Monitoring of a Diamond Polishing System

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Design Team 2 Pre-Proposal

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October 9, 2015

The purpose of this project is to create a device that monitors a diamond polishing as well as output the corresponding data in order to facilitate future experimentation. Additionally, a microphone system must be designed to monitor any extraneous noises in order to indicate any issues in the functionality of the diamond polishing machine.

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Introduction

Diamond polishing, a practical process for creating elements used in circuitry, is an inexact science. When polishing for very smooth finishes, the “sound” of the diamond will differ between a balanced and unbalanced system. All of these sounds are within the audible range (less than 20,000 Hz), but they seem similar to the human listener, and thus are difficult to differentiate. This leads to the main objective of the project: monitoring the diamond polishing process and filtering out all low-frequency sounds to show the differences between balanced and unbalanced diamond polishing. This monitoring system will facilitate future research in the field of diamond surface polishing

The most important aspect of the design involves what type of sensor will be used to detect the noise or vibrations output by the system. The device must use a transducer, which is a type of sensor that converts one form of physical energy into an electrical signal which can be sent through a circuit. Examples of transducers that would suit this system are a microphone or an accelerometer. Once the sound is picked up by the transducers and converted, it will then be filtered into high and low frequency sounds. These signals will be sent through a USB cable to a computer for analysis. This signal will also be output on a digital display, which will give a reading of the instantaneous frequency of noise or vibration emitted by the system. Ultimately this data will be used to conduct future experiments by altering the diamond polishing system setup.

Background

Diamond polishing is performed by placing diamond powder on a cast iron wheel, called a scaife (Figure 1), which rotates at a high speed. Next, the diamond is glued onto the bottom of an arm (Figure 2). Prior to polishing both the wheel and the arm need to be properly balanced. Once the arm and wheel are balanced the arm is placed onto the platform adjacent to the wheel, which starts rotating at a speed of 3,240 rpm. The diamond is polished as it is held against the spinning wheel during the polishing operations. Some important parameters for diamond polishing are the rate of material removal, the roughness of the final polished surface and the subsurface damage of the diamond. It is known by talking with those involved in the diamond polishing process that there exists a "sound" of the polishing process. The polishing of diamond is very directional; some of the directions of the spinning wheel touching the diamond being soft directions and some others being hard directions. In soft directions that diamond is removed quickly and the surface is smoother. In hard directions the polishing rate is slow and the surface is more microcracked. Many of the mechanical and physical properties of diamond are exceptional: it is an ideal brittle solid with greatest hardness and resistance to plastic deformation of any material (Hird 2004). These properties coupled with the thermal conductivity and various electronic properties make it suitable for many applications, particularly those destined to experience harsh environments (Hird 2004).



Figure 1. The scaife of the diamond polisher

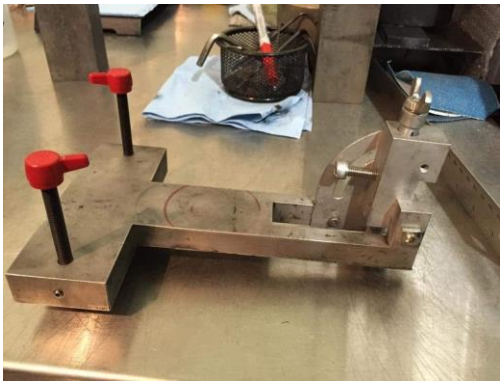


Figure 2. One type of arm that holds the diamond on the polishing wheel.

The tribological (the science and engineering of interacting surfaces in relative motion) behavior of diamond is equally exceptional (Hird 2004). This is perhaps most noticeable when diamonds are fashioned into gemstones, an art form which has been practiced for more than 600 years (Hird 2004). In

this process, diamonds are pressed onto a rapidly rotating cast-iron disk loaded with olive oil and diamond grit (Hird 2004). For any given crystallographic plane, the wear rate has a very large dependence on the direction of polishing (Hird 2004).

In the “hard” direction of polishing, little wear to the diamond can be achieved and the scaife is often damaged together with the production of unpleasant grating noises and vibration (Hird 2004). The diamond is invariably damaged too, showing at best a poor surface finish, and at worst fracture (Hird 2004). In “soft” polishing directions, diamonds undergo wear readily on a well-prepared scaife, and this is accompanied by a rapid heating of the diamond and is relatively vibration-free (Hird 2004). The resultant finish on the surface of the diamond in these directions can be excellent, approaching mirror smoothness to the naked eye, and it is notable that both wear and polishing are achieved simultaneously when a diamond is polishing correctly (Hird 2004).

To measure the frequency of the noise generated by the scraping of the diamond’s surface, a sensor must be placed on the device which will measure the frequency of either the vibration or the sound. This sensor is called a transducer, a device that converts one form of physical energy (a vibration or sound wave), into an electrical signal. In particular, two types of transducers could be used in this system: accelerometers and microphones. An accelerometer is a device that measures acceleration forces, caused by moving or vibrating. Many accelerometers use the piezoelectric effect - they contain microscopic crystal structures that get stressed by accelerative forces, which causes a voltage to be generated. Another way to achieve this is by sensing changes in capacitance. If two microstructures are next to each other, they have a certain capacitance between them. If an accelerative force moves one of the structures, then the capacitance will change (Dimension). The second type of transducer, commonly known as a microphone, picks up a sound wave and converts it into an electrical voltage.

The frequency of the sound emitted by the system will operate with the properties of resonant frequencies. In sound applications, a resonant frequency is a natural frequency of vibration determined by the physical parameters of the vibrating object. A vibrating object will pick out its resonant frequencies from a complex excitation and vibrate at those frequencies, essentially "filtering out" other frequencies present in the excitation. Most vibrating objects have multiple resonant frequencies, which was also evident

in measuring and analyzing the sounds of this system (Nave 2012). An audio sample of the resonant frequencies for this system can be seen below (Figure 3)**.** In this diagram, the distinguished horizontal lines represent resonant frequencies.

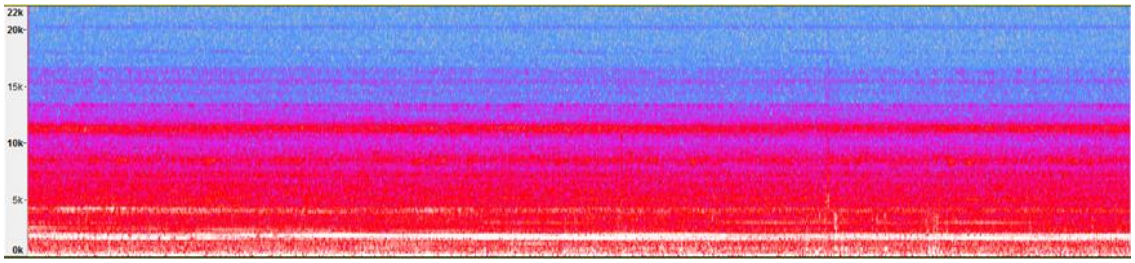


Figure 3. The spectral analysis of a balanced sample as analyzed by the Audacity program. The horizontal stripes show resonant frequencies within the machine and diamond sounds.

In order to display the correct frequency output by the polishing of the diamond, a filter must be used to eliminate the noise created by the machine and output only the higher-range frequencies. A filter is a specific type of analog circuit which performs signal processing functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones, or a combination of the two. In the case of this project, the type of filters that must be used for the sensor are high-pass filter and a band-pass filter. This filter will eliminate all low-frequency signals, and output the high-frequency signal, which will then be displayed digitally. However, on the machine monitor, a band-pass filter can both be used to detect the different sounds the wheel and rest of machine emit. This filter will pass a very specific range of mid-range frequencies, filtering out the low and high frequencies.

Objectives and Design Specifications

The purpose of this project, as stated above, is to provide more information surrounding the process of diamond polishing in order to facilitate future experimentation. This data will be used to run further experiments on emitted noise from the polishing system. In order to design this device, several criteria were taken into account: user friendliness, feasibility, cost, power consumption, size, ease of mobility, accuracy, and frequency range.

In order to construct a viable device, a microphone will pick up the sounds of the system and convert them into a digital signal to be filtered. The diamond polishing process creates a noise when the diamond scrapes against the surface of the wheel. A high-pass filter will be included pick up these high pitched frequencies, which were measured to be between 12 kHz and 20 kHz. Additionally, diamond polishing machine creates a noise when the wheel is rotating at full speed. There are also ambient noises present in the room that are at a lower frequency than the rotating. A band-pass filter must be included in order to selectively output the machine noise, thus excluding the ambient and diamond noises. This frequency range will be between 5 kHz and 12 kHz. Once this signal is filtered, it must be sent digitally through a USB cable for further evaluation. Additionally, a 7-line digital display will show the instantaneous frequency of both the high and band-pass filters. The device needs to be placed on the machine, attached to the wall and suspended above in a fashion that does not obstruct its motion (Figure 4).



Figure 4: The entire diamond polishing machine system. The device will be placed on the rail above the wheel and hang above to pick up any sound

The sponsor also suggested that an accelerometer can be used to pick up the vibrations in order to monitor the balance of the arm, wheel, and entire system. The accelerometer will be placed should on the arm of the polisher (Figure 2), and will display instantaneous frequency when the arm goes off balance. In

the future, the machine will have a plexi-glass shield to prevent the diamond from flying out. This shield will also help to make the system more soundproof. This device will be powered by the 120VAC wall outlet next to the polishing machine. Finally, the design must stay under the budget of $500.

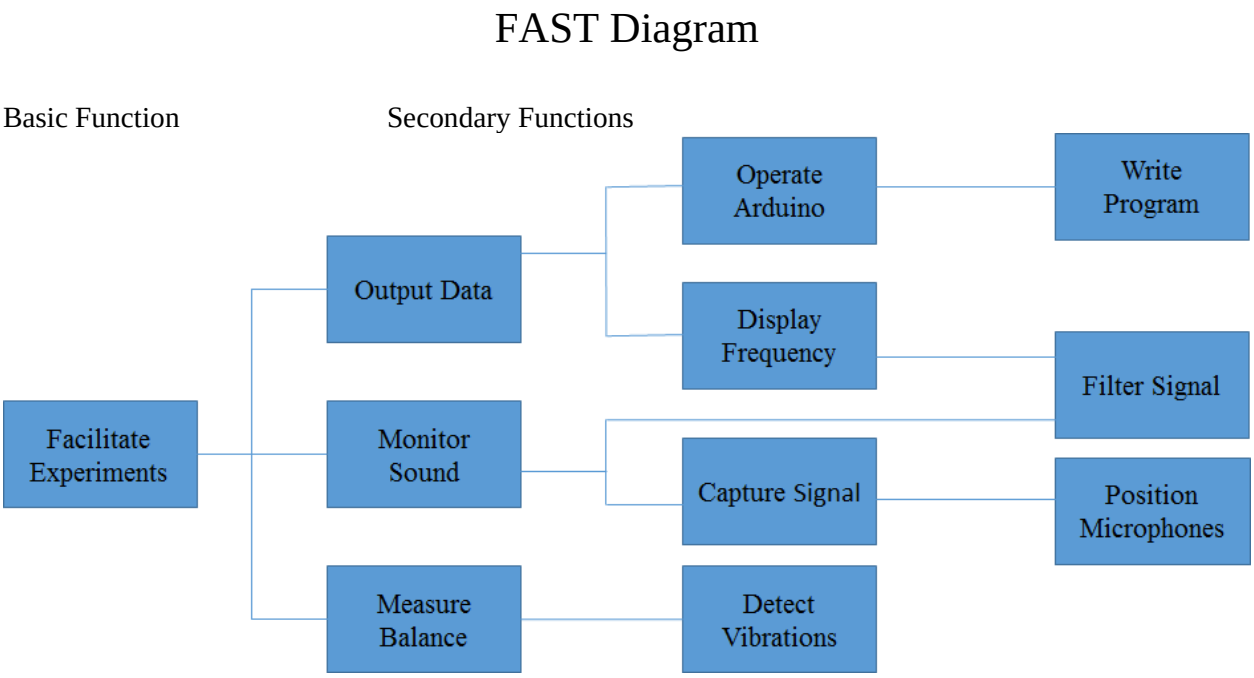


Figure 5. The FAST Diagram describing all of the functions of the desired devices, both primary and secondary.

In writing the function diagram seen above (Figure 5), the group first listed all of the major components that comprise the system. In moving left to right on the chart, the question "how" is answered, and moving right to left, the question "why" is answered. After listing all functions of the device, the basic function and need was facilitating experiments for the customer. This facilitation occurs by completing three secondary functions: outputting the data, monitoring the sound, and measuring the wheel balance. First, the data output is achieved by a digital frequency display, as well as stored memory in an Arduino. This memory will be stored by writing a program on the Arduino which will transfer the data through a USB cable. Second, the monitoring of the sound is achieved by capturing and filtering the signal. The signal will be captured by positioned microphones, and it will be filtered using high-pass and band-pass filters. Finally, the balance of the system will be measured by detecting the vibrations. These vibrations are picked up by an accelerometer and converted into a readable voltage.

Conceptual Design Selection

Each design has five similar pieces: a sensor, a filter to pass low frequencies, a filter to pass high frequencies, a power supply, and a display. A band pass filter, as stated above, will generate an output for a specific range of frequencies, and a high pass filter will do likewise for high-frequency sounds. Both of these filters will be necessary to differentiate machine noise and ambient noise from the diamond noise, as well as to pick out the specific range to be displayed. The values of the resistors and high pass filter will be determined after calculations and experimentation, in order to achieve the specific cutoff frequencies. Once the components for the filters are selected they should remain the same throughout the design process.

For the diamond sensor and the machine sensor, there are multiple design choices. The first design is to place two small microphones at the end of two empty pen casings. These will be mounted externally from the system, and can be directed to point at desired locations (Wildlife 2012). The next is a fabricated transducer microphone which would be attached to the arm of the accelerometer. Finally, the group may also order a manufactured microphone and accelerometer to ease the construction project and meet the time constraint. Considering the device is only being built for one customer, mass production is not a factor that needs to be considered. Thus, manufactured parts may be ordered. The sensor choice depends on the frequency range and the cost.

The display will be fabricated using a 7-line digital readout, which can be created by using a timer integrated circuit. The accuracy (number of digits) that the display reads will largely depend on the accuracy of the sensor chosen. Another factor in the display is the speed with which the data is gathered. These signals will be analyzed and converted to a USB form using a popular microcontroller brand, Arduino. Finally, additional components in the designed device will be driven by the power supply. Their power consumption ratings will be determined upon further research, experimentation, and measurement.

The devices were ranked using two different systems and a variety of criteria, shown in the first column of each table. For the first system, the device was simply determined to be feasible or not, by placing an “x” or “o” in the appropriate box corresponding with the appropriate criteria (Table 1). For the second system, each design was evaluated based on the importance of the criteria on a scale of one to five, as well as the strength of meeting the given criteria. These two numbers were multiplied and added

for each criteria. The resulting total determined which design would be the most suitable, with the highest total being the best design (Table 2).

Design Criteria	Design #1 (transducer mic)	Design #2 (transducer acc)	Design #3 (manufactured acc)	Design #4 (2 pen casings)
User Friendliness	X	X	X	O
Cost	O	O	O	O
Power Consumption	O	O	O	O
Size	O	O	O	O
Ease of Mobility	X	X	X	O
Accuracy	O	O	O	O
Frequency Range	O	X	X	O
Simplicity of Design	O	O	O	O

Table 1. This matrix addresses the feasibility of a particular design. *Note: O = good, X = bad

Design Criteria	Import-ance #	Design #1 (transducer mic)	Design #2 (transducer acc)	Design #3 (manufactured acc)	Design #4 (ultrasonic pens)
User Friendliness	4	3	1	1	9
Cost	3	9	9	9	9
Power Consumption	3	3	3	3	3
Size	2	3	1	3	1
Ease of Mobility	4	3	1	3	9
Accuracy	3	3	3	3	3
Frequency Range	5	9	1	1	9
Simplicity of Design	2	3	9	9	3
Totals		126	78	90	170

Table 2. This matrix ranks the potential design ideas based on a multiplication of importance and strength in achieving a given design criteria. **Note: 9 = strong, 3 = neutral, 1 = weak; #Note: 5 = high, 1 = low

Proposal Design Solution

Based on group discussion, and evaluation of the various possibilities, the optimal design chosen is the 2-pen microphone system, where two microphone transducers will be placed at the end of empty pen casings (Figure 6). These will be mounted externally, but equidistant to, the system. The pens will be fastened to the din rail next to the machine, above the wheel, and pointed at specific points of the system. This way, one pen can be pointed at the wheel to pick up the machine noise, and one pen can be pointed at the diamond to pick up the scraping noise. These two pens will be wired to a 3.5mm auxiliary cable, which will then input to the filter portion of the circuit. (Figure 7). The first pen will connect to the band-pass filter to output the machine noises only. The second pen will connect to the high-pass filter to output the diamond noises only. These signals will be displayed on the 7-line digital readout, which will use a toggle switch to alternate between each of the two filters. This will display the instantaneous frequency being measured by either one of the filters, as a convenience to the sponsor. The signal will be sent to the Arduino microcontroller, which will convert the data into a readable file to be output by the USB cable. This device will be driven by a power supply from the wall (120 VAC). This voltage is not usable for the circuit, so a wall wart will be used to step down the voltage to 9V. Additionally, an accelerometer will be used to detect the vibrations of the systems in order to give information about the balance of the wheel. Also, time permitting, a soundproof shield will be built to isolate the system



Figure 6. An image of a pre-constructed two pen design. Each pen is connected to a 3.5 mm jack and can be directionally positioned.

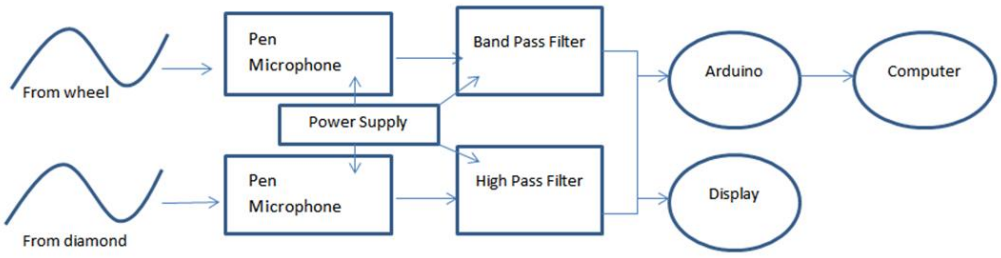


Figure 7. The flowchart detailing each generic component of the design. Each block or circle will be comprised of more complex elements.

Risk Analysis

In constructing the sensors, filters, and display for the diamond polishing machine, several challenges present themselves. The most important factor to consider is the weight of the accelerometer sitting on the arm of the polisher. If this sensor is too heavy, then the diamond polisher may become unbalanced due to the difference in pressure on the diamond surface. The next concern is the fragility of the microphones. If these microphones are too sensitive or fragile and need to be replaced often, this will prove to be a cumbersome task. Thus, the microphones chosen must be robust enough to survive normal wear-and-tear. Also, the fastening device must be removable but stable. If this device detaches too easily, it might fall onto the wheel during the monitoring process, and would certainly damage the sensor. Finally, there is a possibility that resonant frequencies given off by the diamond scraping are too faint to be detected by our microphone.

Project Management Plan

The members of this project are Paul Dionise, Anthony Garvert, Alex Kohler, and Rohan Panda. Paul is the group manager, in charge of overseeing all activities of the group, as well as maintaining contact with the sponsor and advisor. Anthony is in charge of documentation preparation, ensuring the documents are sent and appear coherent, and managing the Google Drive. Alex Kohler is the lab coordinator, in charge of ordering parts and contacting the electronics shop for any needs. Rohan is in charge of organizing presentation preparation, including the final presentation at design as well as all Power Point presentations throughout the semester. All four members will be sharing the responsibility of website designing. Additionally, technical tasks will be appropriately assigned as the project progresses throughout the semester.

This project cannot be completed without several resources at hand. The main resource for the project is the source of information, the sponsor, Aaron Hardy. Aaron answers any questions that we might have and communicates to us exactly what he desires for his project. Ultimately, he will be using the design for his polishing experiments. Additionally, Dr. Grotjohn has experience in the field of diamond polishing and is able to give us information regarding the process as well. Finally, Dr. McGough is the facilitator, in charge of making sure the group progresses with the project as scheduled and steering us in the right direction in terms of productivity. Also available as resources are the electronics shop and the ECE 480 laboratory, located in EB 2221.

Date	Event	Task Achieved
9/9	Group Formation	Introduction of members, non-technical tasks assigned, problem
9/15	Meet Sponsor	Observe diamond-polishing system, obtain details and specifications
10/5	Oral Presentation	Present to the class surface-level details about our project and
10/9	Submit Proposal	Submit a written document with background, ideas, and final
10/19	First Demonstration	Show the initial product to professors, ensure progress is being made
11/9	Technical	Present to the class in detail about the technical project aspects
11/24	Second	After testing and redesign, show the improved project to professors
12/7	Final Report	Submit the written report detailing the entire design process
12/11	Design Day	Present working product to customer, give oral presentation to panel

Table 3. A timeline of the most important events of the semester. Note that there are many more steps in between each of the above dates.

Budget

A crucial constraint is the budget given for the completion of the project. The budget is set at 500 dollars to be used for parts, and fabrication during the design process. If the wanted final product exceeds that limit, addition funds may be obtained from the sponsoring party. A resource that can be used is the ECE shop, and any components in their inventory can be used at no deduction to the budget.

Qty	Item Description	Use	Price (per each)
2	Microphone Transducers	Capture sound	$0.75 to $30.00
1	Manufactured Accelerometer	Measure vibrations	$5.00 to $30.00
1	Arduino UNO rev 3	Transfer data and logic	$24.95
2	Metal Flex Conduit	Mount pen microphones	$11.96
1	Polycarbonate sheet	Sound/projectile barrier	$99.97
2	Casing	House circuitry	$1.00/10g
1	Red Alarm LED	Alert faults in polishing	$7.89
1	Wall Wart	Supply system power	Lab Parts Kit
2	3.5 mm Auxiliary Cable	Interface signals with filters	Lab Parts Kit
X	Circuit Elements	Construct filters	ECE Shop
		Total:	$151.52 to $214.77
		Remaining Budget:	$285.23 to $348.48

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