Two experiments were to find the frequencies delivered to each hand during a strike and push. The other two experiments were to find the difference in frequencies below and above the grip on the shaft of the stick in both new and old grips.

The field hockey stick used for these experiments was a Dita Terra 20, composed of 30% carbon, 60% fiberglass, and 10% aramid. The original grip was used for the “old grip” experiments and had been on the stick and used for 2 years. A Grays Traction Plus Grip was used for the “new grip” experiments. There was no grip on the sticks during the strike and push experiments. The field hockey stick was clamped to a table providing a fixed-fixed boundary condition. An impact hammer was used to induce a force on the stick. 3-axis accelerometers were attached in two locations and the data was collected using 2 Lab Quest minis.

3.1 Push and Strike Frequency Experimental Set Up

Figure 7(a) and (b) depict the experimental set up for the push and strike frequency experiments. To replicate the nodes produced by hands during a strike and push, clamps were placed where the hands would be located during these moves. The accelerometers were attached

just beside the clamps in order to capture the frequency surrounding the nodes which the hands would sense. The stick was then struck at the face with an impact hammer 50 times and acceleration data was collected for each run.



(a)



(b)

Figure 7: (a) Experimental set up for push experiments.⁷ **(b)** Experimental set up for strike experiments.⁷

3.2 Old and New Grip Frequency Experimental Set Up

Figure 8 depicts the experimental set up for the old and new grip frequency experiments. The stick was arbitrarily clamped in this experimental set up, locations of the clamps were not important. The accelerometers were placed right next to each other, one adhered directly onto the stick and the other adhered on top of the grip on the stick. The stick was struck on the shaft at the

location marked with an X, just before the accelerometer under the grip, with an impact hammer 50 times and acceleration data was collected for each run.

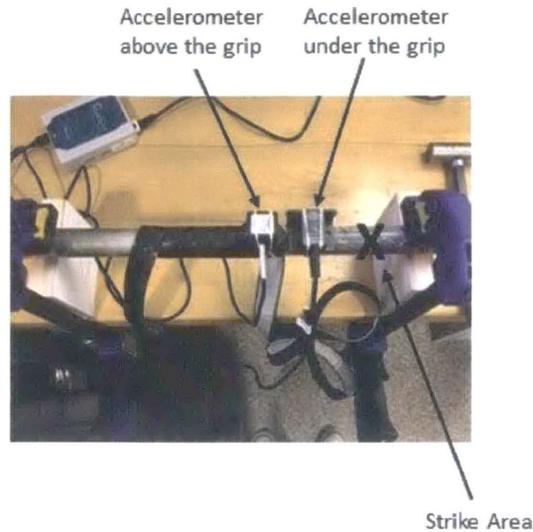


Figure 8: Experimental set up for old and new grip experiments.

4. Results and Discussion

Acceleration and time data from the accelerometers was collected by loggerpro and exported as excel files. These files were then downloaded through a matlab code and processed. For each experiment, data from each run was viewed in order to make sure that each run was fairly consistent and displaying similar behavior. After this was confirmed, data was averaged together.

4.1 Push Results

Figure 9 shows an example of the graphs produced by matlab code from each run.

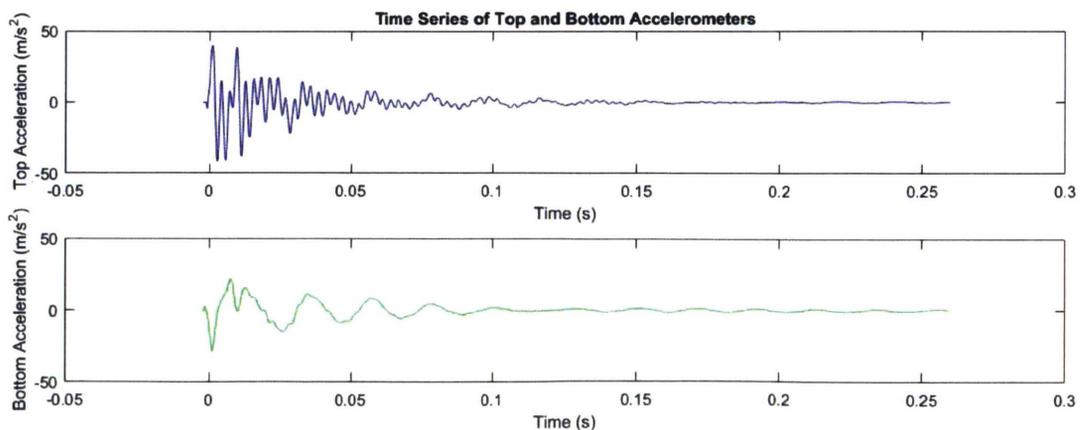


Figure 9(a): Acceleration vs Time for each accelerometer after impact.

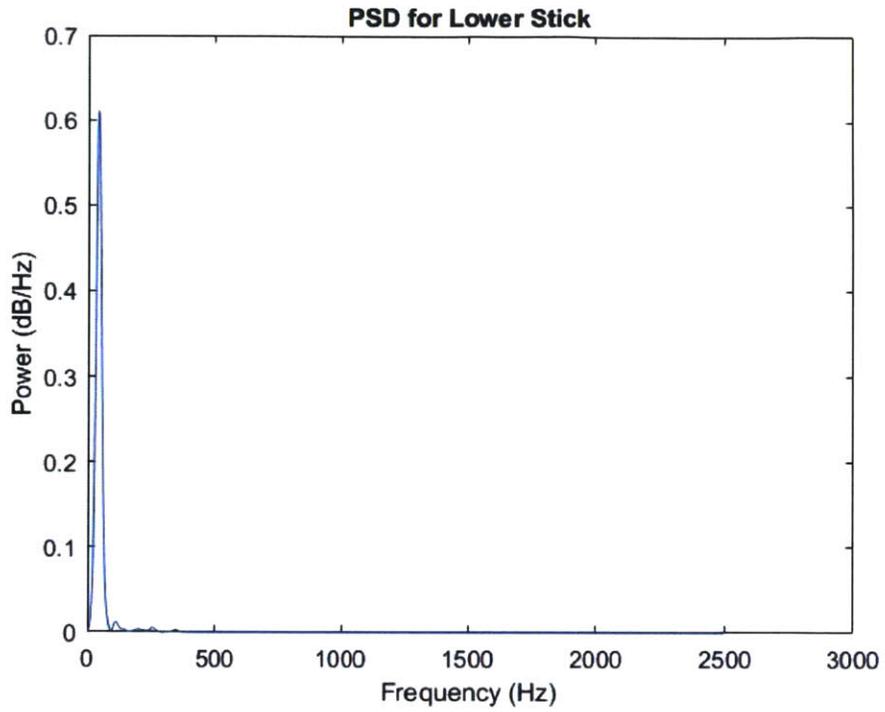


Figure 9(b): Power vs Frequency for accelerometer located on lower stick.

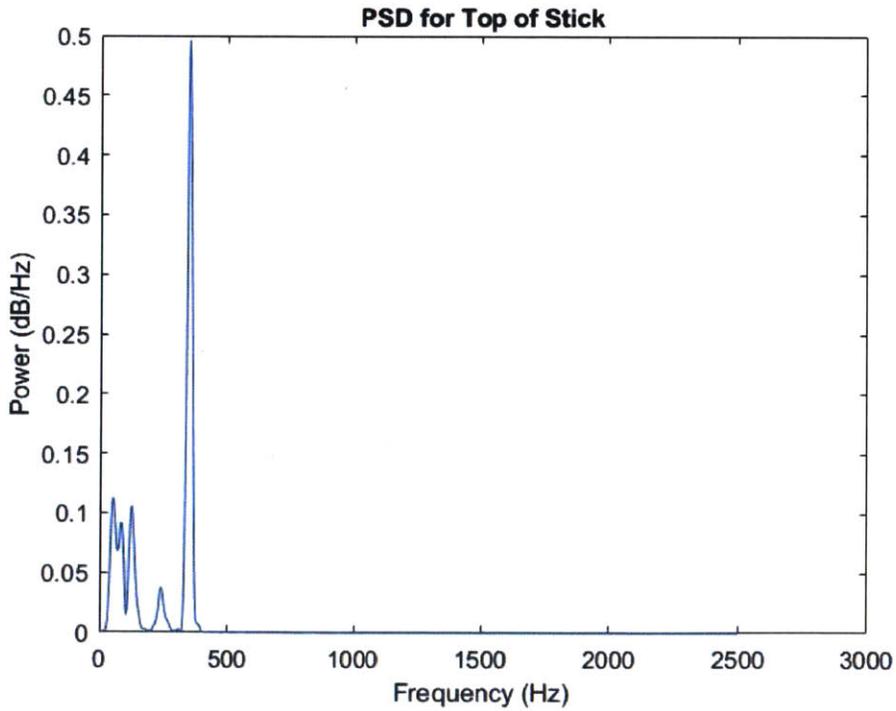


Figure 9(c): Power vs Frequency for accelerometer located on top of stick.

Figure 9(a) plots the acceleration data obtained from the accelerometers. This gives an understanding of the position vs time which will be used to find the frequencies observed during the sticks. The oscillatory behavior of the acceleration data is what is then seen in the following figures. Figure 9(b) plots the PSD (power spectral density) for the accelerometer located lower on the stick (closer to the location of impact). The PSD is a measure of a signal's power intensity in the frequency domain. This is useful in understanding the spectrum of frequencies the hands are observing and which are most powerful. Figure 9(c) plots the PSD for the accelerometer located on the top of the stick (furthest from the location of impact).

Figures 10 (a) and (b), below, are the graphs for the average PSD for both the lower and top accelerometers. Since the objective of this experiment was to determine the frequency experienced by each accelerometer ("hand") in this position, the PSD is the most telling.

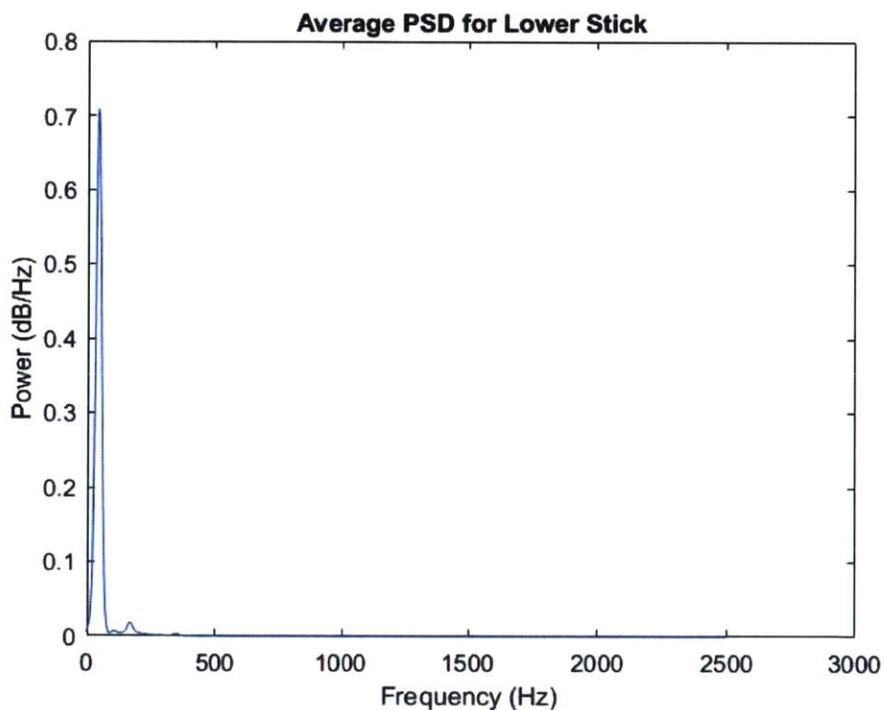


Figure 10(a): Average Power vs Frequency for accelerometer located on lower stick.

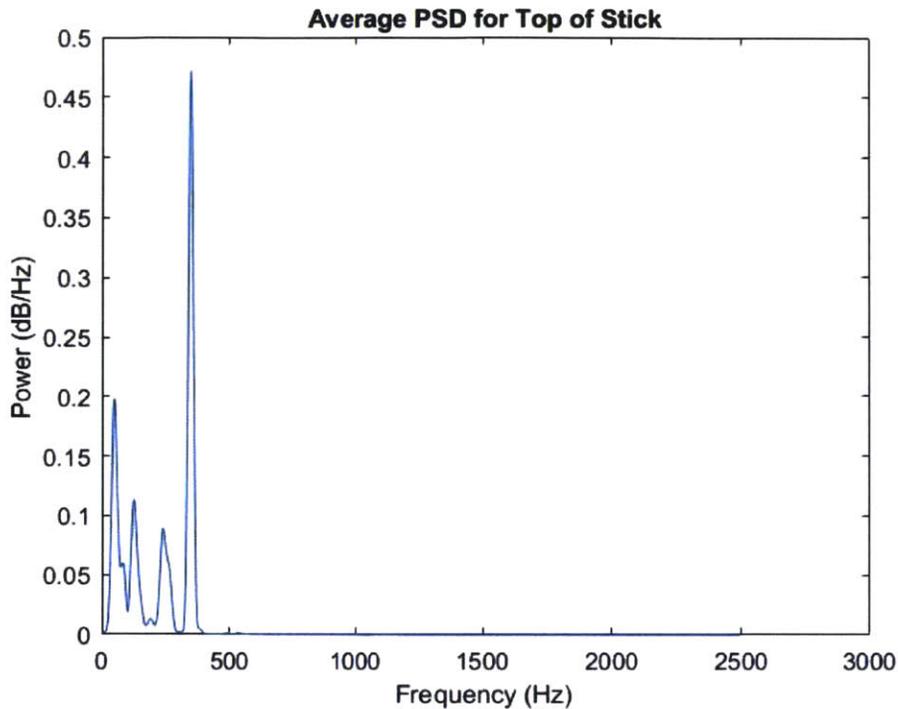


Figure 10(b): Average Power vs Frequency for accelerometer located on top of stick.

As seen in Figure 10(a) there is a peak or resonant frequency of roughly 43.95 Hz at a power of 0.7095 dB/Hz for the hand on the lower stick and smaller peaks of 161.1 Hz at a power of 0.0169 dB/Hz and 344.2 Hz at a power of 0.003835 dB/Hz. Figure 10(b) shows there are several peaks. Smaller ones at 48.83 Hz and power of 0.1987 dB/Hz, 124.5 Hz and power of 0.1136 dB/Hz, and 239.3 Hz and power of 0.08977 dB/Hz. The largest peak is at 349.1 Hz at a power of 0.4723 dB/Hz for the hand at the top of the stick. While the larger peaks show that more of the power produces these frequencies, it is still important to note the smaller peaks in order to have an understanding of all of the frequencies occurring under the accelerometers in these locations.

4.2 Strike Results

Similarly to the push results, Figure 11 shows an example of the same types of graphs produced by matlab code from each run for the strike data.

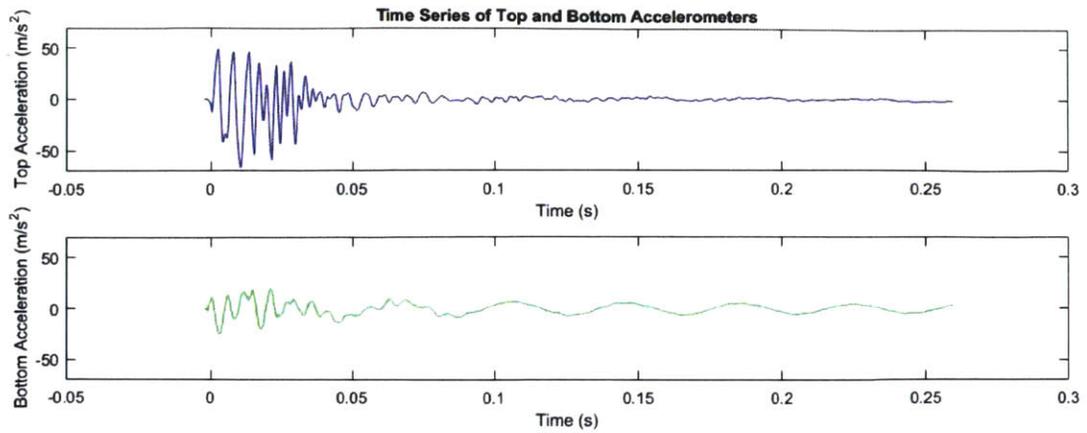


Figure 11(a): Acceleration vs Time for each accelerometer after impact.

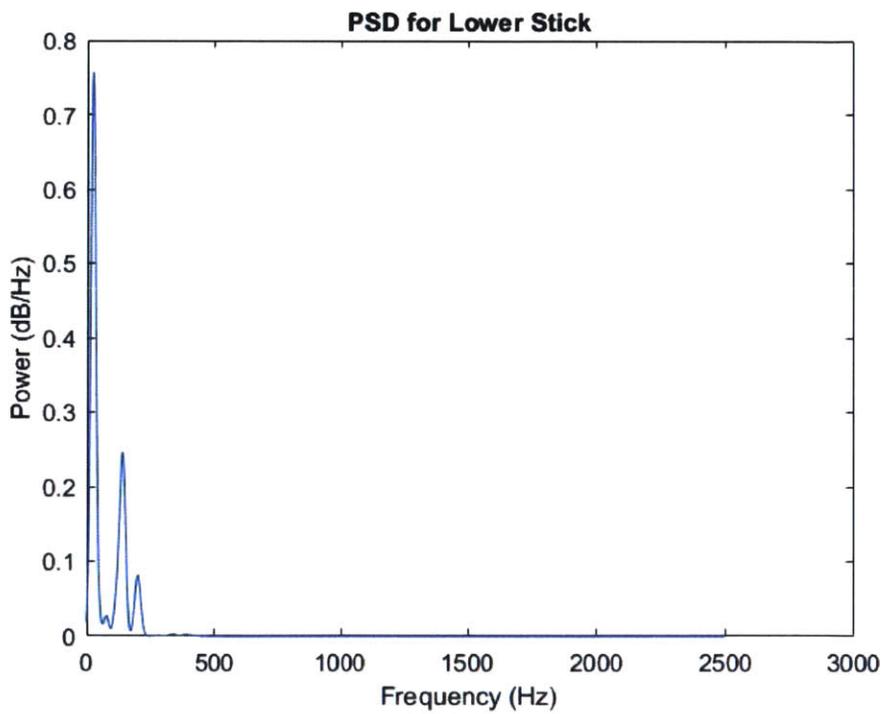


Figure 11(b): Power vs Frequency for accelerometer located on lower stick.

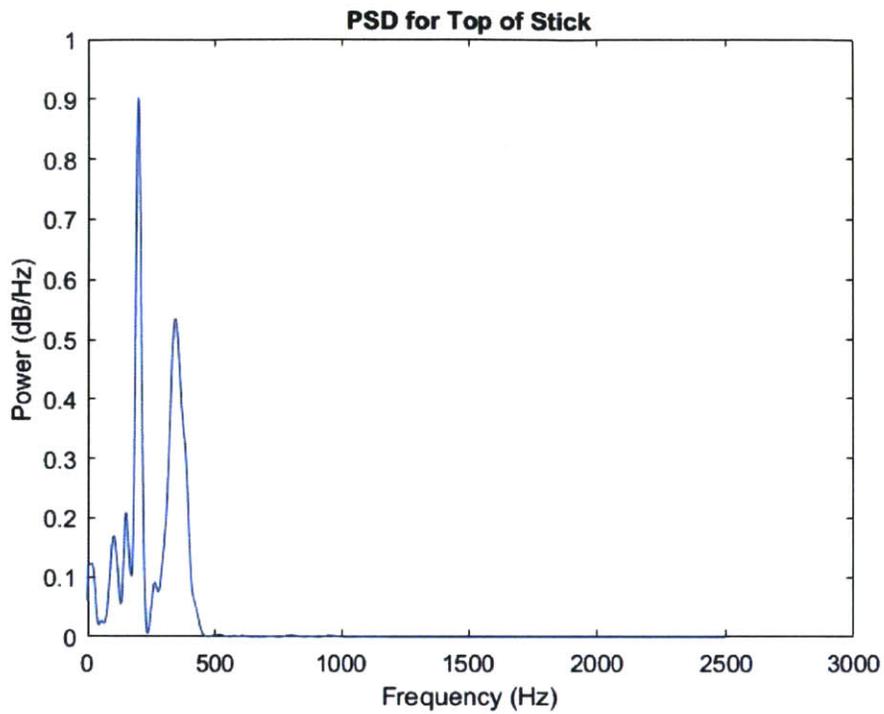


Figure 11(c): Power vs Frequency for accelerometer located on top of stick.

Figure 12, below, are the graphs for the average PSD for both the lower and top accelerometers.

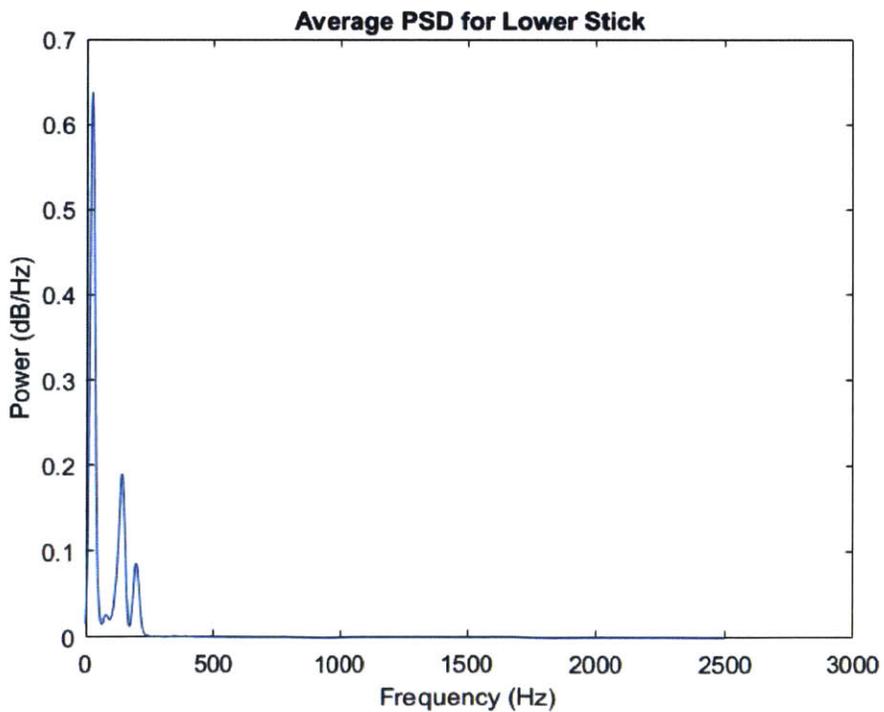


Figure 12(a): Average Power vs Frequency for accelerometer located on lower stick.

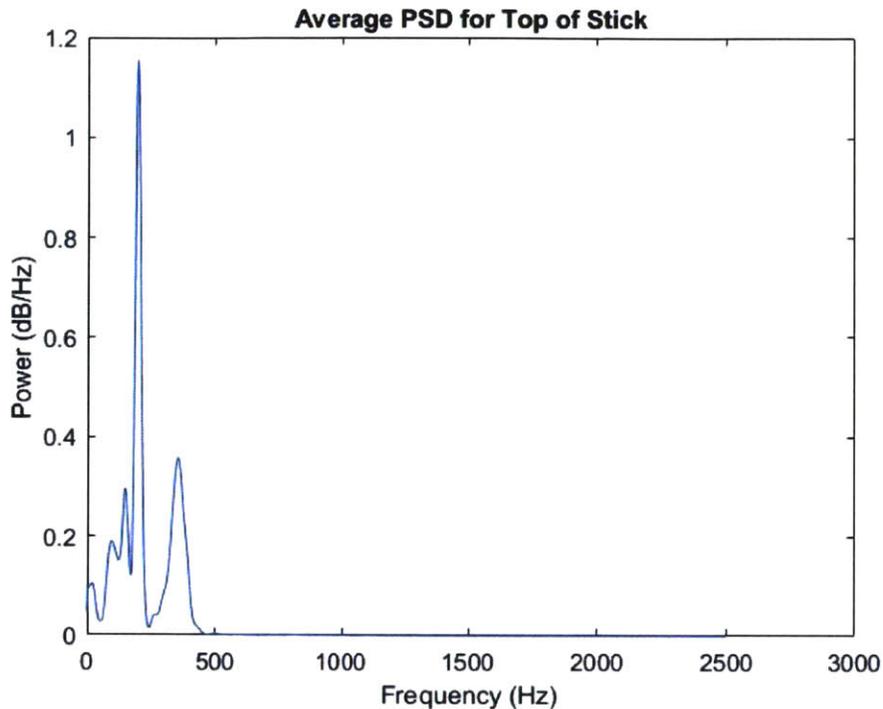


Figure 12(b): Average Power vs Frequency for accelerometer located on top of stick.

As seen in Figure 12(a) there is a peak or resonant frequency of roughly 24.41 Hz at a power of 0.6383 dB/Hz for the hand on the lower stick with smaller peaks at 136.7 Hz at a power of 0.1836 dB/Hz and 195.3 Hz at a power of 0.08649 dB/Hz. Figure 12(b) shows there are several peaks, smaller ones at 17.09 Hz and a power of 0.1036 dB/Hz, 90.33 Hz and a power of 0.1868 dB/Hz, 144 Hz and a power of 0.2833 dB/Hz and 361.3 Hz at a power of 0.3492 dB/Hz. Its largest peak is at 197.8 Hz at a power of 1.155 dB/Hz for the hand at the top of the stick.

4.3 Old Grip Results

Figure 13 shows an example of the graphs produced by matlab code from each run with the old grip. Based on these graphs, focusing on the PSD and Coherence, it was determined to only view the Gain up to a frequency of 500Hz because that was where the transfer function was most accurately predicting the output.

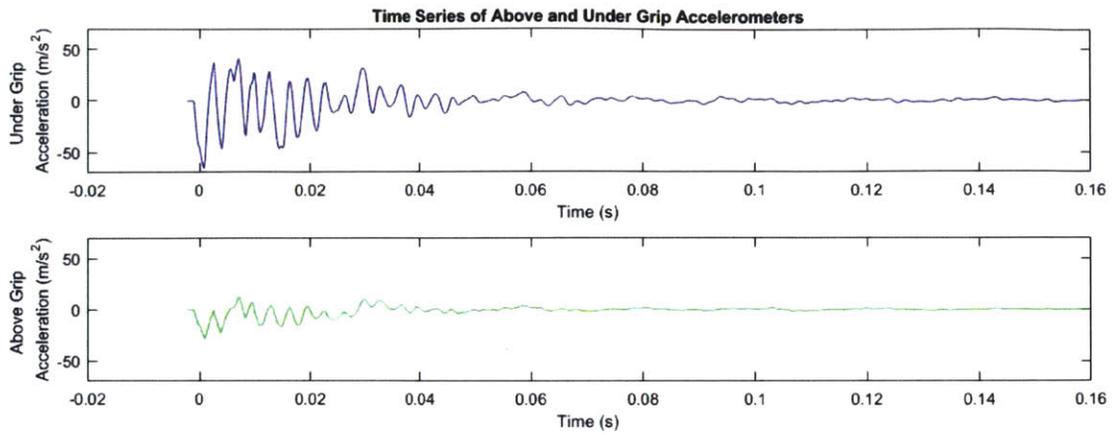


Figure 13(a): Acceleration vs Time for each accelerometer after impact.

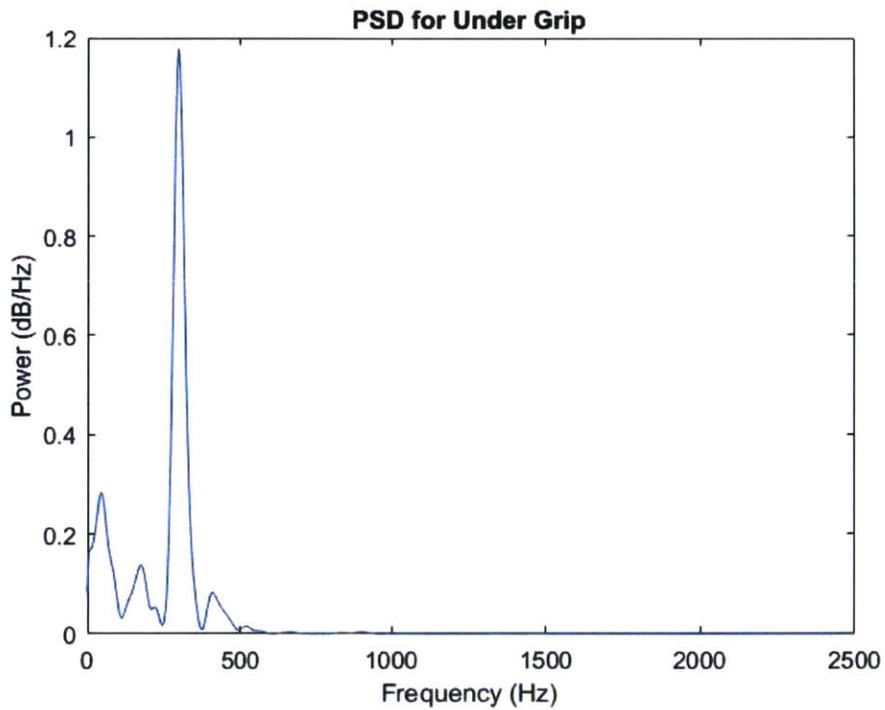


Figure 13(b): Power vs Frequency for accelerometer located directly on the shaft.

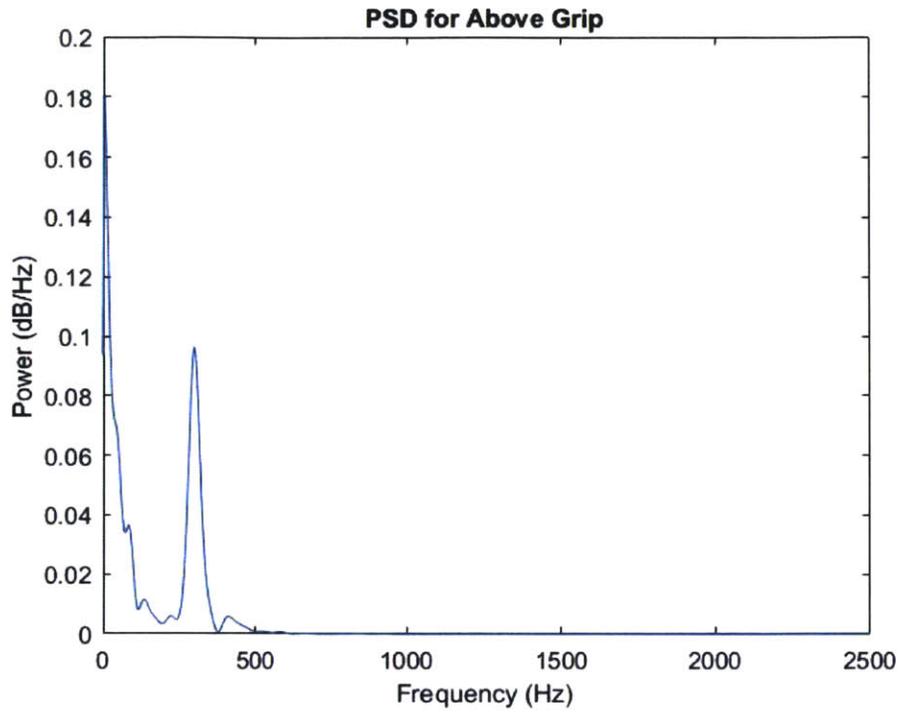


Figure 13(c): Power vs Frequency for accelerometer located on top of the grip.

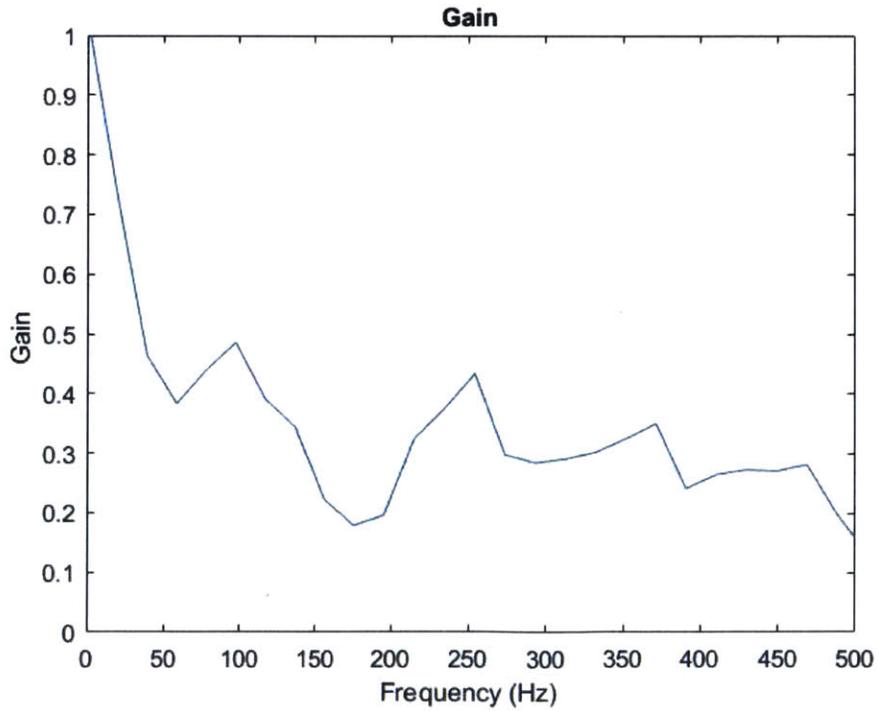


Figure 13(d): Gain vs Frequency for the old grip.

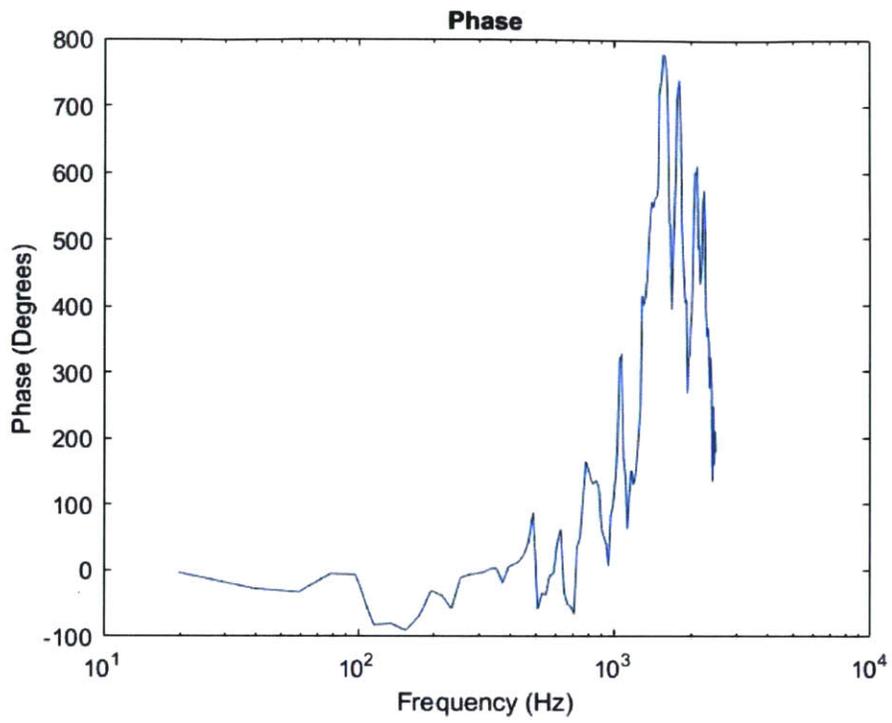


Figure 13(e): Phase vs Frequency for the old grip.

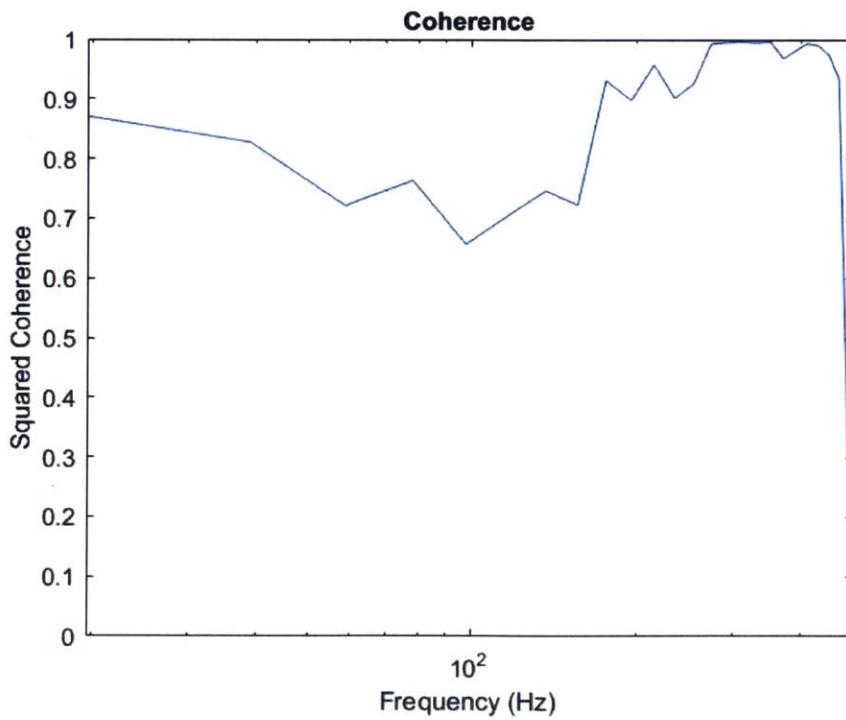


Figure 13(f): Coherence vs Frequency for the old grip.

Figure 13(a) plots the acceleration data obtained from the accelerometers, note the input is the accelerometer directly on the stick and the output is the accelerometer on top of the grip. This gives an understanding of the position vs time which will be used to find the frequencies observed after impact. Figure 13(b) plots the PSD (power spectral density) for the under the grip and Figure 13(c) plots the PSD for the above the grip. This is useful in understanding which frequencies are found below and above the grip. Figure 13(d) plots the gain of the estimated transfer function using the data from under the grip as the input of the transfer function and the data from on top of the grip as the output. The gain is the ratio of the output over the input. Figure 13(e) plots the phase of the transfer function. Finally, Figure 13(f) plots the coherence squared vs frequency. The coherence ranges from 0 to 1 and tells how well the estimated transfer function predicts the output. When the coherence is less than one, the transfer function is no longer “doing a good job” at predicting the output. The coherence is useful in understanding which frequencies to focus on when interpreting the gain plot.

Figure 14, below, gives the graphs for the average gain and coherence of the old grip. These are the most important graphs because the gain gives information on which frequencies the grip is effective over and the coherence gives information on how well the transfer function is predicting the output which in turn effects the accuracy of the gain.

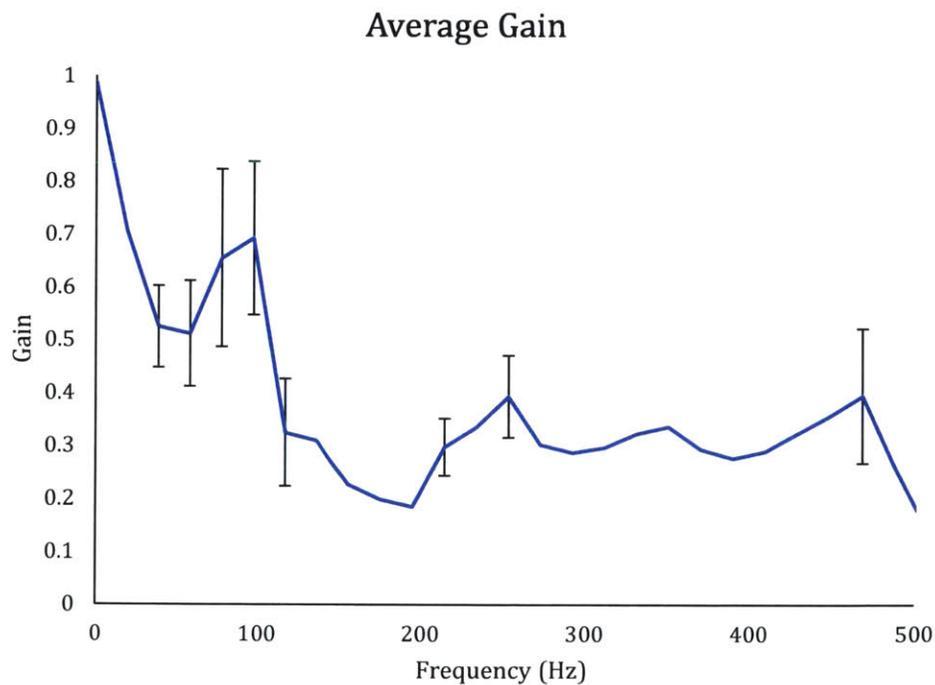


Figure 14(a): Average Gain vs Frequency for old grip.

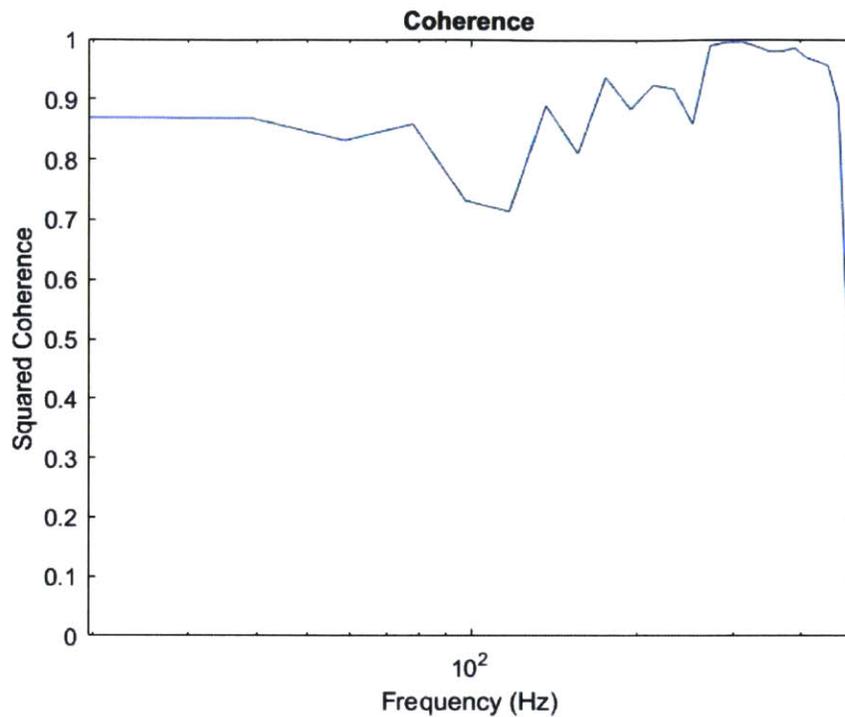


Figure 14(b): Average Coherence vs Frequency for old grip.

As seen in Figure 14(a) the average gain across frequencies of 39.0625 Hz and 58.5938 Hz is between 0.5245 ± 0.0772 and 0.5112 ± 0.1005 , across 78.1250 Hz and 97.6563 Hz is between 0.6540 ± 0.1684 and 0.6919 ± 0.1452 , across 117.1875 Hz and 214.8438 Hz the gain is between 0.3238 ± 0.1017 and 0.2963 ± 0.0537 , and drops as low as 0.1842 for some frequencies. Finally, across 253.9063 Hz and 468.7500 Hz the average gain is between 0.3921 ± 0.0774 and 0.3945 ± 0.1272 , and is as low as 0.2859 for some frequencies. Figure 14(b) shows there is a reliable coherence across all of these frequencies, but begins to drop at 500 Hz.

4.4 New Grip Results

Figure 15 shows an example of the graphs produced by matlab code from each run with the new grip. Based on these graphs, focusing on the PSD and Coherence, it was determined to only to view the Gain up to a frequency of 500Hz because that was where the transfer function was most accurately predicting the output.

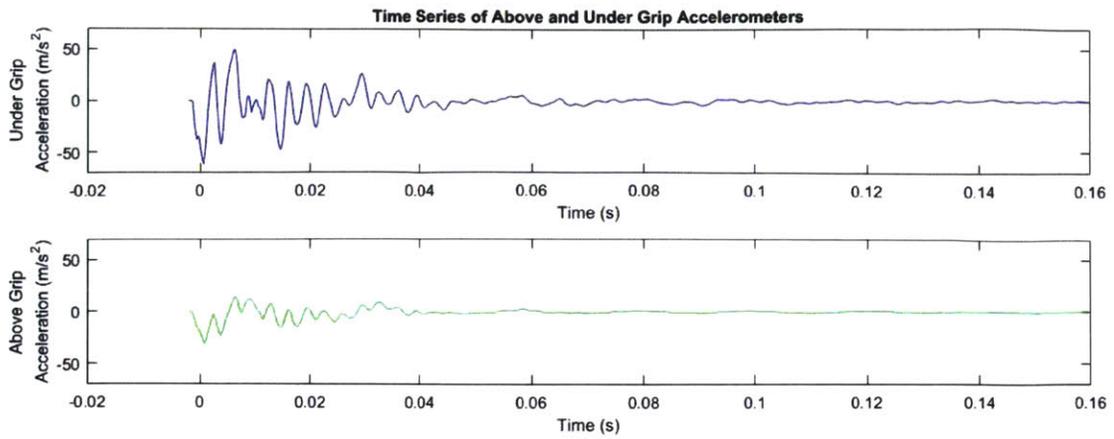


Figure 15(a): Acceleration vs Time for each accelerometer after impact.

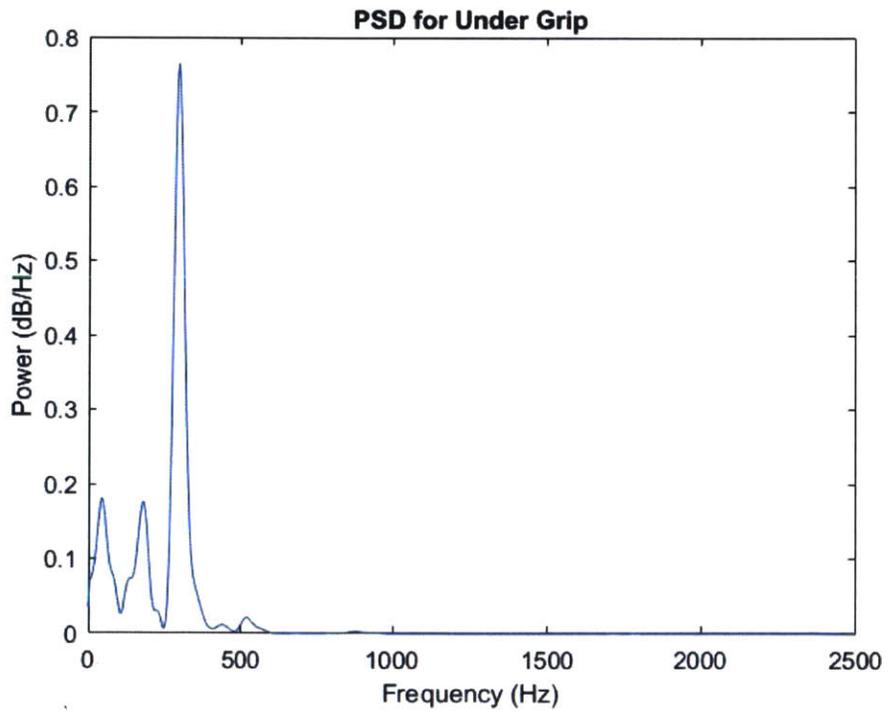


Figure 15(b): Power vs Frequency for accelerometer located directly on the shaft.

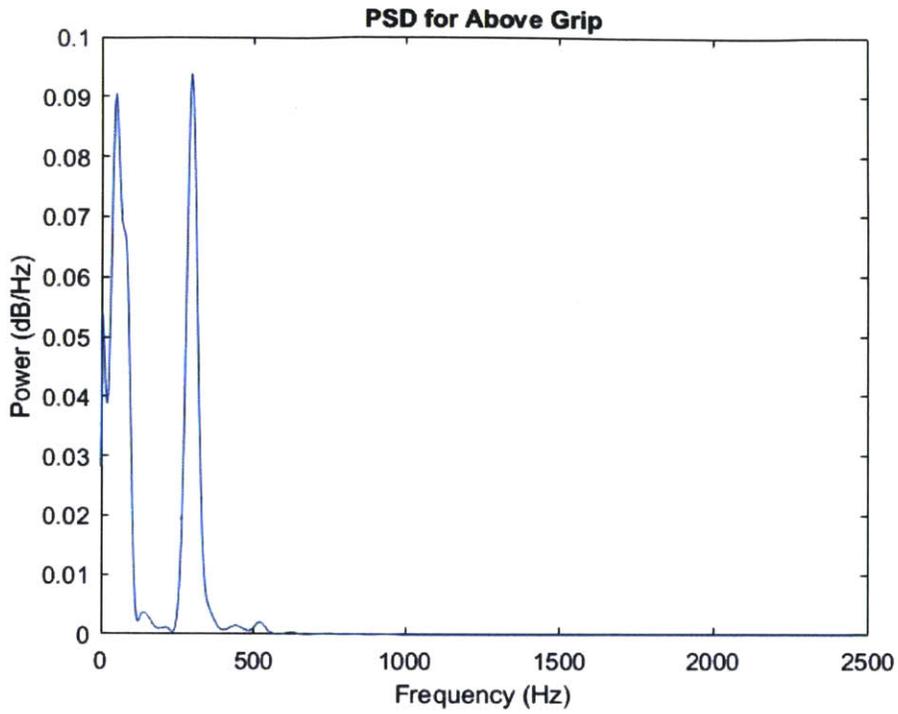


Figure 15(c): Power vs Frequency for accelerometer located on top of the grip.

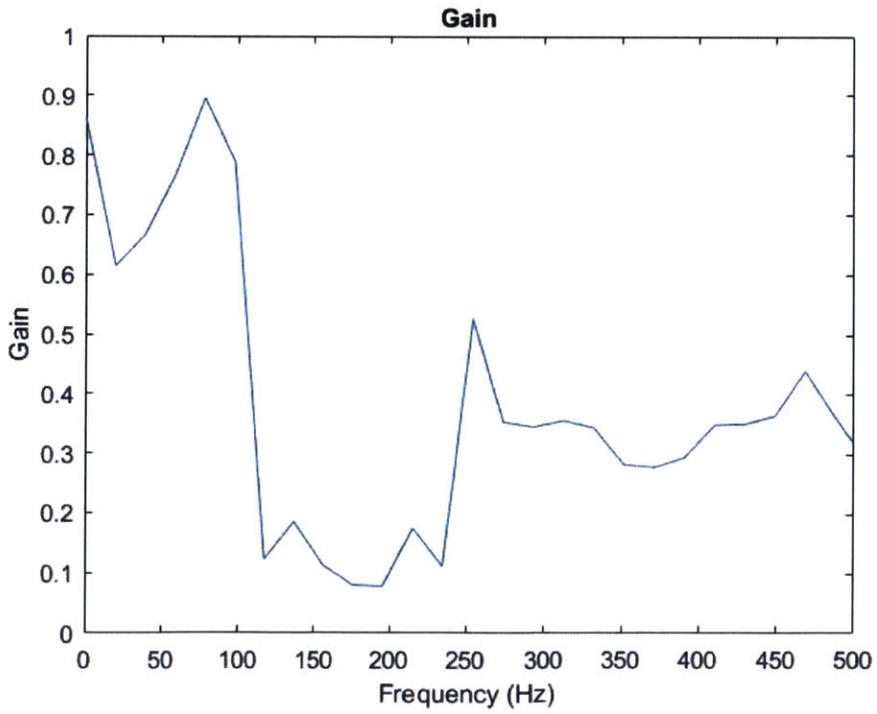


Figure 15(d): Gain vs Frequency of new grip.

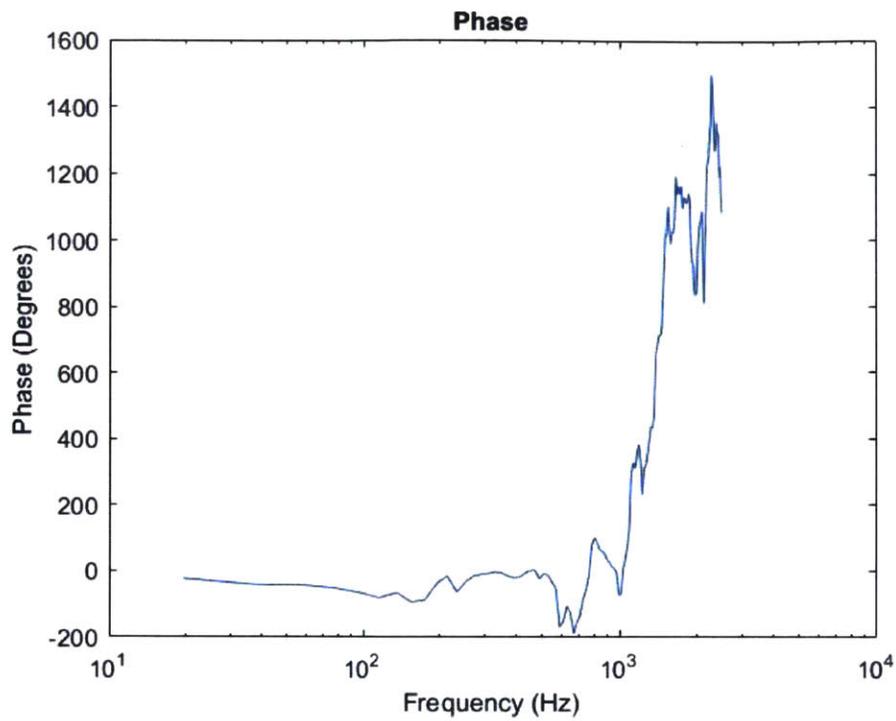


Figure 15(e): Phase vs Frequency of new grip.

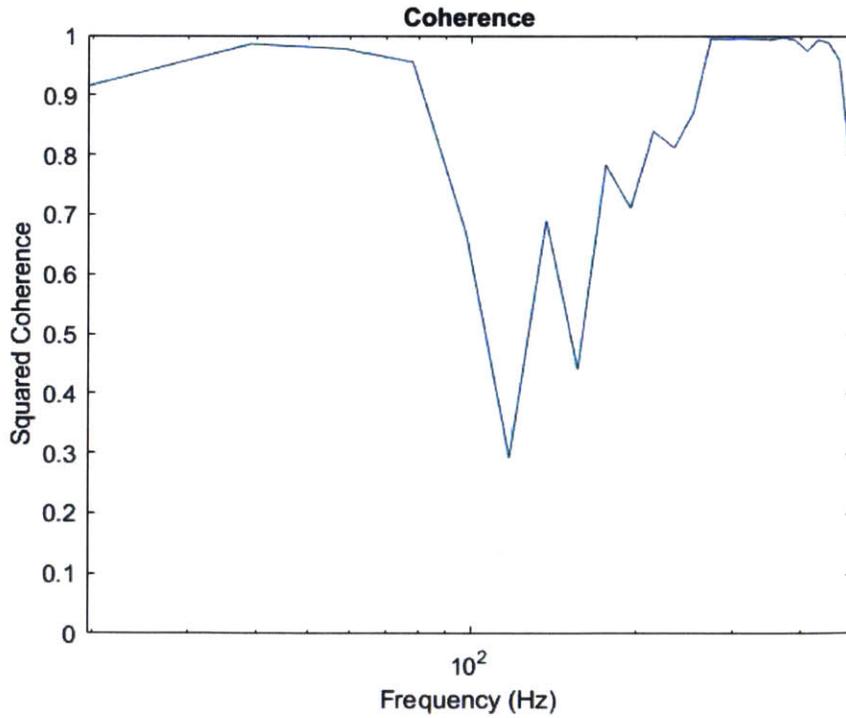


Figure 15(f): Coherence vs Frequency of new grip.

Figure 16, below, is the graphs for the average gain and coherence of the old grip.

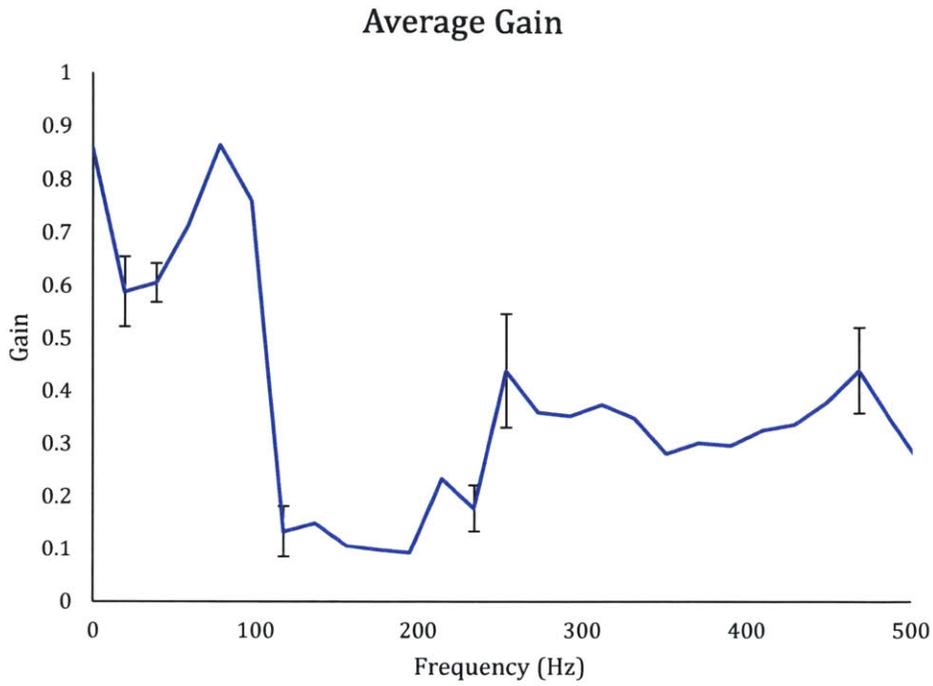


Figure 16(a): Average Gain vs Frequency of new grip.

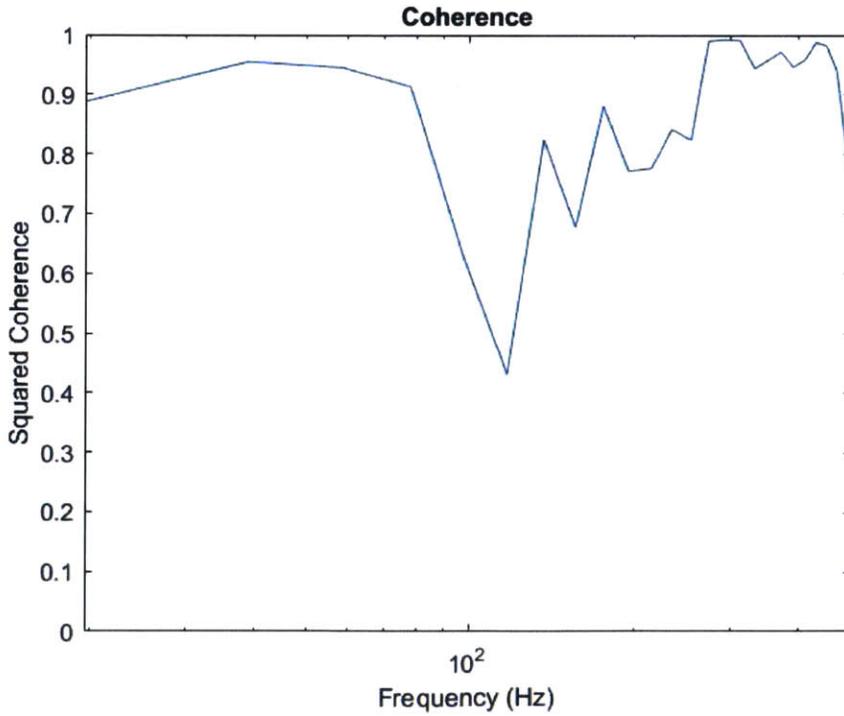


Figure 16(b): Average Coherence vs Frequency of new grip.

As seen in Figure 16(a) the average gain across frequencies of 19.5313 Hz and 39.0625 Hz is between 0.5883 ± 0.0661 and 0.6055 ± 0.0366 , across 117.1875 Hz and 234.3750 Hz is between 0.1332 ± 0.0483 and 0.1781 ± 0.0437 , and is as low as 0.0933 for some frequencies. Across 253.9063 Hz and 468.7500 Hz the average gain is between 0.4372 ± 0.1067 and 0.4384 ± 0.0805 , and is as low as 0.2819 for some frequencies. Figure 16(b) shows there is a reliable coherence across all of these frequencies, though there is a dip at 117.2 Hz, but the uncertainty here is still relatively small.

4.5 Average Total Power Results

In order to find the average power for the each hand during a push and strike, the areas under the average PSDs were calculated. Below in Figure 17 the average total power for each “hand” (accelerometer located where the frequencies a hand would sense occur) in each position was found and compared.

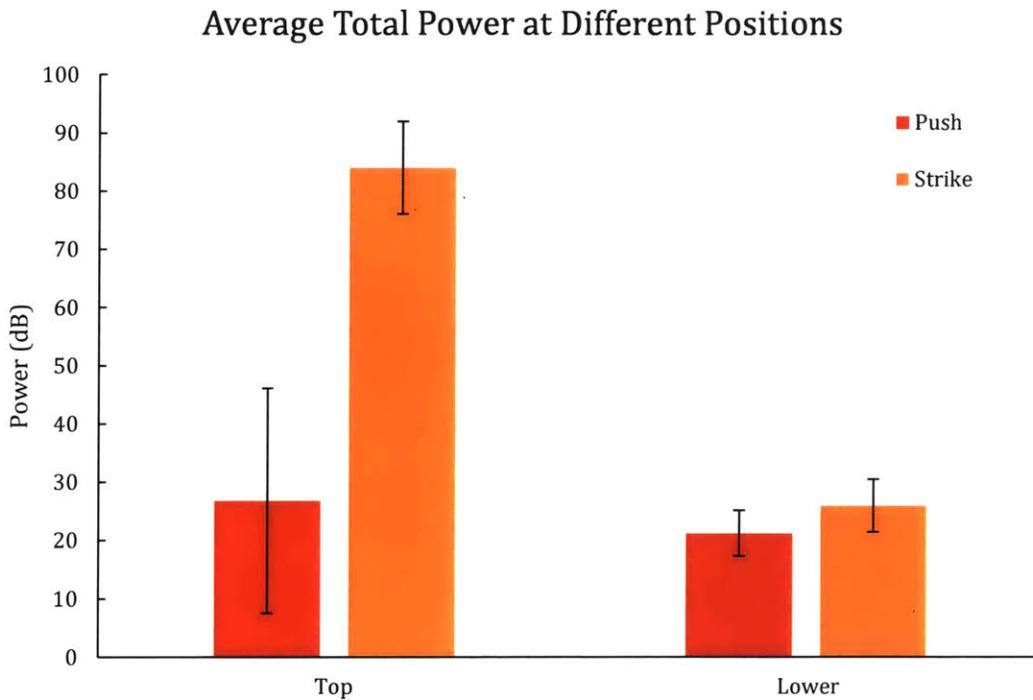


Figure 17: Average Total Power to the top and lower “hands” for a push and strike.

The average total power experienced by the top “hand” was found to be 26.809 ± 7.974 dB for a push compared to a power of 84.032 ± 19.284 dB for a strike. The average total power experienced by the bottom “hand” was found to be 21.189 ± 4.541 dB for a push compared to a power of 25.965 ± 3.932 dB for a strike.

In order to find the average powers for the old and new grips under and above the grip, the areas under the average PSDs were calculated. Below in Figure 18 the average total power for each grip above and below the grip was found and compared.

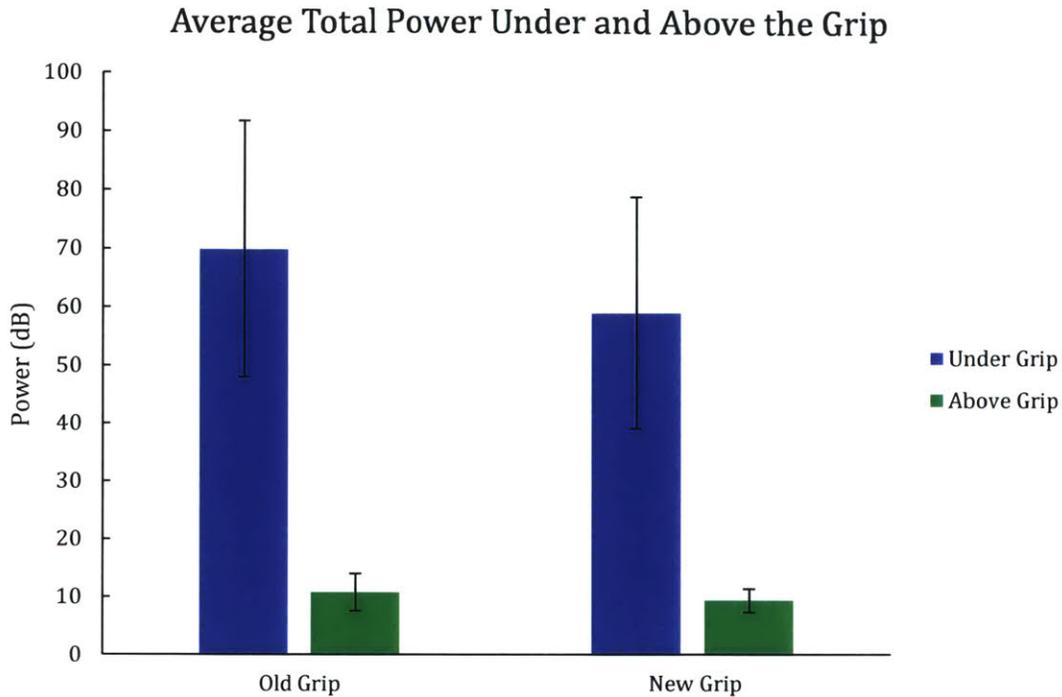


Figure 18: Average Total Power for the new and old grip, above and below the grip.

The average total power for the old grip was found to be 69.866 ± 21.919 dB for under the grip compared to a power of 10.749 ± 3.204 dB for above the grip. The average total power for the new grip was found to be 58.871 ± 19.833 dB for under the grip compared to a power of 9.351 ± 2.015 dB for above the grip.

5. Conclusions

In conclusion the higher resonant frequencies are consistently experienced by the top accelerometer. Even in the case of the strike where the “lower” accelerometer is located on the shaft/grip, it is the top accelerometer that experiences higher resonant frequencies. In the case of the push, for the lower accelerometer the frequency with the largest power is 43.95 Hz at a power of 0.7095 dB/Hz. In the case of the push, for the top accelerometer the frequency with the largest power is 349.1 Hz at a power of 0.4723 dB/Hz. This demonstrates that much higher resonant frequencies are experienced at the top of the stick on the shaft/grip. In the case of the strike, for the lower accelerometer the frequency with the largest power is 24.41 Hz at a power of 0.6383 dB/Hz. In the case of the strike, for the top accelerometer the frequency with the largest power is 197.8 Hz at a power of 1.155 dB/Hz. It is also important to note that in the case of the strike, there are frequencies of 144 Hz at a power of 0.2833 dB/Hz and frequencies of 361.3 Hz at a power of .3492 dB/Hz. Unlike the push, the strike experiences more than one frequency at a power higher than 0.20 dB/Hz, and thus is significant to consider.

Looking at the gain from the old grip, the grip is most effective (when the frequency on top of the grip is lower than the frequency directly on the stick) over the frequencies of 117.1875 Hz to 214.8438 Hz. This corresponds with the region where the new grip is most effective seen over the frequencies of 117.1875 Hz- 234.3750 Hz. The gain for the old grip in this region is between 0.1842 and 0.3238 ± 0.0537 , while the gain for the new grip in this region is between 0.09325 and 0.1781 ± 0.0437 . The frequency of the top accelerometer with the largest power for the strike, 197.8 Hz, falls within this region, in addition to one of the other significant frequencies during the strike, 144 Hz. Returning to the gain of the old grip, it is second most effective over the frequencies of 253.9063 Hz to 468.7500 Hz with a gain between 0.2748 and 0.3945 ± 0.1272 . Over the same frequencies the new grip is second most effective with a gain between 0.2819 and 0.4384 ± 0.0805 . The frequency at the top accelerometer with the largest power for the push, 349.1 Hz, falls within these frequencies, in addition to one of the other significant frequencies in the strike, 361.3 Hz.

The total average power at the bottom “hand” for a strike, 25.965 ± 3.932 dB, is slightly higher than that for a push, 21.189 ± 4.541 dB. The total average power at the top “hand” for a strike, 84.032 ± 19.284 dB, is much higher than that for a push, 26.809 ± 7.974 dB. From this it is clear there is higher total average power during strikes than pushes. This confirms the need of a grip during strikes, especially with the highest power being experienced by the top hand.

In conclusion, it is clear that field hockey grips aid in dissipating the higher frequencies that the hands on the shaft experience during hits, while also being important for comfort and traction during play.

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