The Effect of Testing System Data Collection Rate and Bandwidth Setting On Peel Adhesion Strength Test Results.

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Introduction

A 180 degree peel adhesion test is routinely performed to provide strength information to engineers, chemists, and scientists for formulation, package design, material selection, and process parameter decisions. Results from this testing (maximum load and average peel force) is published in technical data sheets and comparisons of the test results are frequently performed to help the end user select the optimal adhesive for his/her application. One should use great caution when comparing these values without the understanding of the test instrument's bandwidth and data acquisition settings.

Modern peel testing instruments are of two (2) types. The first type of tester uses a digital readout and displays the highest force measured during the peel adhesion test.

The second type of tester uses a PC and software to display a peel strength versus peel length curve. Many engineers and chemists prefer the second type of tester because it displays the full peel adhesion curve and it provides for detailed investigation. For example, the software supplied with these systems will calculate the average peel force for a given length of peel. Computerized peel test instruments provide the user with the ability to adjust the rate of data collection (peel force and peel length versus time). Some units also allow for adjustment of the electronic bandwidth of the instrument's data collection component. Advanced users of these testing systems should understand the importance of these settings (data collection rate and bandwidth) on recorded peel test results and take steps to optimize these parameters.

This paper examines the effect of variation of data collection rate and electronic bandwidth on 180 degree peel adhesion test results (maximum force and average peel force). The testing was conducted on a single roll of adhesive film from the same lot of material.

The computerized peel testing system

A computerized peel testing system is an electronic device that is used to measure the peel strength properties of adhesives and tapes. These testing systems are designed to collect and display mechanical strength information. As an electronic device, the unit's ability to accurately measure and transmit accurate peel force results is a function of its mechanical and electronic design.

All computerized peel testing systems use electronic components for data acquisition called amplifiers and filters. Many use components called Analog to Digital (A/D) Converters and/or digital signal processors (DSP's). Each of these components has electronic characteristics that can limit the "accuracy" of the displayed peel adhesion result.

Higher quality amplifiers, filters, A/D Converters, and DSP's provide more accurate results. However, these higher quality components are more expensive to produce and sell. This can lead to a peel testing instrument that could be very costly.

This paper investigates two variables, data acquisition rate (also known as data sampling rate) and electronic bandwidth. First, some definitions:

Data acquisition: the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (abbreviated with the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing. The components of data acquisition systems include:
Sensors that convert physical parameters to electrical signals.
Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
Analog-to-digital converters, which convert conditioned sensor signals to digital values.

This paper will investigate data acquisition rates of 10 points/second, 100 points/second, and 1000 points/second.

Bandwidth: the frequency range that an electronic device, such as an amplifier or filter, will transmit. Bandwidth is the difference between the upper and lower frequencies in a contiguous set of frequencies. It is typically measured in hertz, and may sometimes be referred to as passband bandwidth. Passband bandwidth is the difference between the upper and lower cutoff frequencies of, for example, an electronic filter, a communication channel, or a signal spectrum.

This paper will investigate the passband bandwidth of 1 hertz, 10 hertz, and 100 hertz. The lower cutoff frequency is 0 Hertz.

Discussion of testing performed

All of the testing was conducted per the guidelines of ASTM D3330 Standard Test Method for Peel Adhesion of Pressure Sensitive Tapes. Method A was employed in this testing.

Strips of 1 inch wide 3M® Brand Blue Painters Tape was adhered to a five inch long stainless steel test panel using the standard 4.5 lb roller. See Figure 1.

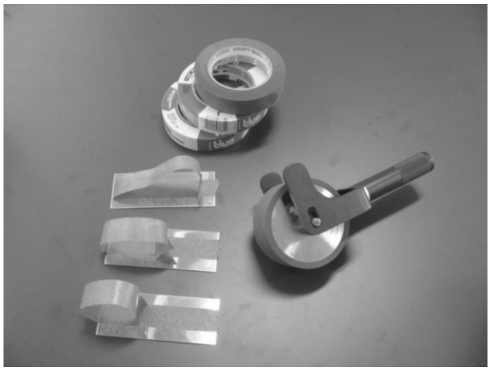


Figure 1

The test panels were installed in the peel testing instrument and tested at a rate of 12 inches/min per ASTM D3330. See Figure 2.

Figure 2

The testing instrument was initially set to a data acquisition rate of 10 points/second and a Bandwidth of 1 Hertz prior to conducting the testing. Ten peel tests were performed with these parameters fixed and the resultant maximum force and average peel force were recorded for each test. The average of the ten specimen's maximum force was calculated and the average of the ten specimen's average peel force was also recorded. The test panels were cleaned and once again strips of 1 inch wide 3M® Brand Blue Painters Tape was adhered to a 5 inch long stainless steel test panel using the standard 4.5 lb roller. The testing instrument was then set to a data acquisition rate of 10 points/second and a Bandwidth of 10 Hertz. Ten more peel tests were performed and the resultant maximum force and average peel force were recorded for each test. The average of the ten specimen's maximum force was calculated and the average of the ten specimen's average peel force was also recorded. Once again the test panels were cleaned and strips of 1 inch wide 3M® Brand Blue Painters Tape was adhered to a 5 inch long stainless steel test panel using the standard 4.5 lb roller. The testing instrument was then set to a data acquisition rate of 10 points/second and a Bandwidth of 100 Hertz. Ten more peel tests were performed and the resultant maximum force and average peel force were recorded for each test. The average of the ten specimen's maximum force was calculated and the average of the ten specimen's average peel force was also recorded.

The above process of cleaning, reapplication of the tape, and testing continued with the following variables in Table 1 changed after each group of ten tapes was tested. Appendix A Graphs 1-9 show the resultant graphs from these groups. Table 1 below summarizes the various test variables.

Table 1. Peel Testing Variables

Test Number	Data Acquisition Rate (points/second)	Bandwidth (Hertz)
1	10	1
2	10	10
3	10	100
4	100	1
5	100	10
6	100	100
7	1000	1
8	1000	10
9	1000	100

Summary of Test Results

The mean maximum load (grams) and the mean average peel force (grams) were determined for each group of 10 specimens. See Table 2 Below.

Table 2 "Mean" Maximum Force and "Mean" Average Force

Test Number	Data Acquisition Rate (points/second)	Bandwidth (Hertz)	Mean Maximum Force (gf)	Mean Average Force (gf)
1	10	1	432	362
2	10	10	457	343
3	10	100	725	332
4	100	1	400	336
5	100	10	463	361
6	100	100	789	315
7	1000	1	404	337
8	1000	10	489	369
9	1000	100	800	301

The following four charts were prepared to graphically display the above tabular results.

Chart 1. "Mean" Maximum Load (gf)

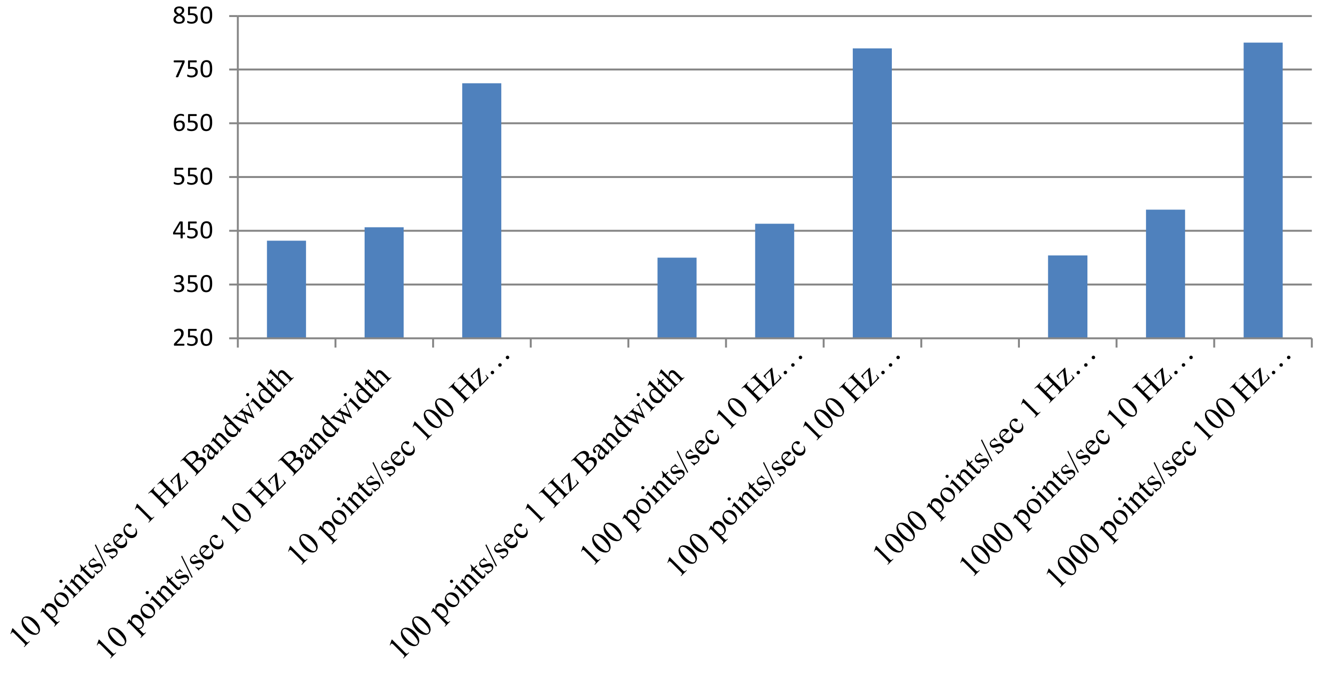
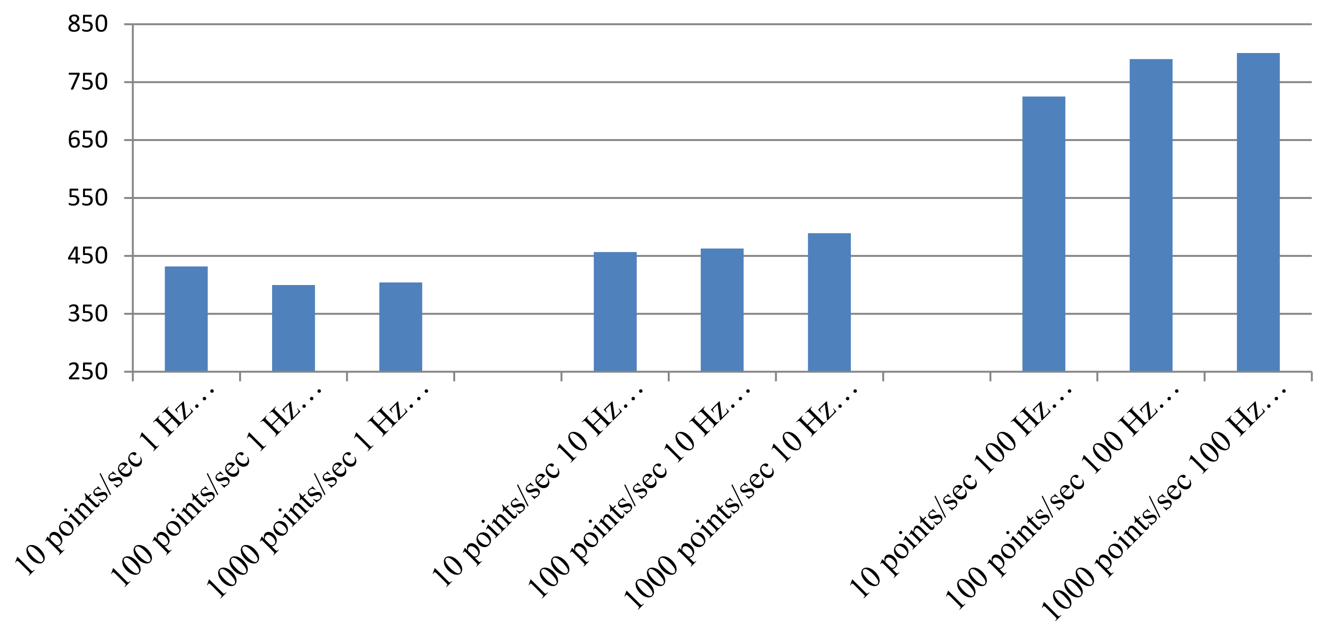
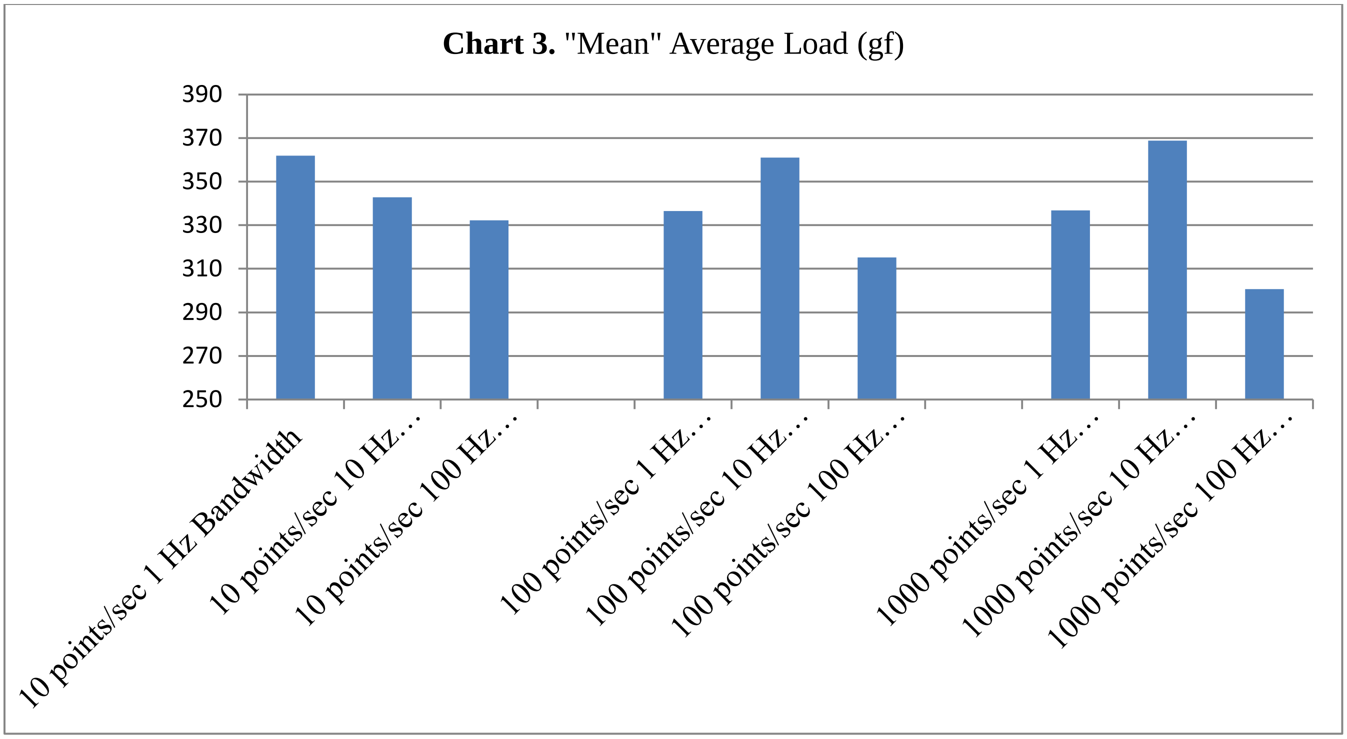
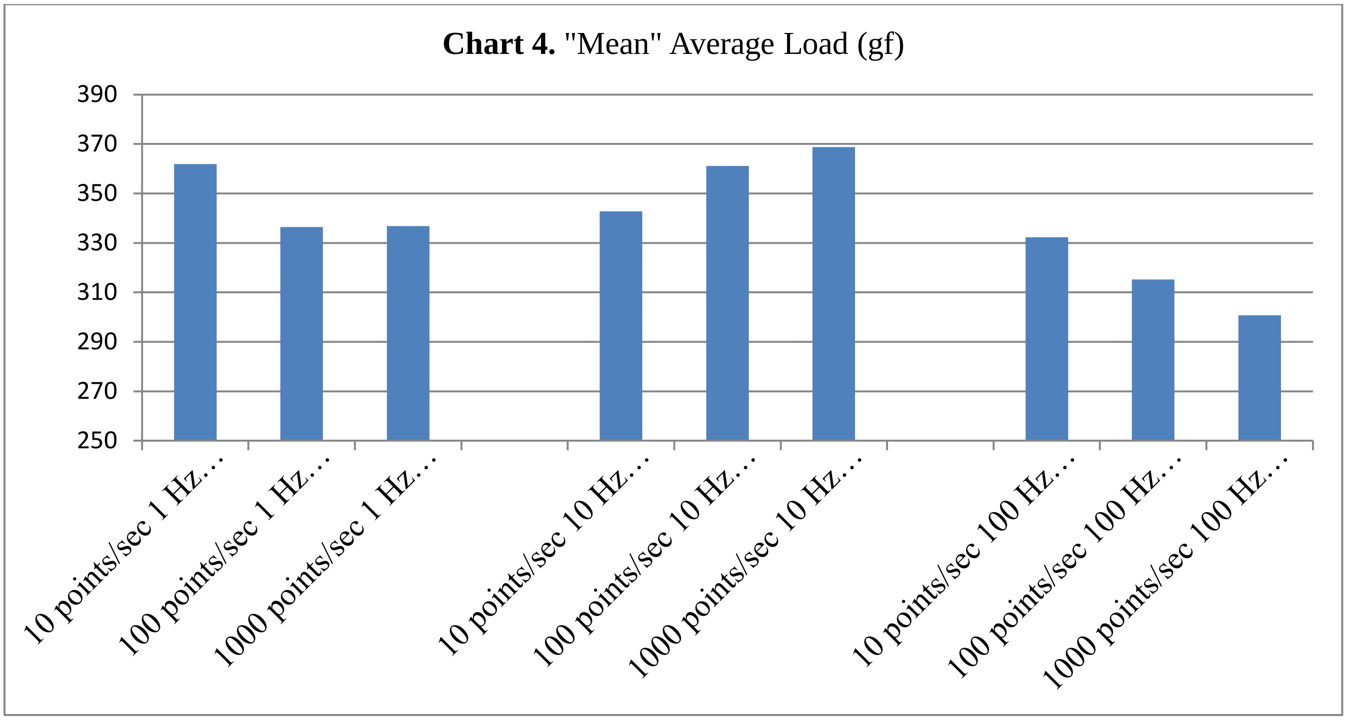


Chart 2. "Mean" Maximum Load (gf)







Analysis of test results

The charts created above provide us with a useful graphical representation of the results and this will be used for the discussion of the results.

Investigating Maximum Load Values

We will first investigate the effect of bandwidth on maximum load while keeping the data acquisition rate constant. One will see by referencing the Chart 1 Maximum Load values that the 100Hz bandwidth setting yields an almost 100% difference in values when compared to the 1Hz and 10 Hz settings. In referring again to Chart 1, and looking at only 1Hz and 10Hz bandwidth settings. One will see an increase of 5.8%, 15.8%, and 21.0% higher Maximum Load Values for the 10 points/sec, 100 points/sec, and 1000 points/sec data acquisition rates respectively.

We now shift our focus to Chart 2. In this chart, we graphically group the bandwidth settings to see if we can detect any noticeable change in data acquisition rate. At the 1 Hz bandwidth setting we see an 8% decrease in load when going from 10 points/sec to 100 points/sec and then a 1% increase from 100 points/sec to 1000 points/sec. At the 10Hz bandwidth setting we see a 1.3% increase from 10 to 100 points/sec and 5.6% change between 100 points/sec and 1000 points/sec. The change between 10 points/sec and 1000 points/sec is 6.7%. Lastly we look at the 100 Hz bandwidth setting and we see similar relative changes in maximum load values of 8.2% between 10 points/sec and 100 points/sec, 1.4% increase between 100 points/sec and 1000 points/sec and lastly 9.4% increase between 10 points/sec and 1000 points/sec. However, as stated in the Chart 1 summary, the overall values are quite high relative to the 1Hz an 10Hz setting.

Investigating Average Load values

We will first investigate the effect of bandwidth on maximum load while keeping the data acquisition rate constant. Referring to Chart 3, at the 10 points/sec setting, one will see a 5.6% decrease at 10Hz versus 1Hz and a 3.2% decrease from 10 Hz to 100 Hz bandwidth setting. The decrease between 1Hz and 100 Hz is 8.9%. At 100 points/sec from 1Hz to 10Hz we see a 6.8% increase, from 10Hz to 100Hz a 14.5% decrease and the overall change from 1Hz to 100Hz is a decrease of 6.7%. At 1000 points/sec from 1Hz to 10Hz there is an 8.7% increase, a 22.6% decrease from 10Hz to 100Hz and an overall decrease of 12% from 1Hz to 100Hz. None of these results match the trend seen in Chart 1 for the maximum load result.

Lastly, we investigate Chart 4. In this chart, we graphically group the bandwidth settings for average load results to see if we can detect any noticeable change in data acquisition rate. This was the same process we used for the analysis of the Chart 2 results. At the 1 Hz bandwidth setting we see an 7.6% decrease in load when going from 10 points/sec to 100 points/sec and then a 0.1% increase from 100 points/sec to 1000 points/sec. The overall change from 10 points/sec to 1000 points per sec was decrease of 7.5%. At the 10Hz bandwidth setting we see a 5.1% increase from 10 to 100 points/sec and 2.1% change between 100 points/sec and 1000 points/sec. The change between 10 points/sec and 1000 points/sec is 7.0%. Lastly we look at the 100 Hz bandwidth setting and we see a completely opposite trend in average load values with a 5.4% decrease between 10 points/sec and 100 points/sec, 4.9% decrease between 100 points/sec and 1000 points/sec and overall a 10.5% decrease between 10 points/sec and 1000 points/sec. In this case, the overall value at 1000 points/sec and 100 Hz bandwidth are quite low relative to the 1Hz and 10Hz setting.

Summary and Conclusions

In reviewing these results thoroughly, one must also investigate the test graphs obtained from the test equipment software. This is done to look for evidence or clues that would point to the results obtained. Appendix A contains the (9) sets of graphs obtained from this testing.

Graphs 3, 6, and 9 all run at a 100Hz bandwidth “look” much different than the remaining 6 graphs. Looking more closely at these (3) graphs, one sees that the minimum load values for each of them goes into the negative range. Some negative values exceed 200 grams of negative force. This is physically impossible as this would suggest that there are compressive forces acting on the instrument’s load cell during a tensile peel test. Hence we come to the reason for a “bandwidth” setting in the first place as outlined in the beginning of this paper. The bandwidth filters out “noise”. These negative and high positive values can only be considered as noise and discounted as not a characteristic of the material or adhesive used, but rather electronic noise. Hence, this author concludes that a bandwidth setting of 100Hz is not appropriate for the material being tested here.

When the engineer wishes to calculate the maximum load value on a peel test, the bandwidth setting of the instrument will have a direct effect on the maximum load value obtained. As shown here, this is particularly true when the setting is 100Hz. Further investigation is required to see the result change when the setting is between 10Hz and 100Hz.

On the material tested here, the data collection rate setting of 10 points/sec, 100 points/sec, and 1000 points/sec also showed an increase in values of up to 9.4%. Hence this setting must also be considered when comparing results.

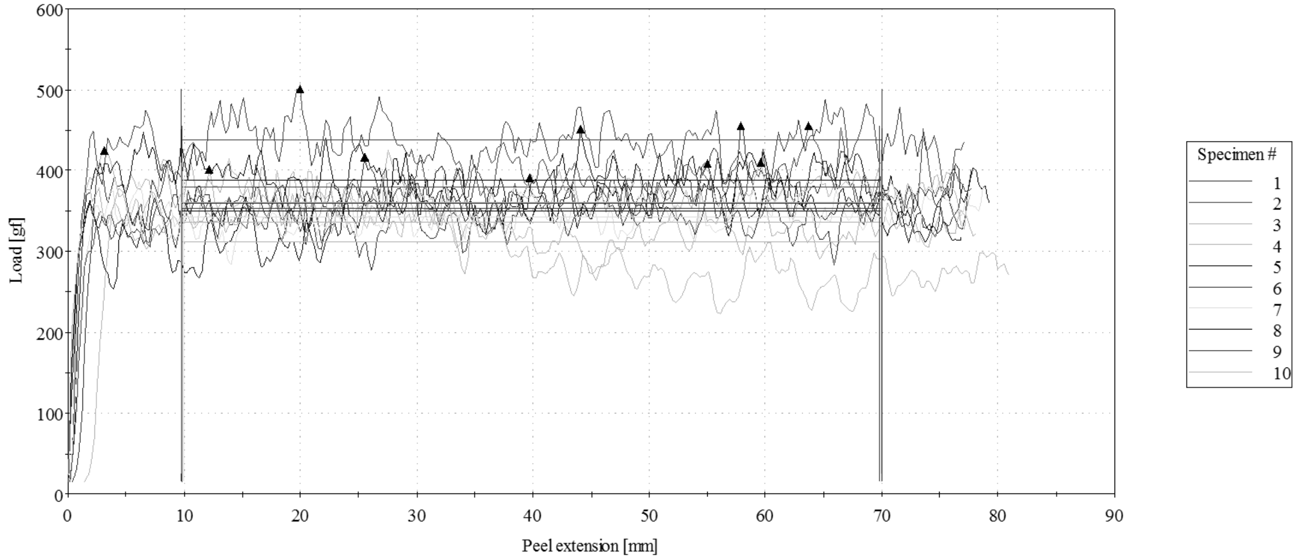
Turning now to the average load readings, as concluded above, the bandwidth setting of 100 Hz does not filter out the electronic noise as shown in Graphs 3, 6, and 9. This author will discount these values. It is quite apparent from Charts 3 and 4 that both data acquisition rate and bandwidth affect the average load readings as well with a variation of up to 12% when looking at a bandwidth setting of 1 Hz and 10 Hz.

The testing performed here has shown that changes in data acquisition rate and bandwidth can have effects on maximum and average peel force measurements and may lead to difficulty in comparing and interpreting results.

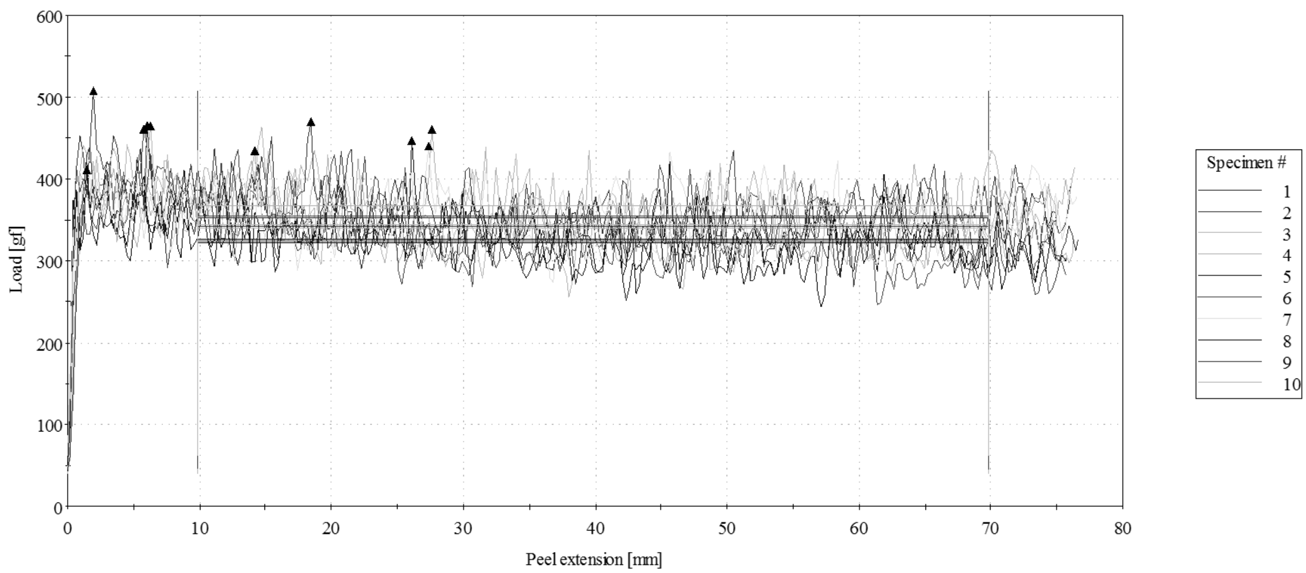
Appendix A

180 Degree Peel Testing Graphs

Graph 1
10 points/Sec 1 Hz bandwidth

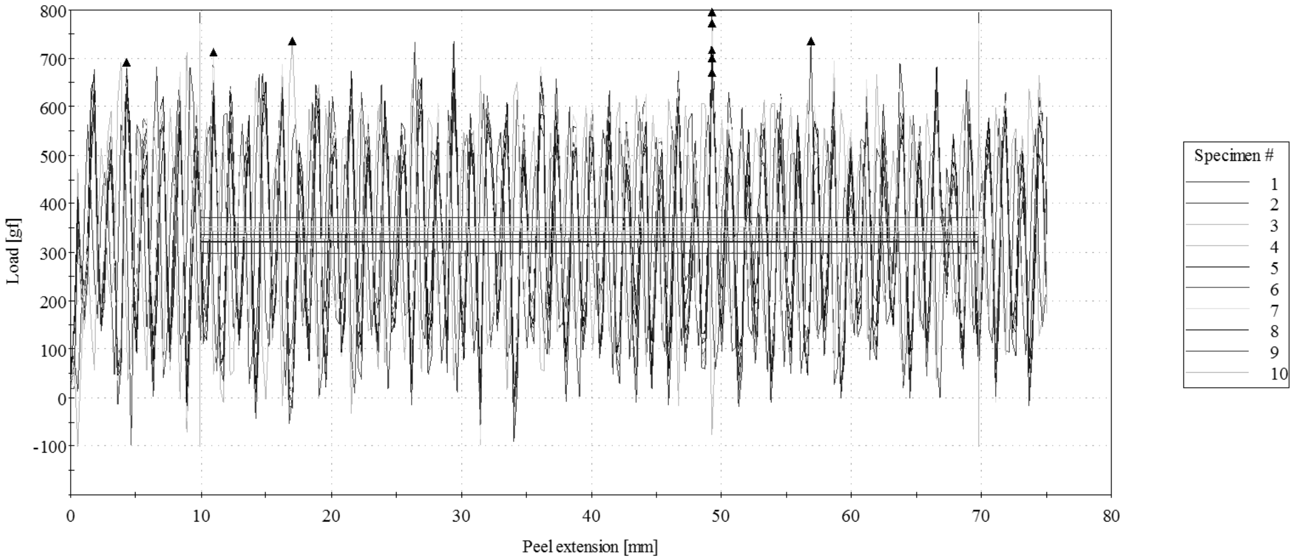


Graph 2
10 points/sec 10 Hz bandwidth



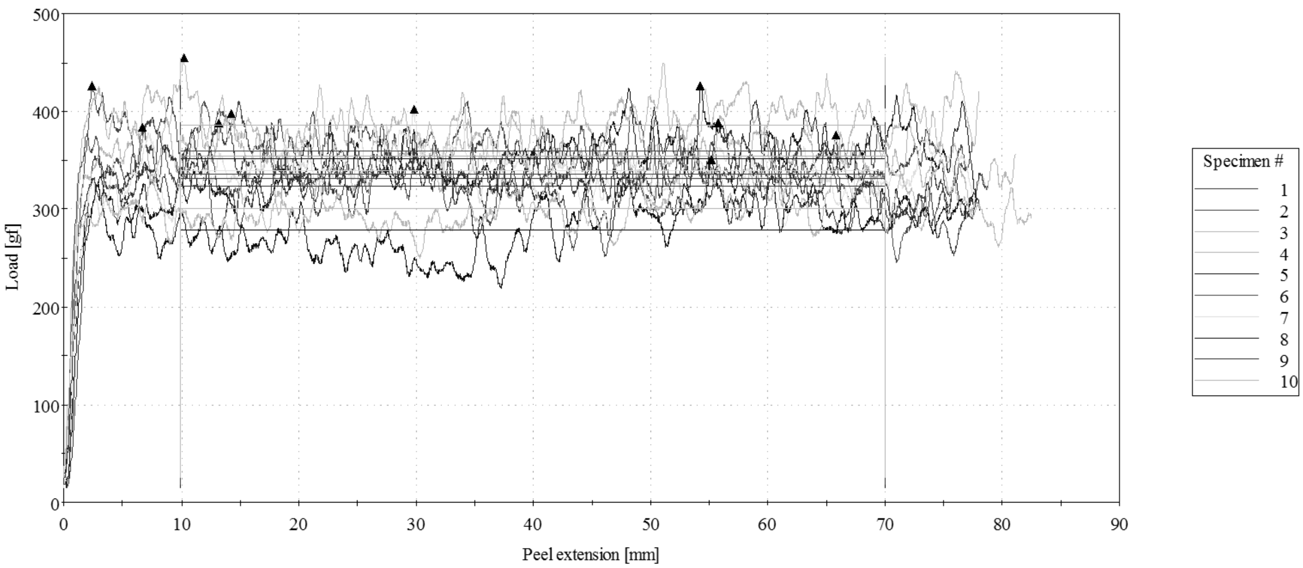
Graph 3

10 points/sec 100 Hz bandwidth

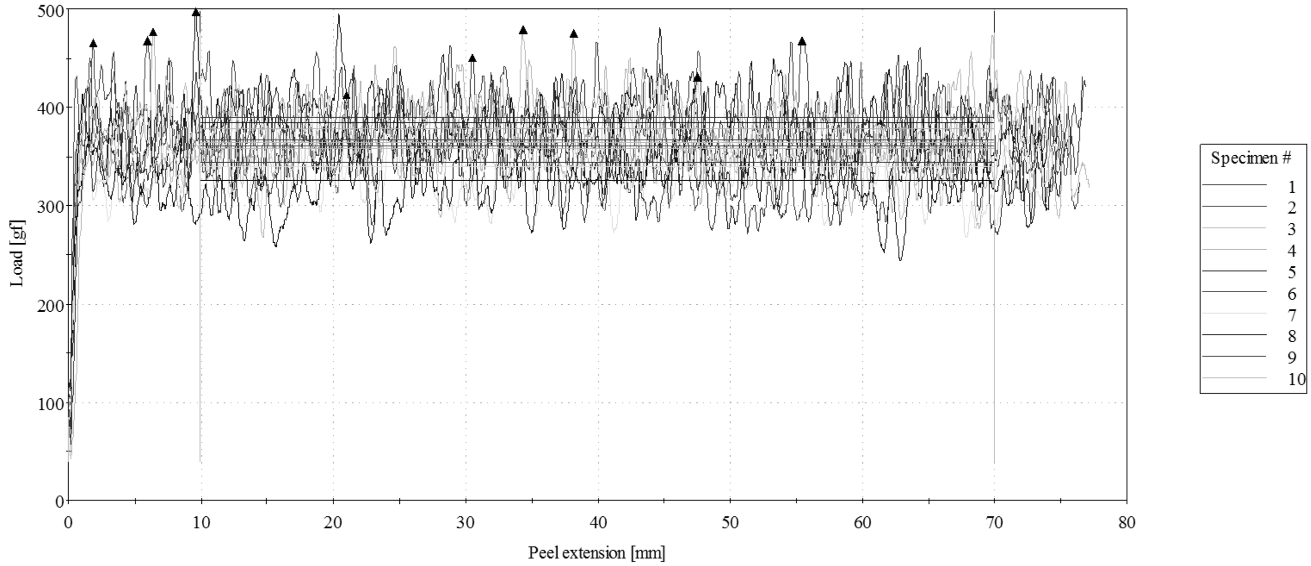


Graph 4

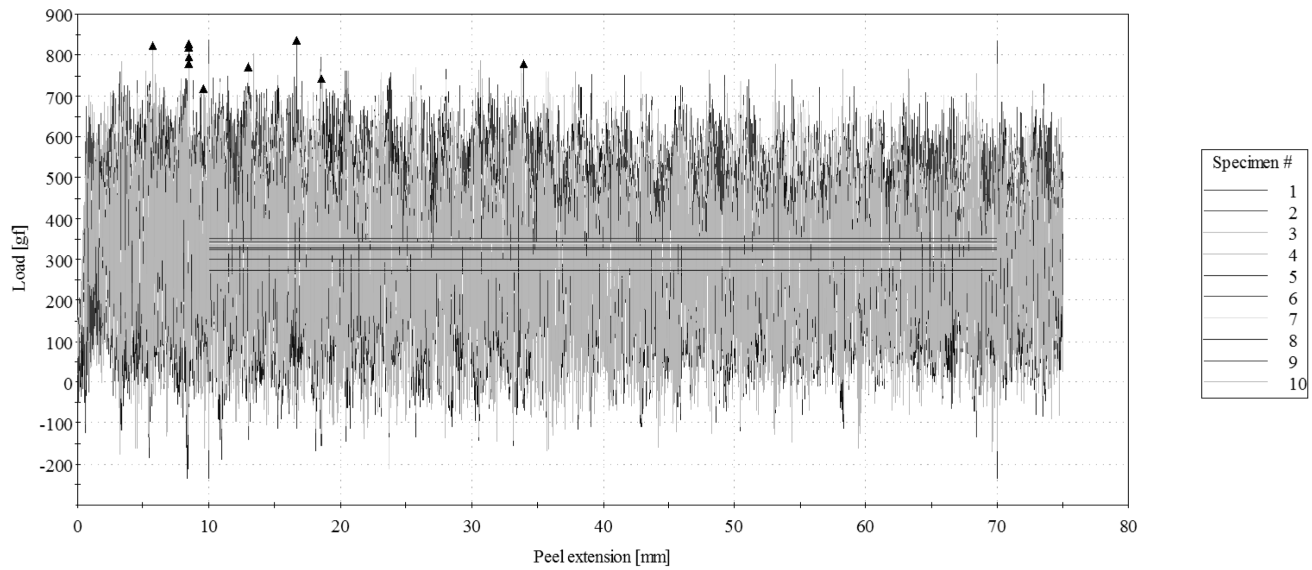
100 points/sec 1 Hz bandwidth



Graph 5
100 points/sec 10 Hz bandwidth

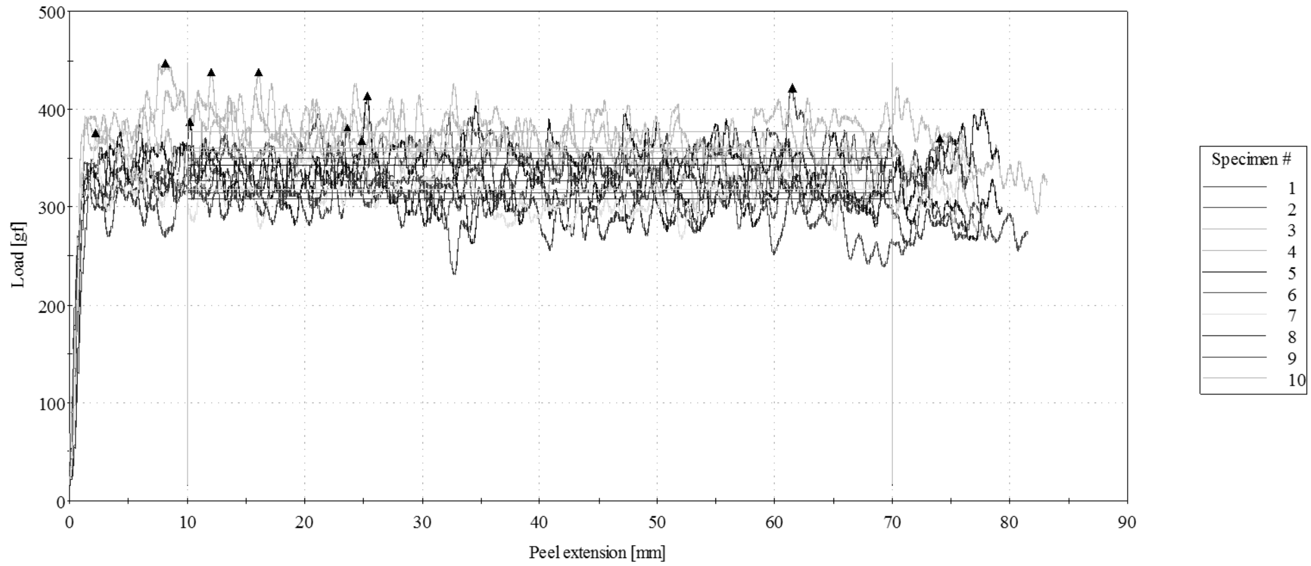


Graph 6
100 points/sec 100 Hz bandwidth



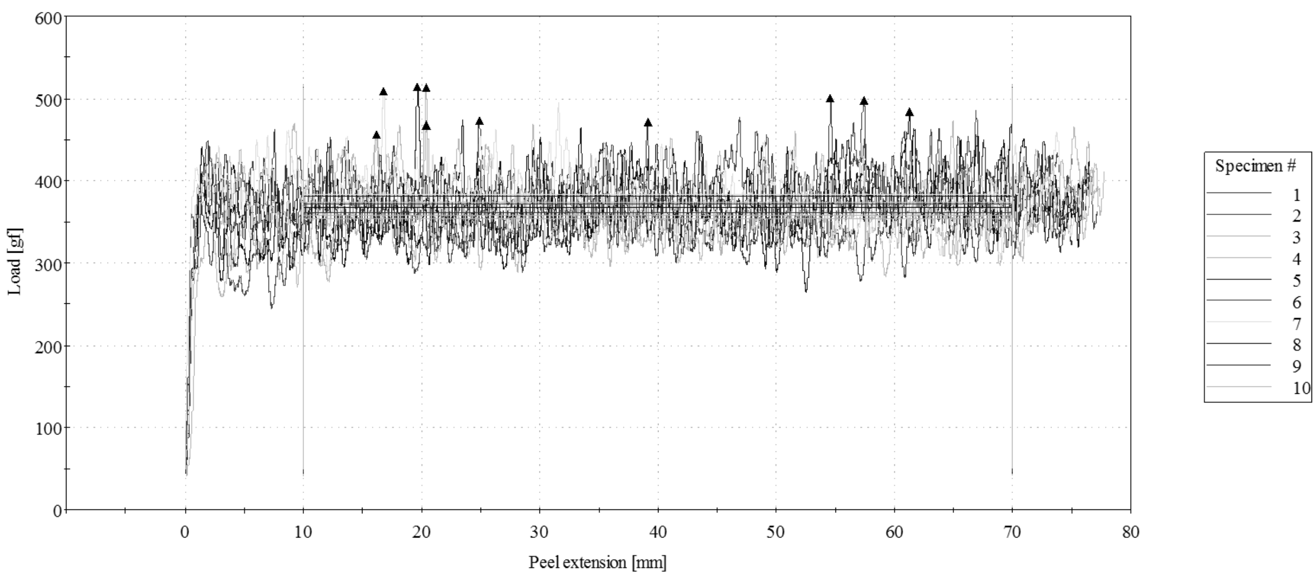
Graph 7

1000 points/sec 1 Hz bandwidth

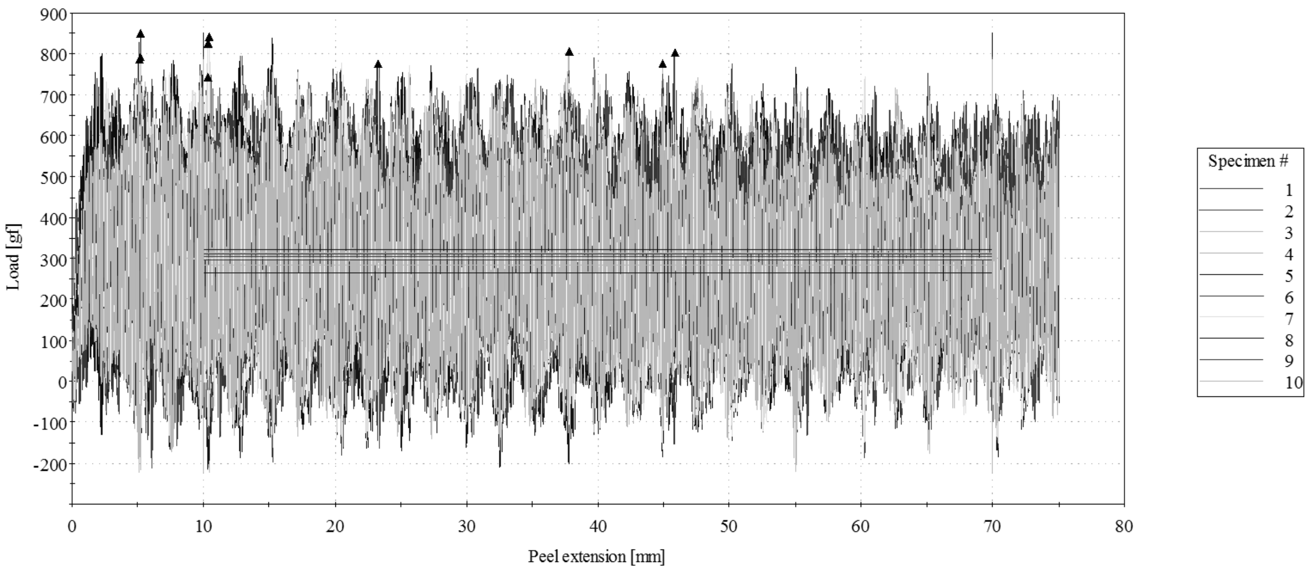


Graph 8

1000 points/sec 10 Hz bandwidth



Graph 9
1000 points/sec 100 Hz bandwidth



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