PROPERTIES OF BROKEN COTTON FIBER

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Abstract

The influence of fiber breakage on measurable length properties of cotton and resultant yarn strength was investigated by artificially inducing various levels of damage as experimental treatments upon reference cottons. Some of these materials were prepared in sufficient quantity to allow pilot spinning studies for yarn properties (reported separately). The degree of damage was indexed by the Quality Factor or "Q" statistic (mass fraction of unbroken fibers). It was found that the theoretically predicted response of length parameters to breaking damage differed depending upon whether the effective breaking gage length (spacing between successive breaks) was: (1) fixed or random; (2) greater or less than the length of the longest fibers in the distribution; and: (3) a function of the length of an individual fiber being broken. The experimental data available to date have been consistent with these predictions.

Background

Mechanical processing is an essential part of modern, automated bale production and textile mill utilization of cotton fiber. The machine-fiber interactions intrinsic to harvesting, ginning, cleaning, preparation, and textile yarn spinning all involve some breakage of fiber. Robert and his co-workers (Robert 1991; Robert and Blanchard 1991; Robert *et al.* 1994) have shown that a model of fiber breakage can be used to track changes in cotton fiber length distributions. The economics of cotton production and textile processing technology dictate that the trade-off of inevitability of cotton fiber damage against the necessity to aggressively manipulate the fibers into usable textile forms must be stringently optimized. Better tools are required, however, for measurement and evaluation of fiber damage to keep up with rapidly changing technology and economics. Since it is crucial that cotton mechanical processes be absolutely optimized, Robert has suggested that the Breakage Model technique can be used to derive a length quality factor, ***Q***, defined as the mass fraction of unbroken fibers for any cotton at a given stage of processing, and that ***Q*** might be used as an index of damage in calculating trade-offs of processing aggressiveness *versus* damage. In this report, theoretical and experimental properties of cottons having controlled levels of damage in the treated feed-stock were investigated. Pilot spinning results from some of these well-characterized materials are given in a companion report (Price *et al.* 1997).

Objectives and Approach

This work was part of a study designed to investigate the way in which cotton's processing behavior depends upon the amount of fiber breakage in the raw stock. Generally, the approach was to establish for each experimental cotton a uniform research substrate in the form of combed sliver, to impose regulated levels of fiber breakage upon this control by cutting the sliver at known gage lengths, to re-process the variously damaged cottons back into a form resembling raw stock, and then to process this stock into yarn in the research textile mill. This part of the study has the objective of characterizing the properties of the reference cottons, the breakage treatments, and the partially broken fiber, so as to understand the way in which breaking damage is manifested as changes in the traditionally measured fiber properties. The purpose of processing each cotton initially to drawn sliver was to provide a homogeneous and well-aligned reference state. Mass-biased fiber length distributions of drawn sliver can be manipulated to an approximately symmetric (Gaussian) shape by an appropriate combing process. Thusly the length profile of each combed sliver becomes analogous to the length distribution of a hypothetical reference distribution, called a "paragon" distribution (Robert 1991). Breakage was applied to the combed sliver through the approach of cutting the sliver transversely at a locations equally spaced along its length. This controlled degradation of the length properties was used as a simulation of fiber breakage during fiber processing as part of bale production. One objective of this design was to achieve a complete mass balance, since no fibers or fiber fragments were taken as waste in cutting. Length distributions of the broken fiber were tracked to reveal the impact of damage on fiber properties.

Cotton Production and Ginning

Four different types of cotton were used in this study. All were produced from commercial seed with normal growing practice and harvested in a routine manner. Ginning was performed under controlled conditions at the USDA cotton ginning laboratories. The four cotton types were:

Pima: irrigated, spindle-picked, extra-long-staple cotton, grown in New Mexico and ginned at the USDA ginning laboratory in Mesilla Park, NM, with standard ginning methodology consisting of air drying without heat, a six-cylinder inclined cleaner, two stick machines, a second six-cylinder inclined cleaner, the gin feeder, a rotary knife roller gin, and two stages of lint cleaning.

Acala: irrigated long-staple upland cotton grown in New Mexico, machine harvested, and ginned at the USDA ginning laboratory in Mesilla Park, NM. The cleaning and ginning machinery sequence consists of two six-cylinder

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inclined cleaners, one stick machine, with no drying for seed cotton cleaning, a saw-tooth gin stand, followed by two stages of saw-type lint cleaning machines before baling.

Delta: medium-staple, southern upland cotton, rain-grown in Mississippi, spindle-picked, and saw-ginned at the USDA ginning laboratory at Stoneville, MS.

West Texas: short-staple upland, stripper-harvested cotton, produced in the Texas Plains area and saw-ginned at the USDA ginning laboratory in Lubbock, TX.

Standard machinery sequences appropriate to the particular cultivar were used for ginning all of the experimental cottons. Bales were gin compressed for transportation to the research mill. HVI fiber properties of the four bale cottons are given along with further information on downstream processing in a companion report (Price *et al.* 1977).

Mill Processing

Combing

At the USDA Southern Regional Research Center (SRRC), New Orleans, LA, the bales of experimental material were opened, cleaned, carded, and processed into combed sliver under controlled conditions in the SRRC Textile Processing Laboratory. Standard machinery sequences were used with appropriate adjustments for each cotton. The SRRC greige process line began with hopper feed to a six-cylinder step cleaner, followed by a fine opener, condensor, and demand-controlled automatic chute feeder. Cotton metered out by the feeder was conveyed pneumatically to the card chute. A Crosrol Mark IV® single cotton card was used to manufacture 55-grain/yard carded sliver, which was doubled six times and first-drawn to 50 grains/yard. The breaker-drawn sliver was doubled by 48 into a Whitin lapper. The lap was combed by a Whitin model J6 machine at a speed of 150 nips/min to produce 50-grain/yard combed sliver. The combed sliver was doubled by six and finisher-drawn into 55-grain/yard sliver, which was used as the reference substrate (or "top") for the experimental cutting.

Cutting

Automated mechanical cutting has a production rate sufficient to allow the practical preparation of sample sizes large enough for spinning trials as well as laboratory testing. For this reason, a commercial tow-cutting machine (model FJS-72E Universal Cutter, F.J. Stokes Pharmaceutical & Chemical Equip. Co., Philadelphia, PA) was used to mechanically damage the combed sliver. In this machine, cotton sliver is fed by conventional feed rolls over a feed plate into the nip of the plate and a rotating knife. Combed sliver was doubled by four into the cutter. The product of this rotary cutter was tufts, or cut cotton "tops." All of the cut tops in a single treatment for a particular cotton were cut to the same length, which was determined by the nominal gage setting of the machine. Cut tops from a cotton at one specific cutting length were collected for blending into an average sample representing that particular gage for that cotton.

Gage Length

In this particular cutting machine, the nominal setting of cutting gage is the product of the surface speed of the feed rolls and the rotational period of the cutting blade. This is controlled by a continuously-adjustable clutch, which allows continuous selection of a nominal setting anywhere within the entire range of the machine. The gage length cannot be set to an exact value, however, without some trial and error, as would be the case if the transmission were geared. So although nominal gage settings were used to set up the machine for each desired cut, strips of paper were fed into the cutter along with the sliver. The actual value of cutting gage length could be confirmed by the average measured length of the paper clippings. It was found that the range of gage lengths can be doubled by removing one of the two rotary knife blades. Thusly the tow-cutting machine was capable of cutting gages from approximately 0.5 inch to 6.5 inch. Samples were mechanically cut in this study at eighteen different gage lengths between 0.5 inch and 5.0 inch. The uncut sliver (a control representing an infinite cutting gage) and a 10-inch cut made manually with a paper cutter constituted the nineteenth and twentieth treatment for each cotton.

Laboratory Testing

Sample Preparation

Cut tops did not represent a natural state for raw cotton fiber. Some sort of blending process was necessary to restore the combed and cut fiber to a more usual state of entanglement and randomization before small specimens could be used for laboratory testing of length distribution. Samples of cut fiber were processed, therefore, through three passes of a Custom Scientific Co. model CS-45 Mechanical Cotton Blender. The uncut (control) treatment was blended in the identical fashion. Because the cut tops from the shorter-gage cuts tended to be yanked out of the nip of the feed rolls by the fillet wire of the main cylinder in clumps rather than to draft evenly over the feed plate, the short-cut materials proved especially difficult to blend. It was essential for the operator to carefully open the cut tops by hand in the delivery chute in order to obtain satisfactory dispersion over the feed plate. The output from the blender was a combed, cut, and blended ten-gram lab sample, which was removed from the main cylinder wire in the form of a cylinder mat (batt) rolled into the form of a biscuit. This batt was then sub-sampled to obtain specimens for the measurements of length distribution.

Measurement Techniques

Length properties were determined for laboratory specimens taken from the blended batts. The Peyer Almeter length measuring system was used on all cutting treatments. The

Almeter system consists of two parts: a Fibroliner FL-101 automated fiber alignment machine, and an AL-101 (Almeter) capacitive measuring instrument. The FL-101 produces a tapered beard having all the fibers aligned on one end. The AL-101 passes the tapered beard through the capacitor gap in an a.c. sensing circuit to measure the (dielectric) density of the beard down its length. This signal was proportional to the cumulative length distribution, and was used as the basis for calculation of the differential length distribution and number-biased distributions, from which the fiber statistical properties were computed. Data were obtained separately for three beards from each batt. Results were printed out individually from each beard. Additionally, the mass-biased length distributions were retrieved manually from the keyboard in 1/20-inch increments. The experiment was replicated three times, with separate blendings for each treatment.

Theory

A theoretical model of fixed-gage mechanical cutting was developed in detail. This model essentially treats the cutting process as a mathematical transformation between an initial length distribution and a final length state. As in the randomly-spaced cutting model (bale production model; Robert 1991), the location of a particular breaking event over the length of a fiber was random. In the fixed-gage case, however, the locations of adjacent breaking (i.e., cutting) events were not random, but rather were spaced exactly one gage length apart. This leads to special conditions in tow cutting.

For instance, in the range of fiber length wherein the gage length, g, is greater than the fiber length, L, there can be only one cut or no cut of a particular fiber in fixed-gage cutting. In randomly-spaced cutting, however, there still can be zero, one, or multiple cutting locations falling on the extent of a single fiber. This is true even though the characteristic (average) gage length is the same as in the fixed-spaced example. In both cases, the average probability, $p(L)$, of a cut for fibers of length L cut at cutting gage length g is given by: $p(L) = L / g$. This is the same as $p(L) = b \cdot L$, where b is the breakage probability density. In addition to being the average value, $p(L)$ is also the probability that any *specific* fiber in length class L will be cut in a long-gage, fixed-spaced cutting process. By comparison, the probability of a cut for a specific fiber in the variable-gage, random-breakage model is governed by Poisson statistics. In fixed-gage cutting, the probability of a specific fiber remaining unbroken is less than in random-gage breakage, even though the average number of cuts per fiber is the same. The difference is made up by the Poisson incidence of multiple breaks on some portion of the fibers in the variable-gage case.

In the short-gage range of fiber length where g is smaller than L, both fixed-gage and random-gage breakage were capable of producing multiple breaks of the same fiber. For instance, if L was greater than twice the value of g, then there must be at least two fixed-gage cutting locations on the fiber, resulting in at least three fragments. If L was between g and $2 \cdot g$, then there could be either one or two fixed-gage breaks per fiber, with either two or three fragments. Expressions for calculating the associated probabilities have been worked out by Robert. In the present work, this model was used to calculate predicted distributions resulting from the fixed-gage cutting of a parallel random tow of cotton having a mass-biased Gaussian length distribution. The normal distributions approximated by the combed cotton slivers were used for input to the calculations. The parameters of the normal distributions were taken to be the measured mean and standard deviation of the combed sliver mass-biased length distributions. The breakage mechanism assumed an ***a priori*** value of breakage probability density, given by: $b = 1 / g$, the reciprocal of the known cutting gage length.

Results and Discussion

Table I lists the measured properties (mean and standard deviation) of the "pseudo-paragon" distributions, along with the corresponding values of other common length properties calculated from the distributions. These distributions were chosen to match the centroid and sigma of the Almeter data for the uncut combed sliver. They were referred to as "pseudo"-paragons because they do not represent the origin of real seed lint distributions. Rather, they were close approximations of (uncut) combed sliver length profiles. The close correspondence is shown by how close the "purity" coefficient given in Table I is to 100%. Length purity is defined herein as equal to the square of Pearson's product-moment correlation coefficient for correlation of the experimentally measured mass-biased length distribution with a Gaussian distribution having the same mean and standard deviation as the measured distribution. It is a measure of the conformity of the measured distribution with a Gaussian. The values of length purity ranged from 98.3% to 99.5%. These pseudo-paragons can reasonably be used as a model to represent relatively undamaged reference distributions for the Breakage Model. Cuttings of a pseudo-paragon at different gage lengths constitute a model of bales of identical genetic and cultural origin having different length profiles due to differences in processing damage during production. Because all other factors were held constant, and the cutting was a "saved-ends" process (i.e., one having complete mass balance), these treatments differ *solely* in length properties.

Experimentally measured fiber properties resulting from the fixed-gage cutting treatments as measured by Almeter were given in Table II. One striking feature of the Almeter statistics is that as the cutting gage was decreased toward the lower limit of cutting gage investigated in this study (g = 0.50 inch), the distributions did not exhibit a strong cap at the cutting gage. At that minimum cut gage length (confirmed by the length of the cut paper strips), the values of ML_M were all greater than 0.5 inch. A perfectly efficient cutting and measurement process would be expected to result in all fibers being measured as short as or shorter than g. So at g = 0.5 inch, **UQL** and **ML** should both be less than (but almost equal to) 0.5 inch. In fact, the values of ML_M all exceed 0.50 inch (UQL_M exceeds 0.60 inch) for all four cottons. The presence of very long fibers was indicated by the values for the longest 1% of fibers by number bias ($L_N 1\%$), which all exceed 1.0 inch. Direct examination of the cut fibers confirmed the presence of fibers longer than the cut gage.

There were three possible classes of explanations for this apparent cutting inefficiency. The first possibility is crimp. In this scenario, fiber hooks or cross-lay in the combed sliver combine to give a substantial fraction of fibers a projection in the machine direction of less than g for fiber segments (or whole fibers) whose actual length was much greater than g. A second class of explanation was based on end-gripping effects. It is known that the efficiency of gripping a fiber decreases at the tips. This is because of the need to exert a clamping force over a finite length of the fiber, particularly for gripping by transverse compression in a highly-aligned assembly. The effective gripping length, δ, is the extent over which a gripping pressure must be applied in order to generate a force sufficient to hold the fiber firm against slippage during application of the stresses associated with the breaking (in this case, cutting) event. Since the tow cutter has a nipping point under the feed rollers, and another nipping point at the edge of the cutting plate, end-slippage effects may possibly occur. A general result of slippage due to end-gripping failure is that, in effect, since the fiber tips do not contribute fully to the length, breaks normally occurring near the ends will not be observed. This means that the length distribution of the damaged (cut) fibers will be longer than otherwise expected based solely on the cutting length. A third explanation was simply that there was a minor inefficiency in the tow-cutting machinery itself that leads to incomplete severing of the tow. An example of this would be a dynamic misalignment of the knife and cutting plate which allows a slight gap across part of the kerf during passage of the blade over the edge of the plate. In cutting a tow having finite thickness, part of the cross-section of the tow might be compressed into the gap and not subjected to a sharp enough nip of the knife against the plate to make the cut. Incomplete cutting would occur, perhaps explaining the presence of some fibers which were several times the length of the cut gage. Double-length fibers are frequently observed in many types of textile tow-cutting processes.

In this paper, all of the cutting inefficiencies were incorporated into the tow-cutting model through the theoretical mechanism of a gripping length. The value δ = 0.20 inch was used for all of the calculations of cut fiber properties. Although this will take the cutting discrepancies into account adequately for the purpose of numerically predicting the cut sliver length properties, it does not represent a determination that slippage due to a failure of end-gripping was the real cause. Further investigations would be required to distinguish between the three options described above, or to identify other possible causes. It is clear, however, that the particular alignment and tow-cutting process described herein was not as precise or simple to model as might be expected, nor was it even approximately perfect in its application.

The behavior of the experimental values of mass uniformity, $U_M = ML_M / UQL_M$, versus the breaking probability density, b, for all four cottons, as determined by Almeter, was roughly similar (see Table II.a through II.d). The initial value dropped steeply with a small amount of damage (low b, long g range), was relatively flat across a middle range of damage intensity (moderate b, with g longer than the staple length), and increased with heavy damage (high b; where g was shorter than the staple length. This implies that uniformity statistics were weak indicators of relative damage, particularly in the range of moderate damage. In fact, since textile processes can be characterized by a spectrum of cutting gages rather than the fixed (single, or pure) gage used in this experiment, there is the possibility that uniformity statistics may not respond to complex processing damage in an interpretable fashion at all. The measured response of the length parameters to cutting damage was in very good agreement, however, with the behavior expected from the Breakage Model.

Conclusions

(1) The particular combing process described here tended to return the mass-biased fiber length distribution to a more symmetric shape closely approximating a Gaussian distribution.

(2) Imperfections in the cutting process were pronounced for the particular tow cutting process used. It was not determined whether the shortcomings were due to fiber gripping, crimp, cutting inefficiency, or their combined effect.

(3) Cotton slivers whose mass-biased length distributions were approximately normal, and which were cut at progressively shorter gage lengths produce experimental cotton treatments having systematic variation in fiber length properties across a wide range from uncut to very heavily damaged. Because of the complete mass balance in the experimental design of the cutting (no fibers lost as waste), the treatments within a cotton should not vary in average non-length properties.

(4) A "saved-ends" fiber-breakage model of the sliver-cutting process was able to accurately and precisely predict the length properties of the cutting treatments, based only upon the value of the centroid (ML_M) and standard deviation (σ_M) of the uncut combed sliver (pseudo-paragon) by Almeter, and a knowledge of the effective gripping length, δ = 0.2 inch and actual cutting gage, g.

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Notes

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Table I. Properties of the uncut combed cotton sliver "pseudo-paragon" fiber length distributions.

Fiber Length Property	Cotton Type			
	Pima	**Acala**	**Delta**	**West Texas**
Mass Centroid (inch)	1.231	1.011	0.990	0.943
Mass Std. Dev. (inch)	0.334	0.307	0.294	0.270
UQL_M (inch)	1.456	1.218	1.188	1.125
U_M (%)	84.5	83.0	83.3	83.8
CV_M (%)	27.1	30.4	29.7	28.6
SFC_M (%)	1.4	4.8	4.7	5.0
ML_N (inch)	1.110	0.870	0.862	0.834
UQL_N (inch)	1.358	1.109	1.088	1.039
U_N (%)	81.7	78.4	79.2	80.3
SFC_N (%)	5.2	14.4	13.6	13.0
UHML (inch)	1.466	1.225	1.195	1.131
UI (%)	84.0	82.6	82.9	83.4
Length Purity (%)	98.3	99.5	99.1	99.0

The pseudo-paragons are normal distributions, chosen to match the centroid (**ML_M**) and standard deviation (**σ_m**) of the uncut combed slivers, as measured by Almeter.
UQL = upper quarter length
U = mass uniformity = **ML / UQL**
CV = coefficient of length variation.
SFC = short fiber content (fiber fraction shorter than 0.5 inch)
UHML = upper-half mean length (number mean of upper half by mass)
UI = uniformity index = **ML_M / UHML**.
The subscripts **M** and **N** denote mass-biased and number-biased statistics, respectively.

Table II.a. Properties of the cut Pima sliver (mass-biased).

Gage (inch)	UQL (inch)	ML (inch)	CV (%)	SFC (%)	U (%)	Q (%)
inf.	1.434	1.231	27.1	0.9	85.8	100.0
10.00	1.397	1.157	33.1	5.1	82.8	91.7
5.00	1.300	1.043	37.0	9.6	80.2	83.4
3.33	1.337	1.080	35.7	7.6	80.8	75.0
2.50	1.253	1.003	36.3	9.8	80.0	66.7
2.00	1.233	0.987	36.4	9.7	80.0	58.2
1.67	1.203	0.980	35.7	9.3	81.5	48.6
1.43	1.103	0.870	38.5	16.6	78.9	37.7
1.25	1.030	0.813	37.6	18.6	78.9	27.7
1.11	1.017	0.817	33.7	15.0	80.3	19.8
1.00	0.967	0.763	37.3	21.3	78.9	14.1
0.91	0.943	0.753	38.3	22.3	79.9	10.2
0.83	0.850	0.683	37.6	26.8	80.4	7.5
0.77	0.837	0.697	36.5	24.1	83.3	5.6
0.67	0.767	0.643	36.8	29.5	83.8	3.4
0.63	0.727	0.617	39.0	33.8	84.9	2.7
0.59	0.680	0.580	38.0	38.8	85.3	2.2
0.57	0.680	0.583	40.2	40.4	85.7	1.8
0.53	0.663	0.577	36.5	39.8	87.0	1.5
0.50	0.670	0.567	39.8	44.6	84.6	1.2

Table II.b. Properties of the cut Acala sliver (mass-biased).

Gage (inch)	UQL (inch)	ML (inch)	CV (%)	SFC (%)	U (%)	Q (%)
inf.	1.220	1.011	30.4	4.4	82.9	100.0
10.00	1.207	0.988	33.2	7.4	81.9	93.7
5.00	1.158	0.932	34.9	10.8	80.5	87.5
3.33	1.150	0.927	35.4	11.2	80.6	81.2
2.50	1.113	0.897	36.5	13.1	80.6	74.9
2.00	1.074	0.854	37.0	15.5	79.5	68.6
1.67	1.052	0.846	36.0	14.8	80.4	62.0
1.43	1.003	0.800	37.5	18.6	79.8	54.2
1.25	0.942	0.747	37.7	22.6	79.3	45.5
1.11	0.897	0.710	38.7	26.4	79.2	36.7
1.00	0.893	0.710	38.4	25.8	79.5	29.1
0.91	0.832	0.665	38.4	30.8	79.9	23.0
0.83	0.797	0.640	39.1	33.4	80.3	18.2
0.77	0.786	0.624	40.2	36.9	79.4	14.5
0.67	0.688	0.567	38.4	44.3	82.4	9.5
0.63	0.651	0.539	39.0	49.6	82.8	7.9
0.59	0.667	0.551	37.8	45.9	82.6	6.6
0.57	0.690	0.567	38.8	47.6	82.2	5.5
0.53	0.654	0.541	38.2	49.1	82.7	4.7
0.50	0.624	0.521	39.4	53.7	83.5	4.0

Table II.c. Properties of the cut Delta sliver (mass-biased).

Gage (inch)	UQL (inch)	ML (inch)	CV (%)	SFC (%)	U (%)	Q (%)
inf.	1.188	0.990	29.7	5.1	83.3	100.0
10.00	1.083	0.860	37.1	14.8	79.4	94.1
5.00	1.083	0.863	36.0	14.1	79.7	88.1
3.33	1.057	0.853	34.9	13.9	80.7	82.2
2.50	1.057	0.853	34.2	13.2	80.7	76.3
2.00	1.063	0.860	34.7	12.9	80.9	70.4
1.67	1.013	0.817	35.3	15.8	80.7	64.2
1.43	0.957	0.767	35.8	19.4	80.1	57.1
1.25	0.930	0.747	35.6	20.3	80.3	48.7
1.11	0.917	0.743	34.3	19.5	81.0	39.9
1.00	0.867	0.687	36.4	26.3	79.2	32.0
0.91	0.860	0.697	34.7	23.7	81.0	25.3
0.83	0.810	0.653	35.5	28.4	80.6	20.0
0.77	0.783	0.653	35.0	27.2	83.4	15.9
0.67	0.703	0.600	34.9	33.8	85.3	10.3
0.63	0.673	0.583	34.6	36.4	86.6	8.5
0.59	0.667	0.580	35.6	38.4	87.0	7.0
0.57	0.647	0.553	37.3	44.7	85.5	5.9
0.53	0.640	0.553	36.0	44.8	86.4	4.9
0.50	0.630	0.537	36.0	48.9	85.2	4.2

Table II.d. Properties of the cut West Texas sliver (mass-biased).

Gage (inch)	UQL (inch)	ML (inch)	CV (%)	SFC (%)	U (%)	Q (%)
inf	1.117	0.943	28.6	5.3	84.4	100.0
10.00	1.060	0.863	34.7	12.9	81.4	94.5
5.00	1.027	0.833	34.4	14.3	81.1	89.1
3.33	1.030	0.833	33.8	14.3	80.9	83.6
2.50	1.023	0.833	33.9	13.6	81.4	78.2
2.00	1.020	0.833	33.0	13.0	81.7	72.7
1.67	0.990	0.790	35.9	17.9	79.8	67.2
1.43	0.923	0.730	37.3	23.4	79.1	61.0
1.25	0.903	0.720	38.0	24.7	79.7	53.4
1.11	0.867	0.697	37.0	26.0	80.4	44.8
1.00	0.847	0.680	36.6	26.8	80.3	36.3
0.91	0.823	0.660	36.5	29.1	80.2	28.9
0.83	0.790	0.633	38.2	34.0	80.1	22.8
0.77	0.763	0.610	37.8	35.8	79.9	18.1
0.67	0.737	0.597	38.8	39.8	81.0	11.5
0.63	0.680	0.557	39.6	46.4	81.9	9.3
0.59	0.657	0.547	39.4	48.6	83.3	7.6
0.57	0.663	0.550	38.8	47.7	83.0	6.3
0.53	0.627	0.517	37.8	53.6	82.5	5.2
0.50	0.607	0.510	38.5	55.4	84.0	4.4