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Analysis of Crepe Blade Vibration

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The goal of this project was to take the first step in analyzing this vibration. This meant setting up measuring equipment and analyzing basic blade vibrations.

In this experiment, a laboratory coater (Dow coater at Western Michigan University) was used instead of a tissue machine because it was readily available and easy to control and modify. An accelerometer was used to measure the vibration of a blade on the coater. A computer using Labview was used for data acquisition. Trials at various speeds were run with a piece of tape on the coater roll to cause and distinguish vibration at a given frequency. Spectral analysis was used to recover the given frequency.

Analysis of the data showed several things. First, it was apparent that the data were not as hypothesized. A distinct disturbance was found, but it was at the same frequency regardless of coater speed. Since the first thing done in the experiment was to use a signal generator to make sure the data was being read properly, it is speculated that the fault lies in the accelerometer. It is very possible that the accelerometer is not sensitive enough to detect vibrations at such low frequencies as it was designed for high-frequency tissue applications. More experimentation needs to be done to explore this.

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A Senior Thesis
Submitted to the
Faculty of The Department of Paper and Printing Sciences
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Requirements for the
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PROJECT PROBLEM STATEMENT

Though there are many problems with research in the tissue industry, lack of published research is the most predominant. This lack of publishing is due to the competitive nature of the industry. Consequently, trying to look up information is often very difficult.

At the end of a Yankee dryer is the crepe blade. The crepe blade serves to pry the tissue from the dryer surface. Subsequently, this contact with the tissue causes the blade to vibrate. The vibration is caused by the change in pressure required to remove the tissue from the dryer surface. The difference in required pressure is due to a constantly changing surface form of the dried sheet. Before the tissue matte reaches the dryer, it is in contact with a forming fabric.

A forming fabric is more or less a crossing pattern of fabric fibers designed to leave the tissue fiber matte in a specific form. This is done to have a consistent matte entering the dryer section of the machine and ultimately a consistent final product. Due to the weaving of the fabric fibers (which can be seen in figure 1 on page 7), knuckles are formed. These knuckles are high points in the forming fabric causing indentations in the tissue fiber matte. This means that when the adhesive contacts the sheet, the adhesive, which is sprayed onto the dryer, will hold more firmly to the high spots in the tissue matte. These high spots will hold more firmly because of the pressing of the sheet. This will come into play when the sheet reaches the crepe blade.

A crepe blade's function is to force the tissue off the Yankee and on towards the final product. Whether the blade cuts into the adhesive or only touches the fibers is yet unknown (it could be a combination of both, varying as it goes). Where the blade is contacting the sheet is very important because it determines what element is taking the bulk of the stopping force as the Yankee rotates. Some background information on the mechanics will be needed to help answer this.

As the Yankee spins, it generates a large amount of momentum for the fibers and adhesive. When they hit the crepe blade, the fibers stop and sheer from the adhesive. Each time this hitting action occurs, it causes slight movement of the blade. At rapid speeds, this movement becomes a vibration.

The vibration of the crepe blade is hypothesized to be caused by the knuckles in the tissue sheet. This is because as the knuckles pass under the blade, it takes a greater force to pry the sheet from the Yankee. As the force required to pry the sheet from the Yankee changes, the force on the crepe blade will change, causing the blade to vibrate.

An example calculation for the frequency would be:

@ 100 knuckles per inch and a machine speed of 5000 ft/min,

Frequency = 60,000 In/min * 100 kn/in = approximately 10^5 Hz

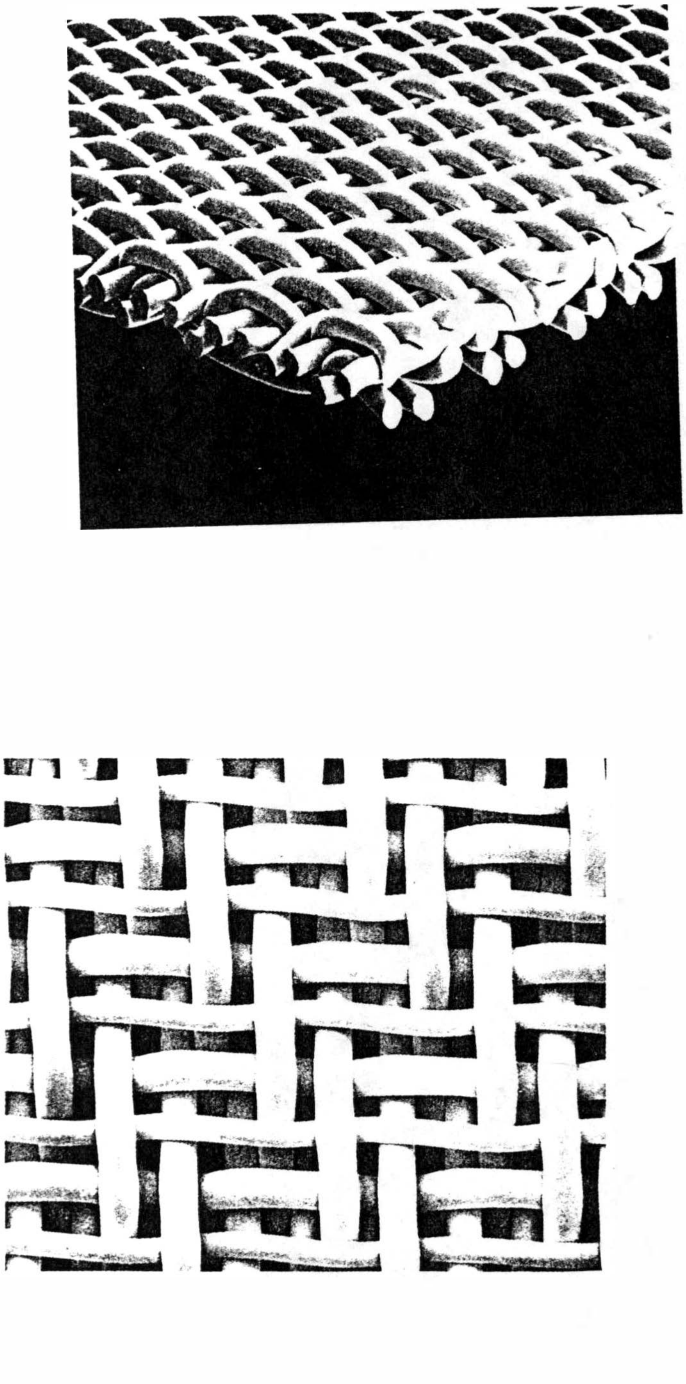


Figure 1

OBJECTIVES

The overall objective of this project is to determine whether or not the forming fabric affects the vibration of the crepe blade. In order to obtain this goal, several things must be accomplished. The objective of this experiment is the first step in this process. This experiment was designed to be a learning process in vibrational analysis by setting up a system to acquire data from a vibrating coater blade. The system consisted of an accelerometer, amplifier, and a computer. Running at known speeds allowed for the data to be compared to where the vibration occurred using spectral analysis.

BACKGROUND INFORMATION

The creping process is affected by three main factors. The first of these factors is the physical properties of the formed sheet itself. Tensile strength and formation are the most important (for this thesis, this property will be assumed to be constant). The next factor is sheet adhesion to the Yankee dryer surface. This is important when thinking about how the crepe blade comes into contact with the sheet. A uniform adhesion to the dryer is beneficial for trying to create a uniform crepe response. The third factor is the geometry of the creping blade, which is the angle at which the creping blade strikes the Yankee dryer surface (Sloan 1994). These factors together are the key components affecting the creping process.

There are several factors which can affect the adhesion of the sheet to the Yankee dryer. The first is obviously what type of adhesive is used. A proper type and amount of adhesive must be selected so that the sheet is easily pried from the Yankee, but not so easily that it comes off on its own. Another factor is the condition of the dryer surface. As Oliver (1980) states, even a highly polished dryer still possesses a microscopic surface roughness on the order of 0.1 – 0.2 micrometers. The presence of such fine-scale roughness can profoundly influence liquid spreading and surface wettability. It is very difficult to keep the Yankee dryer consistent in surface smoothness. This obviously increases the difficulty in creating a consistent creping process.

A critical factor is the angle at which the blade contacts the Yankee dryer. Micro and macrofolds are created in the creping process. "The impact angle of the doctor blade determines, among other things, the wavelength of the macrofolds, the occurrence of the microfolds and the dimension of the macrofolds in the cross machine direction" (Falk 1989). Parker (2000) points out that as the blade wears, this angle will change. The blade will tend to get flatter, so to speak, and this means that the pressure applied to the blade will change. Also, as the edge of the blade gets "flatter," the way in which it severs the sheet-adhesive-Yankee bond will change as well. These factors must be taken into consideration when looking at the crepe angle.

Another important aspect to look at in the creping process is the buckling of the sheet as it impacts the blade. Wang (1984) compares the buckling of a heavy column to that of a sheet, which lies on a rigid horizontal surface. This can be related to the sheet of tissue on the Yankee dryer. He has also created mathematical formulas to show how the sheet will buckle. Primarily, he refers to the height of the amplitude as the sheet comes off the Yankee. He also states how different angles create different sized microfolds, which in turn change, the size of macrofolds (since macrofolds are bundles of microfolds). This helps us analyze how the sheet will react to the blade at the end of the dryer.

Studies have been done to analyze the creping wavelength. Oliver (1980) states that these studies showed that the fineness of creping on an experimental pilot machine was directly related to the "cutting" angle. He also states that although these studies provide considerable insight into the actual creping mechanism they have several shortcomings in terms of commercial creping operations, the most notable of which is the relatively low operating machine speed. It can be speculated that as a machine increases in speed, the shearing resistance of the sheet-adhesive-Yankee bond will change. Also, these studies overlook the effect of friction between the blade surface and the creped web. Both of these are likely to have vital roles in the creping process.

As we can see, not much public research has been done to investigate the creping process. This primarily is due to the competitiveness of the tissue industry. It is likely that much research has been done and many of these questions have been looked into; however, due to the nature of the industry, these results are kept secret.

The end result of this project is to have published data in the area of crepe blade vibration. This will help eliminate the problem of obtaining previous research, which is a predominant problem in the tissue industry. As this project is extended by others, hopefully it will spur other projects to create a quantity of published and accessible data.

EXPERIMENTAL DESIGN

The basic goal of the design of this system was to work efficiently as well as being easily controlled and modified. A Kistler Instruments model 9132 A21 accelerometer was used measure vibrations. The object being measure was the blade on the laboratory coater at Western Michigan University. Running the machine caused a roll on the coater to move the blade in a sequence of vibrations as it came in direct contact. A Kistler amplifier model 5010 Bm2 was used to create a large enough input signal for the computer to read. This was done with a National Instruments PCI-6111E DAQ card.

The purpose of this system is to measure, capture, and prepare data for analysis. After the vibration is detected by the accelerometer, it is captured by the amplifier. The amplifier then allows the card to obtain the data and save it to disc using Labview. Finally, SAS was used to graph the data in a form which allows us to see the frequency at which vibrations occurred.

The first part in setting up this project is setting up the apparatus, which will take measurements on the Dow coater. In this case the apparatus was an accelerometer. This involved attaching the accelerometer to the blade of the coater. Using a drill press, a hole was drilled towards the center of the blade. The hole was big enough to allow a screw to pass through, which was then used to attach the accelerometer. The center of the blade was chosen to keep the vibration on the accelerometer as constant as possible and to eliminate potential error.

The accelerometer was connected to the amplifier so that the computer would have a large enough input signal to read. From the amplifier, the system ran to a card connected to the computer, which would act as an interpreter for the computer, allowing information to be processed accurately.

The next portion of setting up the experiment involved the preparations on the computer. Labview 5.0 was the program used to read the data taken in by the system. A pre-made oscilloscope virtual instrument was used to save the data to disk. The modification which needed to be made was the addition of the "save to disk" function.

Making sure that this system worked properly before running it on the coater was the next step. To do this, a signal generator was used to create various sine and square waves at different frequencies. The oscilloscope showed exactly what was expected and when saved to disk, the data were collected and opened in Microsoft Excel. After creating graphs from the data points, a virtually identical plot could be seen. This meant that the system was in fact capable of taking in the data and reproducing it properly.

The setup on the coater was the next important step. Two pieces of standard Scotch tape were placed on top of each other on the roll which the blade contacts. This was done in order to have a disturbance of the blade at the same point in every revolution. It should be noted that the roll was 4 inches in diameter. As the tape was an inch wide, this would easily be within the range at which the oscilloscope would be running.

The major parameter for the trials was the rate of the coater roll rotation. At full speed, the roll moved at 91 RPM. To vary the speed, it was also run at 71 (3/4 speed), 43 (1/2 speed), and 24 (1/4 speed) RPM. This was done to change the frequency at which the tape would hit the coater blade. Also, several runs were made at each speed to ensure that the results were repeatable.

When the experiment was run, several parameters were set on the oscilloscope as well. The first was the scan rate, which was set to 1000 scans per second. This was a low enough rate such that the computer could handle the amount of information in the time given and fast enough where picking up the tape would not be a problem. Also, the total amount of scans to be saved to disk for each run was 60,000. This allowed enough points to find a distinct pattern in the data for each time the tape would contact the blade.

As the experiment was run, it was decided that more runs should be added. The runs included a trial with 0 RPM. The purpose for this was to analyze the background noise. A trial at full speed with no blade contact was also run, which would show any major disturbances due to the coater itself. Finally, trials were run at full and half speeds with a nail attached to the coater roll. This was done to show a great disturbance of the blade.

RESULTS AND DISCUSSION

At this point, the basis behind spectral analysis should be noted. When a given signal is imputed into the computer, it basically gives some sort of wave such as square or others. Spectral analysis breaks down the wave using a combination of sine and cosine waves. The sum of these waves is then taken and the points at which the coefficients are the largest represent the points of most significance. These are indicated as spikes on the resulting graph.

After the data were obtained and analyzed using spectral analysis, a very interesting result was discovered. A spike was found, which was expected, however it occurred at the same frequency for all the data. At first glance the spike seemed to indicate that the tape was being picked up and everything was working as expected. Looking closer however, it was realized that the frequency was the same regardless of coater speed, which can be seen in figure 1. Since it was expected that the sample frequency would work as planed, this was surprising. Trials were then run to determine if the instruments were causing this frequency spike.

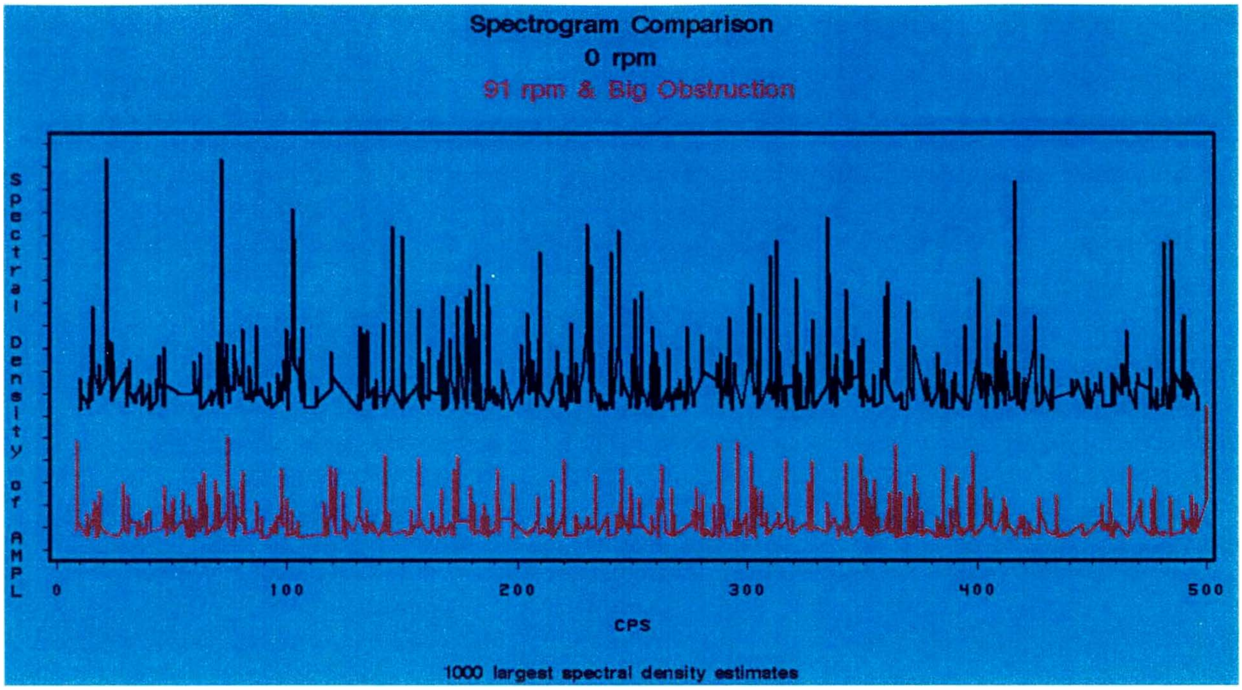
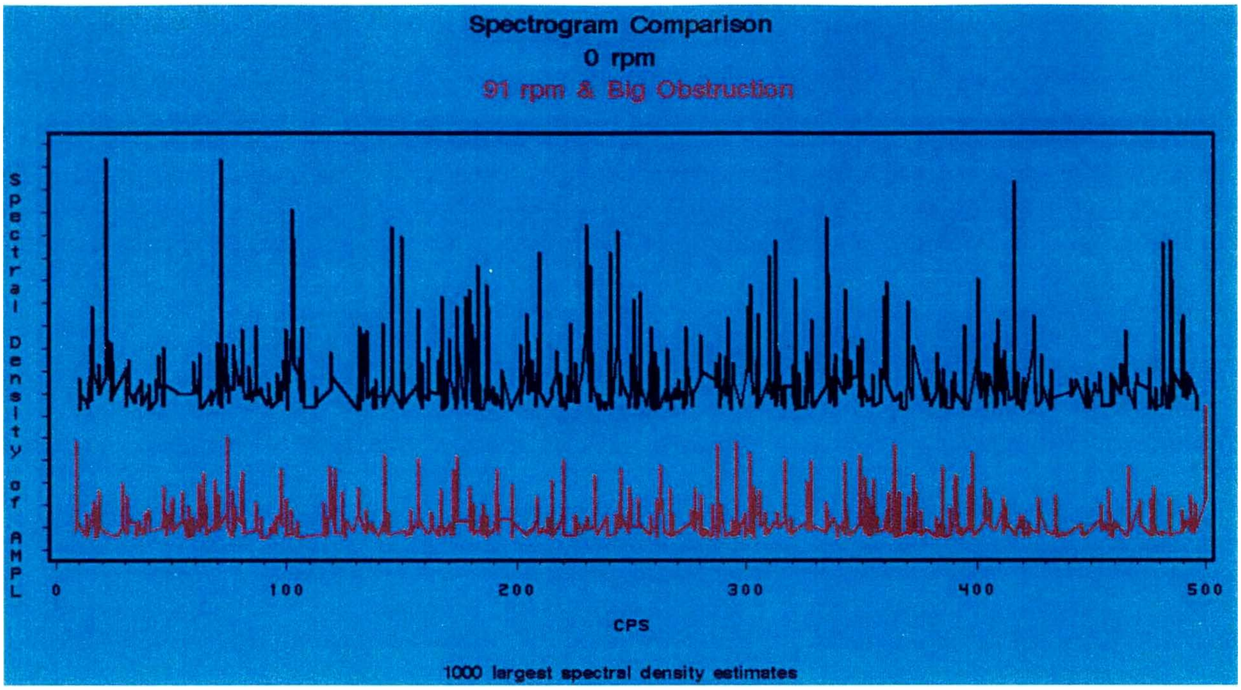


Figure 2

It is apparent that the accelerometer isn't able to pick up the low vibration caused by the obstruction. It is speculated that the accelerometer is not sensitive enough to pick up vibrations of such low frequency. It is designed for high frequency operation, but the manufacturer does not indicate a lower limit. More work needs to be done in this area. Also, the source of observed spike remains a mystery. More work needs to be done in this area as well.



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RECOMMENDATIONS

There are several things which could be done in the future to further the overall goals of this project. First, it would be advantageous to run this same experiment on a faster machine. The best would be a full size tissue machine as this is what the accelerometer was designed for. It could be possible to run it on a pilot machine or some other coater somewhere, if that machine runs at a faster rate. Second, at some point in the future, paper of some sort should be run to see how the vibration due to the paper looks. This would lead to great insight on the objectives. Finally, after other testing, this experiment should be run on a tissue machine so that the data can be compared to the forming fabric pattern.

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