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Auto Plot Stiffness Tester-Performance Evaluation of Controlled Samples with Shirley Stiffness Tester

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Abstract

A new Auto-Plotter stiffness tester is developed to reduce the human interference in the bending measurement. This paper highlights the investigation made on the tester in order to confirm the reliability of its measurement. For that, 40 controlled samples were developed and tested for bending length, bending modulus. These results are compared with the Shirley stiffness tester results of the sample.

The statistical tools such as ANOVA, paired mean test, Wilcoxon signed rank test and multiple correlation regression are used to know the significance differences among the samples as well as between Auto-Plot tester and Shirley. The results of Auto-Plot tester are comparable with Shirley Tester; Auto Plot Stiffness Tester has advantage of examining the intermediary behavior of samples before reaching 41.5 degree. This Auto-Plot tester has provision for storing the data's and further it may be electronically transmitted to other sources.

Experimental

Eight controlled samples are generated based on following titles

a) Two different counts namely 40's and 2/20's are used
b) Keeping both warp and weft count constant, changing the constructions
c) Keeping both wrap and weft, as well as construction constant changing EPI and PPI

Sample Nos	Wrap Count	Weft Count	EPI	PPI	Weave
1	40's	40's	84	70	Plain
2	40's	40's	84	70	Matt
3	40's	40's	58	52	Plain

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4	40's	40's	58	52	Matt
5	2/20's	2/20's	58	40	Plain
6	2/20's	2/20's	58	40	Matt
7	2/20's	2/20's	40	30	Plain
8	2/20's	2/20's	40	30	Matt

SCOURING

Further the Eight Samples are scoured to remove actual vegetable matters with following recipe
Liquor ratio: 1:20
Wetting Agent: 0.751
Caustic Soda : 2.1
Temp: - 100° C
Time: - 4 to 6 hours
The scouring bath is set by taking required quantities of caustic soda, Soda ash and wetting agent, keeping M:L ratio of 1:20 the wetted material is entered into scouring bath and Temperature is immediately raised to boil and in boiling temperature, the material is worked for 4-6 hours. The samples were steeped over night in the same liquor and then washed thoroughly with water on the next day.

BLEACHING

Retaining some portion of scoured sample, remaining samples are subjected to the bleaching to remove natural colouring matter with following recipe

Liquor ratio: 1:20

Wetting Agent: 0.751

Hydrogen peroxide one volume (half bleach)

Sodium silicate 2 gpl

Initially the samples are soaked in water containing wetting agent, then the bleaching bath is set at the room temperature by taking one volume of Hydrogen peroxide and 2 gpl of Sodium silicate (stabilizer) for obtaining half bleach. Buffer the bleach solution with caustic or soda ash at Ph 11.5 now the pre wetted samples are entered into the bleaching bath and worked for few minutes then the temperature of the bath is raised to 80 to 90 degree centigrade and the material is worked 30 minutes and temperature is raised to 95 degree centigrade at this temperature the samples were treated for 60 minutes

Finally after the treatment the sample is taken out rinsed well in clean water and washed thoroughly

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DYEING

Previously scoured and bleached samples are further dyed with reactive dyes (prawn magenta MB) using cold method with two shade percentage of 0.5 and 3% with following recipe.

Reactive Dye: - 0.5% to 3%

Soda Ash: - 5 gpl to15 gpl

Common Salt: - 15 gpl to 80 gpl

The Dye stuff is pasted in cold water and diluted with water at 30 to 50 degree and should not be boiled under any circumstance. Then the diluted dye stuff is added to the required quantity of water, previously wetted samples are entered in this dye bath, worked for 10 minutes. The requisite quantity of common salt is added to this dye bath in installments over the period of 40 minutes. During dyeing the samples were turned several times and required quantity of soda ash is added to this dye bath which assists in dye fixation. Further the samples were worked for one hour then taken out washed with clean water.After dyeing the samples were soaped at boil with 1.5 gm per liter by synthetic detergent for 30 minutes and finally washed.Totally 40 samples were prepared in this fashion (8 each of grey, scoured bleached, 0.5% dyed, 3% dyed) to test on the newly developed Auto Plot Stiffness Tester.
All these 40 controlled samples are tested on Auto Plot Stiffness Tester and Shirley Tester. In Auto Plot Stiffness Tester, controlled samples are tested in 1, 2, 5 and 10 mm movement, as sensor is fixed at 7 mm distance from edge of sample measurement bed, for 1 and 2 mm movement, the samples have to be moved 10 mm initially, then has to commence the testing. This 10 mm should be added to the Auto Plot Stiffness Testers output readings

The results of controlled samples are tested with Wilcoxon signed Rank Test, below table shows the results of the test.

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Wlcoxon Signed Rank Test Results - indicate p-valu with * if it is Retain Null Hypothsys otherwise indicate numberin red color without *

Sample ID			2mm-5mm	2mm-10mm	5mm-10mm	2mm-Shirley	5mm-Shirley	10mm-Shirley	1mm-2mm	1mm-shrley	1mm-5mm	1mm-10mm
58X40	Plain	Grey	.496*	.892*	.102*	.892*	.223*	.892*	**0.655***	**0.892***	0.221*	0.892*
58X40	Plain	Scoured	0.042	0.043	0.577*	0.102*	0.043	.068*	0.273*	0.892*	0.080*	0.225*
58X40	Plain	Bleached	0.223*	.413*	1.00*	1.000*	.223*	.416*	0.854*	1.00*	0.136*	0.408*
58X40	Plain	1 Dyed	0.357*	.068*	.655*	.269*	.854*	.581*	0.414*	0.144*	0.223*	0.041
58X40	Plain	3 Dyed	.157*	.157*	1.00*	.414*	1.00*	1.00*	0.564*	0.465*	0.276*	0.276*
58X40	Mat t	Grey	0.068*	0.257*	0.564*	0.785*	0.041	.480*	1.00*	0.683*	0.066*	0.257*
58X40	Mat t	Scoured	.680*	.131*	0.025	.786*	.564*	0.041	0.680*	0.854*	1.00*	0.039
58X40	Mat t	Bleached	.141*	.141*	1.00*	1.00*	0.041	0.041	1.00*	0.705*	0.066*	0.066*
58X40	Mat t	1 Dyed	0.043	0.042	0.317*	0.034	.683*	.336*	0.317*	0.042	0.043	0.043
58X40	Mat t	3 Dyed	.336*	.221*	.705*	0.041	.216*	.683*	0.039	0.223*	0.104*	0.223*
40X30	Plain	Grey	.461*	.194*	.317*	.564*	.461*	.059*	1.00*	0.480*	0.683*	0.131*
40X30	Plain	Scoured	0.034	0.034	0.046	.059*	.492*	0.034	0.039	1.00*	0.492*	0.038
40X30	Plain	Bleached	.345*	0.042	0.034	.273*	0.041	0.041	0.786*	0.496*	0.221*	0.041
40X30	Plain	1 Dyed	0.042	.144*	.066*	.686*	0.343*	.078*	0.891*	0.588*	0.080*	0.104*
40X30	Plain	3 Dyed	.892*	.109*	.317*	.416*	.684*	0.038	1.00*	1.00*	0.786*	0.066*
40X30	Mat t	Grey	.221*	.684*	1.00*	.180*	.098*	.680*	1.00*	0.083*	0.408*	0.683*
40X30	Mat t	Scoured	.059*	.059*	1.00*	.713*	0.041	0.041	0.066*	0`046	0.083*	0.083*
40X30	Mat t	Bleached	.157*	0.038	0.046	.059*	.498*	0.039	0.039	0.083*	0.408*	0.034
40X30	Mat t	1 Dyed	.414*	.285*	.197*	.102*	.273*	.683*	0.414*	0.285*	0.285*	0.269*
40X30	Mat t	3 Dyed	.892*	.221*	0.046	1.00*	.102*	0.039	0.893*	0.586*	0.581*	0.141*
84X70	Plain	Grey	1.00*	0.041	0.025	.273*	.892*	.144*	0.705*	0.588*	0.343*	0.042
84X70	Plain	Scoured	0.046	0.046	1.00*	.317*	.180*	.180*	0.713*	0.713*	0.109*	0.109*
84X70	Plain	Bleached	.066*	.059*	.317*	.129*	0.042	0.039	0.713*	0.157*	0.042	0.041
84X70	Plain	1 Dyed	.655*	.317*	.317*	.317*	.705*	1.00*	0.083*	0.059*	0.713*	0.059*
84X70	Plain	3 Dyed	0.034	0.025	0.046	.063*	1.00*	0.041	0.564*	0.059*	0.102*	0.041
84X70	Mat t	Grey	.131*	.336*	0.046	.786*	.223*	.157*	0.257*	0.893*	0.102*	0.223*
84X70	Mat t	Scoured	0.025	0.025	0.025	.083*	.655*	0.038	0.038	0.414*	0.083*	0.038
84X70	Mat t	Bleached	.684*	.157*	.564*	.854*	.683*	0.129	0.68*	1.00*	0.892*	0.039
84X70	Mat t	1 Dyed	0.034	0.034	0.025	.157*	0.034	0.034	0.564*	0.257*	0.066*	0.042
84X70	Mat t	3 Dyed	0.039	0.039	1.00*	.577*	0.038	0.038	0.257*	0.414*	0.041	0.041
58X52	Plain	Grey	.343*	.223*	.480*	.786*	1.00*	.336*	0.317*	0.786*	0.461*	0.279*
58X52	Plain	Scoured	.059*	.059*	1.00*	.891*	.141*	.141*	0.892*	0.581*	0.041	0.041
58X52	Plain	Bleached	.713*	.059*	.083*	.655*	.891*	0.041	0.783*	0.48*	0.655*	0.038
58X52	Plain	1 Dyed	0.025	0.025	0.025	.063*	0.041	0.041	0.157*	0.157*	0.038	0.038
58X52	Plain	3 Dyed	0.038	.077*	.317*	.074*	0.042	.414*	0.046	0.157*	0.041	0.102*
58X52	Mat t	Grey	.680*	0.034	.102*	.450*	1.00*	0.041	0.564*	0.414*	0.786*	0.041
58X52	Mat t	Scoured	1.00*	0.039	0.025	1.00*	1.00*	0.039	0.334*	0.334*	0.066*	0.042
58X52	Mat t	Bleached	.221*	.496*	.705*	.713*	.066*	.786*	0.157*	0.496*	0.680*	0.683*
58X52	Mat t	1 Dyed	.221*	0.038	0.034	.059*	.705*	0.034	0.655*	0.034	0.480*	0.025
58X52	Mat t	3 Dyed	.465*	.109*	.317*	.581*	.078*	0.042	0.317*	0.854*	0.343*	0.041

The instrument developed has been tested at rate of sample movement of 1, 2, 5 and 10mm. There is very good agreement between 1 mm and Shirley test results and also 2mm and Shirley test results. The lower agreement of 5 mm and 10 mm movement with Shirley test results is understandable as the faster rate of movement of sample is not allowing for complete relaxation

Variance and Mean test

Since the same specimens were tested at various movement in the Auto plot stiffness tester and Shirley tester to check for difference between the samples and the process conditions. Paired mean test has been carried out and table shows the "t" test result at the test condition of 2mm.

Sample	**ANOVA p-value**
58X40, Plain	6.7E-08
58X40, Matt	4.2E-08
40X30, Plain	1.4E-02

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40X30, Matt	3.6E-02
58X52, Plain	4.8E-07
58X52, Matt	3.0E-09
84X70, Plain	3.3E-15
84X70, Matt	2.7E-12

Table 6.2 t-test p-value (test condition- 2mm)

The table shows the results of ANOVA. It is very clear that in each sample with the process condition there exists the variance difference. The process conditions namely scoured, bleached and dyed do affect the bending behavior.

Grey and Scoured Samples

Sample	**T-Test p-value**
58X40, Plain	3.4E-04
58X40, Matt	1.4E-04
40X30, Plain	1.2E-02
40X30, Matt	1.9E-04
58X52, Plain	3.2E-03
58X52, Matt	5.0E-06
84X70, Plain	2.9E-07
84X70, Matt	1.5E-06

Table : 6.3 Grey and Scoured T-Test results

The Table shows the t test results between grey and scoured condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between grey and scoured conditions of all the controlled samples.

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Variance and Mean test

Since the same specimens were tested at various movement in the Auto plot stiffness tester and Shirley tester to check for difference between the samples and the process conditions. Paired mean test has been carried out and table shows the "t" test result at the test condition of 2mm.

Sample	ANOVA p-value
58X40, Plain	6.7E-08
58X40, Matt	4.2E-08
40X30, Plain	1.4E-02
40X30, Matt	3.6E-02
58X52, Plain	4.8E-07
58X52, Matt	3.0E-09
84X70, Plain	3.3E-15
84X70, Matt	2.7E-12

Table 6.2 t-test p-value (test condition- 2mm)

The table shows the results of ANOVA. It is very clear that in each sample with the process condition there exists the variance difference. The process conditions namely scoured, bleached and dyed do affect the bending behavior.

Grey and Scoured Samples

Sample	T-Test p-value
58X40, Plain	3.4E-04
58X40, Matt	1.4E-04
40X30, Plain	1.2E-02
40X30, Matt	1.9E-04
58X52, Plain	3.2E-03
58X52, Matt	5.0E-06
84X70, Plain	2.9E-07
84X70, Matt	1.5E-06

Table : 6.3 Grey and Scoured T-Test results

The Table shows the t test results between grey and scoured condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between grey and scoured conditions of all the controlled samples.

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Grey and Bleached Samples

Sample	T-Test p-value
58X40, Plain	8.7E-03
58X40, Matt	9.6E-06
40X30, Plain	8.7E-01
40X30, Matt	2.0E-02
58X52, Plain	2.3E-03
58X52, Matt	5.0E-06
84X70, Plain	7.0E-07
84X70, Matt	2.2E-05

Table : 6.4 Grey and Bleached T-Test Results

The Table shows the t test results between grey and bleached condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between grey and bleached conditions of all the controlled samples.

Grey and 0.5% Dyed Samples

Sample	T-Test p-value
58X40, Plain	2.1E-04
58X40, Matt	1.7E-06
40X30, Plain	9.9E-02
40X30, Matt	1.9E-05
58X52, Plain	1.0E-03
58X52, Matt	8.0E-08
84X70, Plain	6.1E-07
84X70, Matt	3.8E-06

Table : 6.5 Grey and 0.5% Dyed T-Test Results

The Table shows the t test results between grey and 0.5% dyed condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between grey and 1 dyed conditions of all the controlled samples.

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Grey and 3% Dyed Samples

Sample	T-Test p-value
58X40, Plain	3.4E-04
58X40, Matt	1.8E-07
40X30, Plain	6.4E-01
40X30, Matt	2.7E-01
58X52, Plain	3.4E-04
58X52, Matt	1.0E-05
84X70, Plain	1.1E-08
84X70, Matt	4.2E-06

Table : 6.6 Grey and 3% Dyed T-Test Results

The Table shows the t test results between grey and 3% dyed condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between grey and 3 dyed conditions of all the controlled samples.

Scoured and Bleached Samples

Sample	T-Test p-value
58X40, Plain	4.5E-04
58X40, Matt	5.8E-01
40X30, Plain	1.3E-01
40X30, Matt	3.9E-03
58X52, Plain	7.6E-01
58X52, Matt	1.0E+00
84X70, Plain	6.1E-01
84X70, Matt	1.3E-02

Table : 6.7 Scoured and Bleached T-Test Results

The Table shows the t test results between scoured and bleached condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between scoured and bleached conditions of all the controlled samples.

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Scoured and 0.5% Dyed Samples

Sample	T-Test p-value
58X40, Plain	4.3E-01
58X40, Matt	2.5E-01
40X30, Plain	1.1E-02
40X30, Matt	5.6E-02
58X52, Plain	1.4E-01
58X52, Matt	6.6E-02
84X70, Plain	6.7E-02
84X70, Matt	3.2E-04

Table : 6.8 Scoured and 0.5% Dyed T-Test Results

The Table shows the t test results between scoured and 0.5% dyed condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between scoured and 0.5% dyed conditions of all the controlled samples.

6.2.2.6 Scoured and 3% Dyed Samples

Sample	T-Test p-value
58X40, Plain	2.9E-01
58X40, Matt	4.0E-01
40X30, Plain	3.2E-02
40X30, Matt	7.3E-01
58X52, Plain	3.9E-03
58X52, Matt	1.3E-01
84X70, Plain	4.1E-06
84X70, Matt	1.3E-02

Table 6.9 Scoured and 3% Dyed T-Test Results

The Table shows the t test results between scoured and 3% dyed condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between scoured and 3% dyed conditions of all the controlled samples.

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Bleached and 0.5% Dyed Samples

Sample	T-Test p-value
58X40, Plain	2.0E-04
58X40, Matt	4.7E-01
40X30, Plain	1.2E-01
40X30, Matt	1.9E-04
58X52, Plain	1.7E-01
58X52, Matt	6.6E-02
84X70, Plain	6.5E-02
84X70, Matt	2.6E-01

Table : 6.10 Bleached and 0.5% Dyed T-Test Results

The Table shows the t test results between bleached and 0.5% dyed condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between bleached and 0.5% dyed conditions of all the controlled samples.

Bleached and 3 % Dyed Samples

Sample	T-Test p-value
58X40, Plain	2.8E-05
58X40, Matt	6.4E-02
40X30, Plain	8.7E-01
40X30, Matt	5.7E-01
58X52, Plain	2.7E-03
58X52, Matt	1.3E-01
84X70, Plain	2.3E-04
84X70, Matt	2.0E-01

Table : 6.11 Bleached and 3 % Dyed T-Test Results

The Table shows the t test results between bleached and 3% dyed condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between bleached and 3% dyed

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conditions of all the controlled samples.

0.5% Dyed and 3% Dyed Samples

Sample	T-Test p-value
58X40, Plain	6.5E-02
58X40, Matt	6.2E-03
40X30, Plain	6.7E-02
40X30, Matt	3.7E-01
58X52, Plain	4.5E-04
58X52, Matt	7.6E-01
84X70, Plain	6.6E-07
84X70, Matt	6.1E-01

Table : 6.12 0.5% Dyed and 3% Dyed T-Test Results

The Table shows the t test results between 0.5% dyed and 3% dyed condition of different controlled samples. From the table it is clear that the mean value of hanging length significantly differs between 0.5% dyed and 3% dyed conditions of all the controlled samples.
From the above discussion it has been established that Auto-Plot tester is sensitive enough to show the differences between various samples.

Uniqueness Of Auto-Plot Tester

The Shirley tester is designed such that the measurement has taken when the fabric edge bends at 41.5 degree, the assumption is that the fabric bends like a cantilever.

The Auto-Plot tester has a feature of giving a real time out put of the bending of fabric at angle against length. From the Wilxoson test said earlier it is already inferred fabric movement of 1 and 2mm has agreement with Shirley tester. While 5 and 10mm differ than the test condition of 1 and 2mm and hence 1 and 2 mm is recommended.

Also it is justified in the sense that when the fabric is moved at 5 and 10mm

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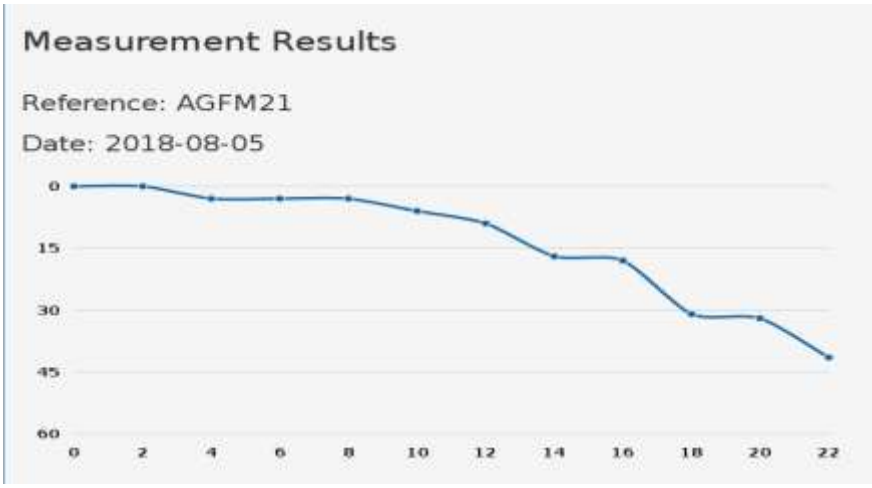
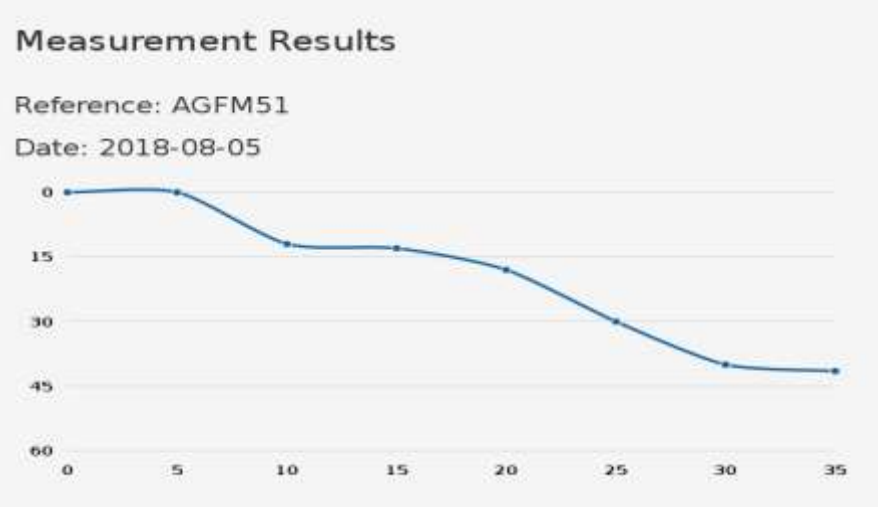
the bending angle is sensed only in steps of 5 and 10mm, thus not very useful.

As a typical example plots of 2/20's Matt with 40x30 EPI and PPI is shown below for the various conditions. The plots of all other controlled samples are given in appendix.



Graph : 6.1 Grey 2mm movement



Graph : 6.2 Grey 5mm movement

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Graph : 6.3 Grey 10 mm movement

Comparing the above three graphs recorded for 2, 5 and 10 mm, it is clear that at 5 and 10 mm plots has low discrimination compared to 2 mm. Thus test conditions of 1 and 2 mm is preferable to be employed, wherein samples can be discriminated better.

From looking at the plots it can be inferred that more flatter region indicates that the fabric has more resistance to bending in that region. This type of information is not evident in Shirley tester. Thus proves the superiority of Auto plotter.

Indeed the similar interference one can conclude when one looks at the graph carried out at other process conditions namely Scoured, Bleached and Dyed. The graphs of which are given below for only 2 mm movement.

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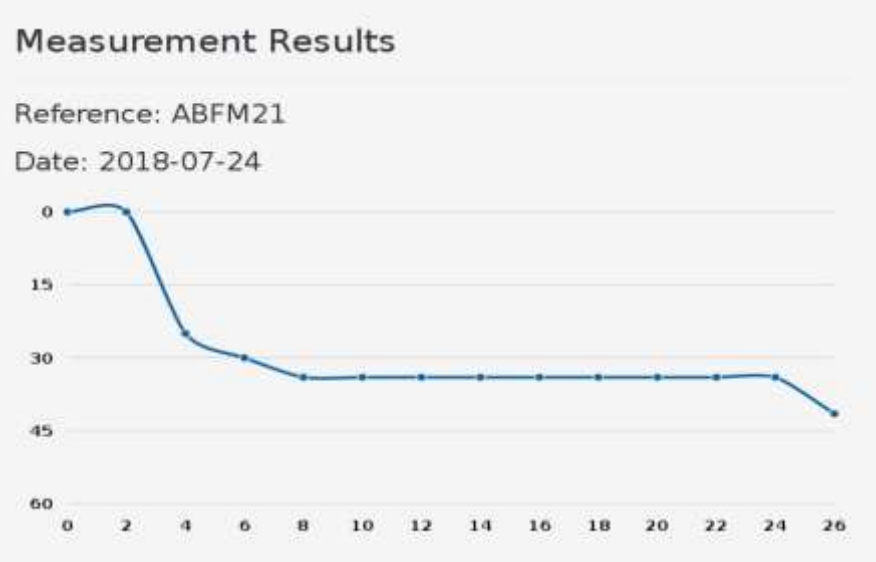
Graph : 6.4 Scoured 2mm movement



Graph : 6.5 Bleached 2mm movement

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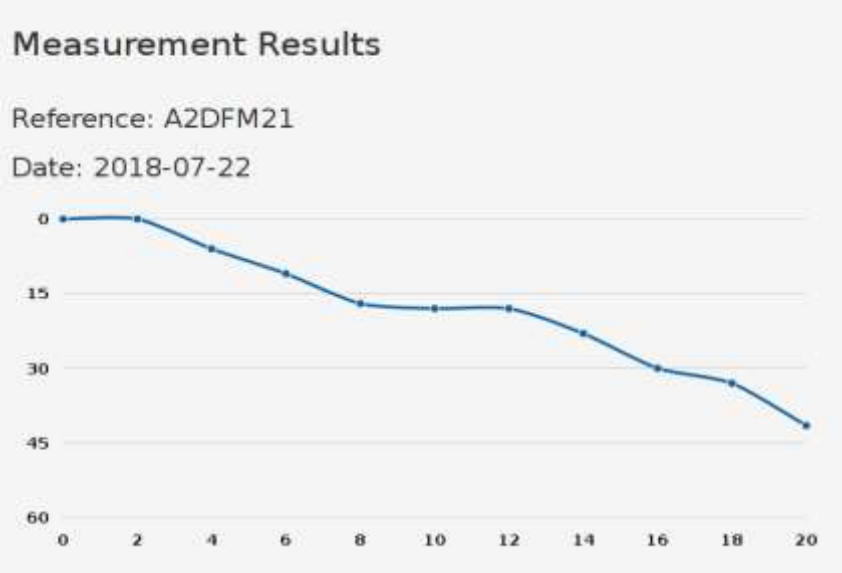

Graph : 6.6 3% Dyed 2mm movement

Compared to Grey Sample, Scoured Sample is showing more flatter region and Bleached shows much more flatter region indicating that resistance to bending is better with the scouring and bleaching for certain critical length.

Bending Modulus in Kg/Sq.mt and Single factor ANOVA

Bending Modulus in Kg/Sq.mt and Single factor ANOVA			
Process condition	2mm	Shirley	ANOVA p-value
Grey	4.14651419	3.45542849	0.84156703
Scoured	4.44314601	4.56007091	
Bleached	3.12468019	3.23242778	
3 Dyed	3.43776495	3.54986598	

Table : 6.13 Comparison of Bending Modulus

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The Bending modulus values are computed for Auto plotter and Shirley tester is not significantly different, again confirming the validity of Auto plot tester. But the advantage the Auto plot stiffness tester has explained in the above graphs which Shirley tester is deficient.

Summary and Conclusion

This Auto-Plotter has been designed and developed using sensors, hardware and operating systems, which is also very portable, To test this instrument Forty controlled samples are generated to test and to know the validate and comparability of the Auto-Plot tester with Shirley tester.

The statistical tools such as Anova, paired mean test, Wilcoxon signed rank test and multiple correlation regression are used to know the significance differences among the samples as well as between Auto-Plot tester and Shirley.

All the controlled samples results of Auto-Plot tester and Shirley are subjected to Wilcoxon signed rank test. It clearly indicates that a very good agreement between 1, 2mm results of Auto-Plot tester and Shirley. Further because of not allowing for complete relaxation of samples (fabrics) it is showing lower agreement between 5, 10mm results of Auto-Plot tester and Shirley.

In the next step results of controlled samples are tested with paired mean test. From this it is very clear that, because of different process conditions namely Scoured, Bleached and Dyed, variance difference exits. Mean hanging length of each process significantly differs from each other. As stated above the reason may be attributed different process conditions of controlled samples. The bending modulus values computed for Auto-Plotter tester and Shirley tester is not significantly different , confirming the validity of Auto-Plot tester

The results of Auto-Plot tester are comparable with Shirley tester. Auto Plot Tester has advantage of examining the intermediary behavior of samples before reaching 41.5 degree. This

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Auto-Plot tester has provision for storing the data's and further it may be electronically transmitted to other sources.

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