Fiber Quality Measurements in 2025

Axel Drieling, Faserinstitut Bremen e.V. (Bremen Fiber Institute), Bremen, Germany

Introduction: Changes in cotton quality measurements in the past 18 years

The year 2025 seems to be far away, but it is only 18 years from now. To get an impression about possible developments in 18 years of cotton measurement, it may be helpful to look at some details about testing 18 years ago, in 1989.

The currently used testing instruments can be seen in the Bremen Round Trial. Although it is certainly not representative for all testing facilities, it gives an overview based on approx. 150 laboratories and their instruments (see table 1).

Table 1: Trends in instruments participating in the Bremen Round Trial from 1989 to 2007

Property	Instrument	RT 1989	RT 2007	Trend
		%, typical	%, typical	
No.of Round Trial participants		no.=140	no.=165	
Fineness/Maturity	Micronaire stand alone	56	34	⇓
	FMT	28	8	⇓
	Gravimetrical fineness	7	4	⇓, minor
	Maturity with Causticare	8	2	⇓, minor
	Fibrograph FM	10	0	⇓⇓
	AFIS Diam./Fineness/Mat.	0	29	⇑⇑
Strength	Pressley	60	10	⇓⇓
	Stelometer	37	13	⇓
Length	Length Fibrograph	48	11	⇓
	Length Comb Sorter	10	1	⇓⇓
	Length Almeter	6	3	⇓
	AFIS Length	0	32	⇑⇑
Neps	AFIS Neps	0	39	⇑⇑
High Volume Testing	HVI - total	23	80	⇑⇑
	HVI with ICCS calibration	14	19	⇔
	HVI with HVICCS calibration	13	67	⇑⇑
	ICCS calib. of all HVI's	60	24	⇓
	HVICCS calib. of all HVI's	54	84	⇑

With a view to the percentages in 1989 and now, it can be seen that stand alone test instrument shares are decreasing drastically for all properties

- e.g. Pressley for strength
- e.g. the manual comb sorter for the length distribution

Especially methods with intense labor input are decreasing or even ceasing.

Partly, the same test methods are now integrated into a high volume testing device, like Micronaire, but the majority of properties is tested with different methods and therefore different parameters, only correlating to the formerly used parameters.

On the other hand, more complex instruments like AFIS are replacing the established and labor intensive stand alone methods

- Integrated methods measuring different properties and parameters at the same time
- Higher automation of fiber handling to reduce the influence of testers
- But also significantly higher acquisition costs

For High Volume Testing

- there is a significant increase in the share of High Volume Testing / the number of instruments (see additionally table 2)
- there is a trend towards standardization of calibration towards HVICCS calibration cottons.

Table 2: Numbers of High Volume Instruments

Year	approx. no. of instruments	*Source*
1980	24	*Schenek 1990*
1990	430	*Schenek 1990*
2000	1400	*Hunter 2002*
2007	> 2000	*estimate*

Besides the use of instruments, research on testing topics is an important input to see the developments of cotton measurement. The agenda of the Bremen Cotton Conferences in 1988 and 1990 and/or the ITMF International Committee on Cotton Testing Methods include - as a non representative choice - these topics:

- High Volume Testing
  - Utilization of High Volume Testing for classing and for trading
  - Problems with High Volume Testing
  - Measurement uncertainty and harmonization
  - Calibration of High Volume Instruments
- Maturity Testing
  - Harmonization between the testing methods
  - Reference method for maturity standards
  - Speeding up for maturity testing
- Short Fiber Content - Problems with the high variability of the data
- Stickiness testing: Introduction of the Sticky Cotton Thermodetector for routine stickiness testing
- AFIS testing - Introduction and first experience

Comparing these topics to the current situation, two instruments, which were introduced in 1988/1990, can now be seen as widely accepted and used.

- Uster AFIS for single fiber based testing of e.g. length, neps, trash, fineness/maturity
- Sticky Cotton Thermodetector

Additionally other instruments, which are less known, were introduced in the past years.

At this stage it is not necessary to give a complete overview about the current research in cotton testing. Just a few keywords will be enough to show that many research topics are still the same:

- For Short Fiber Content, there is still no solution to reduce variability

- For maturity, there is still no solution to fulfill requirements in high volume reliable testing
- Use of High Volume Test results for trading is now in progress to be widely used for commercial / trade purposes, but still did not replace manual classing.

The overview about the past 18 years of development shows that we cannot expect a quantum leap in an 18 years' period. Trends that can already be seen will be put into practice. New technology like computerization and miniaturization will certainly help to develop solutions which were not possible up to now. Instrument testing of cotton is still a challenge, and many problems addressed 18 years ago are still unsolved.

Basic Conditions

Developments in testing have to be embedded into the surrounding conditions. For this reason, the following general aspects have to be considered:

- The cotton market is a global market: This requires objective, internationally comparable/harmonized results for cotton production, trading and processing.
- The cotton price is very low, allowing only minimum costs for testing.
- Cotton is in competition with synthetic fibers, and changes given for synthetic fibers do affect cotton.
- Cotton processing is a high technology. Detailed information about the input material allows to adapt the process and to avoid insufficient product quality as well as oversized expensive quality.
- Reduced long term experience of staff in cotton processing can be covered by on-line testing and automatic process control/adaptation.
- Upcoming demands from the textile consumers require corresponding testing methods.

Requirements and Aims Given in the Cotton Value Added Chain

All developments are driven by market demands, so it is important to have a look at the different stages of the cotton value added chain in order to acquire the given demands.

In order to understand demands, a short description of the actual status has to be looked at. For High Volume Testing, the established, accepted and sufficiently reliable parameters are:

- Micronaire as a combination of fineness and maturity
- Strength
- Length, Length Uniformity
- Color Rd and +b

Other properties like Elongation, Short Fiber Index, Fineness, Maturity, Moisture Content and Trash are included in the integrated High Volume Instruments, but are not fully accepted and/or not sufficiently reliable.

Low Volume Testing is done for many properties, and there are reliable test methods for additional properties that are not included in High Volume Testing, like the staple length distribution. But it is not possible to state, which test method and which parameters are established and which are not; this is largely depending on the interests of the single users. Nevertheless there is a strong demand to test some parameters more reliably.

The reason for testing in cotton breeding is the improvement of the cotton to achieve a higher price. Testing is necessary for those properties, which can be influenced in cotton breeding and which affect the price. The aim is to measure the plant based properties, not influenced by processing. Besides the given testing, additional properties to be tested include mainly elongation and fineness in order to test the potential properties of the plants.

The reason for testing according to cotton production is to establish the monetary value of the raw material. Additional properties that should be tested in order to achieve payments based on the cotton quality are e.g. fineness, maturity, leaf content and stickiness. All testing should preferably be done on high volume testing basis to allow testing each produced bale. Additionally it will be beneficial for cotton producers to test the properties on seed cotton samples.

For cotton ginning, testing offers to control the ginning process and to optimize the fiber quality, avoiding e.g. fiber breakages by over-cleaning. Tests have to be done on those parameters that have influence on the cotton ginning and/or that can be influenced by the ginning process. Additional parameters to be tested are e.g. moisture, leaf content and size, length distribution, short fiber content, neps and seed coat fragments.

On-line testing allows best for process control. Additionally on-line testing can provide variability information within each bale. On-line testing is useful for those properties that are already tested by High Volume Instruments and for some additional parameters. Currently systems are available that measure the moisture content, fiber color and trash.

Instrument testing in classing / for trading is meant to give objective and reliable information about the cotton quality. Only those parameters may be tested that are reliable enough for trading. Results have to be given on the internationally accepted level (based on Universal Standard Material), and have to show variability which is small enough to fix properties in trade contracts. The main keywords for this are standardization and harmonization. Harmonization aims in shifting all laboratories to the same result level. At this stage, only micronaire, strength, length, length uniformity and color can be used. Future additions can be e.g. fineness, maturity, elongation, short fiber content, leaf/trash, stickiness, and moisture content. The prerequisite is to allow measuring every single bale by high volume testing. An important aim besides adding the mentioned parameters is to reduce the necessary control limits of the properties.

In cotton processing, there are many different reasons for testing, leading to different directions in testing:

- To buy cotton varieties/bales fitting to the envisaged yarn quality – based on results given by classing / given by traders
- To optimize bale laydowns based on results for every single bale, preferably without testing the bales a second time
- To assure sufficient quality of cotton as the input material during the whole processing time, without tolerating oversized quality
- To optimize machine settings based on the maximum possible information
- To automatically control the process based on continuous quality parameters given by on-line testing.

For this, requirements for test results that are given by the traders are to get harmonized results on the internationally accepted level with low variability. Test results, which are additionally generated for process optimization, do not have to follow this strict constraint. But the results have to be reliable and have to be meaningful for the process.

Additional properties to be tested for cotton processing cover all properties with influence on cotton spinning; the maximum information, meaning all important parameters with influence on cotton spinning, is aspired (as long as the costs for testing are reasonable). The most important properties are elongation, short fiber content, nep content, seed coat neps, fineness, maturity and stickiness.

Besides the average results of the properties, variability information is helpful:
- variability between single bales – to be achieved by testing every single bale
- variability within the bale – to be achieved e.g. by on-line testing
- variability in the feed sliver

A different kind of information is the variability between single fibers, given as a frequency distribution. Sometimes the average test results of fibers are not sufficient information, but the distributions do affect the process. Single fiber property distributions have to be achieved by special testing methods, which do in most cases not fulfill the requirements of high volume testing.

Finally, requirements for testing are given by textile consumers, based on their current demands. Examples are
- Oeko Tex – test of fibers and products for harmful substances / residues
- Protection against ultraviolet rays
- DNA analysis for the detection of genetically engineered cotton

The listing of the requirements from the different stakeholders does not allow a prediction of the status of testing in 2025, but allows a view on the diverse and sometimes contrary demands of the different sides. Certainly it is not reasonable to develop different testing methods for the different stakeholders, so the joint demands have to be considered for future developments.

Objectives and Outlook

A few keywords allow combining all requirements and objectives:
- More reliable testing
- Speeding up of testing
- More information: properties
- More information: variability

On the other side, there are the different directions that can be followed:

- High Volume Testing for classing purposes
- Detailed Testing / Low Volume Testing
- On-line measurements

All objectives and developments can be found in the matrix of both itemizations.

But first, a few general trends should be mentioned.

- Instruments are more and more shifting from single stand alone instruments to integrated instruments. This trend will continue.
- With reliable and accepted test results, it is not necessary to test for the same properties a second time. Hence it will be useful to test in the early stages, shifting more and more to the gin. And with on-line measurements, it is possible to achieve information about the whole bale.

Direction: High Volume Testing for classing purposes

High Volume Testing is needed for classing purposes as well as for processing, breeding and ginning. This chapter is only addressing High Volume Testing for classing purposes. The most important topics for High Volume Testing for classing purposes are the observation of the same results in every laboratory, based on an internationally agreed level, and the variability of the data. Standardization and harmonization is the central aspect for this (see below: more reliable testing). Up to 2025, some more parameters will be integrated for classing purposes:

- Short Fiber Content
- Elongation
- Trash Content, probably gravimetrically instead of optically measured
- Moisture Content
- Neps, Seed Coat Fragments
- Maturity, Fineness
- Stickiness

The purpose is not only to include them (like it is already done for some of them), but to care for reliable/reproducible results (see below: more reliable testing).

For the existing and accepted properties, it is always difficult to improve the test method, as this may affect the internationally accepted level of the results. Nevertheless, some problems are existing for the accepted parameters and have to be treated, as e.g.

- Strength and Length: Strong influence of humidity on test results
- Strength: Variability
- Color: Interference of trash color in fiber color measurement, to be solved by image analytical methods
- Color: Inclusion of redness, shift to CIELAB color coordinates using full visible range spectrophotometers

High Volume Testing is mainly designed and used for typical saw-ginned upland varieties, and problems are getting larger with long staple cottons or roller-ginned cottons. Different calibrations for upland and Pima varieties can only solve a part of the problems. Additionally the difference between both calibrations leads to inconsistencies in the area between both calibrations. These problems will have to be addressed before 2025 in order to use High Volume Testing for all cottons.

Direction: Detailed Testing / Low Volume Testing

Other properties will not be included in High Volume Testing for classing purposes. The aim is to get more information, which is necessary for processing, breeding and ginning. It may be added to High Volume Testing instruments or tested with other instruments, "high volume" is not the main criterion.

The development has to consider mainly

- Satisfactory reproducibility in each laboratory
- Obtaining of additional useful information for the user
- Reflection of the tested fiber properties, not influenced by other fiber properties
- Reduction of the necessary labor input
- Reduction of the necessary time from sample delivery to test results
- Reduction of subjective influence of operators.

Directions for detailed testing up to 2025 are:

- Testing of fiber property distributions
  - e.g. length distribution including reproducible short fiber results
- Single fiber testing
  - e.g. fiber maturity distribution
  - e.g. single fiber strength and elongation distribution
- Testing of fiber contaminants, characterized by their type and their properties
  - e.g. trash for type, size, shape, color
  - e.g. stickiness based on the different sources and sugars
- Testing of properties related to cotton processing
  - friction, wax content
  - cleanability

Direction: On-line Measurements

On-line measurement can be used in the gin and during cotton processing. In the gin, on-line measurements have already been implemented for moisture, color and trash. The most useful addition up to 2025 is fiber length and its distribution, as this is directly influenced by the ginning.

All tests should be enhanced not only to allow process control, but to give in-bale variability information that can be given as additional information to the customer. Long term development will include on-line test data for some more typical High Volume Test parameters, so that the customer will not only be informed about the average properties, but their distributions, too.

In the spinning mills, on-line measurements are very common for yarn. For process control, fiber properties can be measured at different processing stages with different results. Examples for current developments or techniques related to fiber properties are

- Detection of foreign particles and automatic separation
- Neps and trash measurements at the carding machine, which allow to control the carding process
- Waste measurement at the cleaners to control the intensity of cleaning and the amount of fibers in the waste

Other on-line measurements do not relate to fiber properties, but to the semi-finished product as the sliver, or record process parameters like temperatures, pressures, flow rates, gap lengths etc.

The aim of on-line measurements is always to control of machine settings based on the results. So any on-line test will only be developed in connection to a related machine setting. Future developments up to 2025 will e.g. focus on foreign matter.

Besides on-line measurements, there is the possibility to use at-line measurements. At-line measurements are not directly in line with the process, but form a small bypass to the process without need for a laboratory. In ginning the Rapid-Tester is used in this way, in processing, the fiber length distribution in the slivers is measured at-line [Trützschler length control].

Objective: More reliable testing

The first and main topic for reliable testing is the substitution of manual classing with instrument testing. For this, commercial practice has to shift for those properties which are already measured with sufficient accuracy and precision. The ICAC CSITC Task Force is trying to make progress in this topic. Additionally the still existing human measurements of leaf and extraneous matter have to be replaced. For 2025 the shift to instrument classing can finally be expected to be finished.

Instrument classing instead of manual classing needs globally standardized test methods. As for many properties there are no physically direct measurements available, which are at the same time fast enough for daily use, calibration material is inevitable. Up to now, there is no valid calibration material for Short Fiber Content, Fineness, Maturity, Elongation, Trash, Neps and Stickiness. Steps to be followed are:

- Development / definition of physically direct, valid reference measurements which do not need natural fiber calibration material
- Production and distribution of internationally accepted calibration cotton standards based on the reference measurements.

The second best solution, which should only be taken when the steps above are not possible, is to define a robust reference method based on indirect measurements and to control these measurements as close as possible. For 2025, it can be expected that such calibration material will be developed at least for Short Fiber Content and fineness and maturity.

Harmonization activities assure that laboratories are capable of testing reliable results on the internationally accepted level. CSITC Task Force activities are making progress on this, and it can be expected that the certification of reliable testing by the ICAC CSITC Round Trial will be widely accepted in 2025.

All test methods show a given measurement uncertainty or variability of the data. The higher the variability, the lower is the possible use of the test results. The uncertainty is sufficiently low as soon as the control limits of the test method are lower than the practically required resolution. It can be expected that improved test methods will reduce the measurement uncertainty. Additionally faster test methods will allow measuring more specimens from the same sample in the same time, and will reduce result variability therewith. Quantum leaps in reducing uncertainty can despite this only be expected with new test methods.

Table 3: Variability of HVI Data based on Single Tests
(based on CSITC Round Trial 2007-3 with 69 instruments in 52 labs)

Property	Standard Deviation	Coefficient of Variation (CV%)
Micronaire	0,09	2,3 %
Strength HVICCS, g/tex	1,4	5,0 %
Length (UHML), inch	0,017	1,5 %
Length Uniformity	0,79	1,0 %
Color Rd	1,1	1,5 %
Color +b	0,40	4,0 %
Not included due to the high variability of the data: e.g. Trash, Elongation, SFI		

Some properties that are already measured today show quite high variabilities between laboratories. This inhibits these methods to be taken for any purpose in inter-laboratory comparisons as classing. This is e.g. Trash Content, Elongation and Short Fiber Index. Nevertheless the data can be useful for single users as spinning mills as soon as the in-laboratory variability is sufficiently lower.

Influences given by the testing environment are still a large problem. Sample conditioning is one of the most important influences on strength result variability. Up to 2025 this problem will be reduced by rapid or even instant conditioning and by moisture measurement and correction. Operator influence will be more and more reduced by automatic sample preparation and testing.

The final topic for reliable measurement is to obtain meaningful information for the measured property, not influenced by measurement interactions. The well-known example is micronaire, which is reflecting fineness and maturity at the same time. Up to 2025, I expect color measurements not to be influenced by trash anymore, based on image based color measurement.

Objective: Speeding up of testing

Faster testing is necessary to allow testing of every bale for classing purposes and for processing purposes. Those properties, which are going to be enclosed for High Volume Testing, are already mentioned at High Volume Testing. Harmonization of testing will allow testing bales one time, and use the results in all next stages of the value added chain without re-testing. For this reason, testing has to be done in the early stages.

Automatic testing will allow speeding up testing and reducing the necessary labor input. Rapid conditioning or instant conditioning will reduce time for conditioning.

On-line and at-line measurements will replace some measurements being done in laboratories up to now.

Objective: More information – properties
Possible additions for High Volume testing and detailed testing are mentioned above.

Additional properties might have to be tested due to new challenges, coming from the customers' side, which might e.g. be

- Oeko Tex – test for harmful substances / pesticides
- protection against ultraviolet rays
- DNA analysis for the detection of genetically engineered cotton

Objective: More information – properties
Besides an average result for a property, representing a large amount of fibers, detailed variability information is becoming more important.

Variability between bales will automatically be covered by testing every single bale.

In-bale variability can be either achieved through intense sampling, which will not be acceptable. On-line testing at the gin will fill this gap.

Variability between fibers can be tested by appropriate testing methods or single fiber testing methods. Single fiber testing will never be High Volume Testing, but will get more important for processing. Besides length distributions, maturity, strength and elongation distributions will be tested in 2025.

Summary / Conclusions

Developments in cotton testing are driven by market demands. The various stakeholders in the cotton value added chain exhibit different requirements and aims. They can be sorted to different objectives, which are

- More reliable testing,
- Speeding up of testing,
- Testing of additional properties and achieving variability information.

High Volume Testing for classing purposes will replace manual classing and will go to 100% testing of the bales. Standardization and harmonization measures are necessary to assure reliability. Parameters like short fiber content, elongation, trash content, neps, maturity, fineness and stickiness will be added as soon as these properties can be tested reliably, including e.g. cotton calibration standards.

Detailed testing will include more processing related properties, will address contaminants, and will allow testing of fiber property distributions. Current developments prefer integrated instruments measuring several properties to stand alone instruments.

On-line testing is mainly based in the gin and in spinning. Results can be used for process control as well as for the representation of the properties and their in-bale variability.

Bibliography

Faserinstitut Bremen e.V. and Bremer Baumwollbörse:
Proceedings of the International Cotton Conferences, Bremen, (from 1990 on) and the International Cotton Testing Conferences, Bremen (up to 1988)

Faserinstitut Bremen e.V.: Results of the Bremer Baumwoll-Rundtest, 1989 and 2007

Breuer-J, Färber-C: Determination of the optimum machine settings with intelligent systems; 28th International Cotton Conference, Bremen, Germany, March 22-25, 2006

Ghorashi-H-M: New Developments in Fibre Testing; 26th International Cotton Conference, Bremen, Germany, March 13-16, 2002

Ghorashi-H-M: A Progress Report on On-line Fibre Testing; 27th International Cotton Conference, Bremen, Germany, March 24-27, 2004

Harig-H, Drieling-A: Important Fiber Properties that are not Currently Measured; ICAC Technical Seminar, Charleston, SC, October 28, 1999

Harig-H, Drieling-A: New Perspectives in Improving Cotton Fibre Quality und Processing Efficiency, Part II; World Cotton Research Conference - 2 , September 6-12, 1998, Athens, Greece

Hunter-L, Spies-A: HVI Testing of Cotton: Its present status and future prospects; 26th International Cotton Conference, Bremen, Germany, March 13-16, 2002

Shofner-F-M, Shofner-K: Cotton Classing in the New Millenium; 25th International Cotton Conference, Bremen, Germany, March 1-4, 2000