β -Gauges for Textile Industry

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Introduction

Radiation, after passing through a material, declines in strength in proportion to the thickness of the material and according to a certain law. This property of radiation has been utilized in gauges for the measurement of the thickness of various materials, including metal sheets, paper, rubber, plastics and tobacco. However, radiation-using thickness gauges have not been used in the textile industry often, and there are not many published technical works on the subject.⁽¹⁻⁵⁾ The few published technical works deal mainly with these subjects:

- (1) Measurement of Linear Bodies
 - (a) Measurement of sliver evenness.
 - (b) Measurement of denier variations in the tow of a man-made fiber.
- (2) Measurement of Plane Bodies
 - (a) Measurement of area density of fabrics.
 - (b) Measurement of the amount of wet pick-up of fabrics.
 - (c) Measurement of amount of wear of fabrics.
 - (d) Control of heat-setting of warp-knit nylon fabrics.

The measurements and control just mentioned are made with apparatus which use β -ray. Such apparatus are, therefore, commonly called β -gauges. The present article considers several problems on measurement and control by these apparatus.

1. Measurement of Linear Bodies

1-1. Measurement of Sliver Evenness

β -gauges have been used by experts, Japanese and foreign, in their fundamental experiments⁽⁶⁻¹¹⁾ on methods to measure sliver evenness. Figure 1 is model SKS sliver evenness tester using β -ray. Now a service β -gauge⁽¹²⁾ has been produced experimentally.

When several fiber bundles are measured with a β -gauge, their measured values differ according to the kind of compression the fiber bundles receive from the gauge, even if they are equal in thickness. This phenomenon is the so-called bulk effect, which must be avoided. Therefore, fiber bundles for measurement with a β -gauge must have an equal area in their

cross sections. The values shown by measurement with a β -gauge depend on the shape of the slot of the gauge.⁽¹¹⁾ However, β -gauges for sliver evenness measurement require hardly any further discussion, because a mechanical or an electrical measuring instrument measures sliver evenness so much more easily and accurately that β -gauges are unlikely to be used for the purpose.

1-2. Measurement of Denier Variations in Tow of Man-made Fiber

A β -gauge is, at present, the only practical instrument to measure these denier variations. The reason is that the tow of some man-made fiber shows short-term variations in denier which are difficult to measure by the conventional sampling method.

Short-term variations occur in the first stage of production of man-made fibers. They are not large enough to cause mechanical troubles in the spinning processes, but indirectly influence the physical properties of products made of tows having short-term denier variations.

A β -gauge makes it possible to measure short-term denier variations in tows. It has facilitated inquiry into the relations between denier variations and the concentration irregularity of spinning solution or irregularity of rotations of the extrusion pump and the take-up roller.

Fig. 1. Model SKS sliver evenness tester using β -ray.

Various methods to treat fibers while they are still to have been devised and some of them put into practical use. A β -gauge can be used to measure fibers treated while they are to and to control the amount of wet pick-up of to during such treatment.

2. Measurement of Plane Bodies

Generally, cloths, whether treated or untreated, are easier to measure in thickness with the use of β -gauges than are linear bodies, such as tow and slivers.

2-1. Structural Difference between Cloths and its Bearing on Measurement with β -Gauge

Readers will probably ask a question about measuring the area density of a fabric with a β -gauge. Do fabrics differently constructed and made of different raw materials differ in measured values?

In the measurement of the area density of a fabric, only the counting rate for β -ray shows on the scale of a β -gauge. To get the area density of a fabric from the counting rate, we must ascertain the relation between the area density of the fabric and the counting rate for β -ray preparatory to measuring the area density.

Experiments have established approximately that the mass absorption coefficient of β -ray by a material is dependent on the ray's energy but independent of the kind of the material. Accordingly, different materials of the same weight per unit area, when measured with the same β -gauge, should show the same value. In theory as well as in more precise experiments, however, the measured value differs. Why?

The decline in the intensity of β -ray is induced by the interaction of β -ray and electrons around an atomic nucleus. Therefore, the degree of the interaction differs with the number of the electrons of an atom. Furthermore, the relation between the mass absorption coefficient of β -ray by a textile fiber and the mass of that fiber is as follows: The ratio of the sum of neutrons and protons and the number of electrons is 1:1 in hydrogen (not hydrogen isotope); about 2:1 in other atoms. In other words, the hydrogen atom has the highest electron density of all atoms.

Therefore, the larger the number of hydrogen atoms in molecules constituting a textile fiber, the higher the electron density of the fiber. This means that the mass absorption coefficient of β -ray by a fabric depends on the number of hydrogen atoms in molecules constituting a

textile fiber.

However, because measurement with a β -gauge is made in such a way as to detect deviation from a standard value, the thickness irregularity of every fabric can be *approximately* given by one curve showing the relation between the thickness and the counting rate of β -ray. Some fabrics made of the same raw material and having the same weight per unit area differ in yarn count and in the number of yarns per unit area. Hence the question: How does the mass absorption coefficient of β -ray by a fabric vary with the difference in yarn count and in the number of yarns per unit area?

To find an answer, we investigated the relation between the mass absorption coefficient of β -ray by cotton fabrics differently constructed and their weight per unit area. Having ascertained the relation, we drew a relation curve for each fabric; all curves turned out to be the same. This result leads us to think that the structural difference between fabrics has a negligible bearing on the mass absorption coefficient of β -ray by a fabric.

The coefficient of mass absorption of β -ray by laps and slivers differs fairly largely with the difference in the degree of the "bulk effect." However, most fabrics (except pile cloth) being thin, the mass absorption coefficient of β -ray by a non-pile fabric always shows nearly the same value if measured in such a way as to prevent the deviation of the path line of the fabric, i. e., in such a way as to keep the position of the fabric between the β -ray source and the detector the same. This is proved by our experiment in which both sides of a fabric were measured and showed the same values.

2-2. Response Characteristics of β -Gauge

Preparatory to continuous measurement of the thickness of a material, we must get the response speed of the β -gauge. Generally, the intensity of β -ray is measured by an apparatus designed to have a several-second time constant so as to reduce statistical variations in the intensity of β -ray received into the apparatus. Such statistical variations decrease with an increase in the intensity of radiation. β -ray can be easily sealed up and is, therefore, sometimes used as a source of strength several hundreds mC in intensity for the apparatus. A β -gauge also has a strong merit in the fact that the resolving time of the ionization chamber (the gauge's detector) is very short and that the counting rate of β -ray can be set at a large rate.

A β -gauge with a five-second time constant usually shows 63% of the actual value five seconds after the beginning of radiation and shows the actual value 15~20 seconds thereafter. Therefore, a β -gauge does not show the actual value unless the duration of radiation in one place exceeds 20 seconds, or unless the material being measured is uniform in thickness in an area enough large for more than 20 seconds' one-way run over the gauge.

This means that we must get the relation between the gauge's time constant and what is called "the changing ratio of irregularity" of the material before it is put on the gauge.

In measuring a plane body, a β -gauge runs to right and left and vice versa on the body, while the body runs from the top to the bottom of the gauge or vice versa. Therefore, both the gauge and plane body must be moved at suitable speeds.

2-3. Examples of Measurement with β -Gauge

2-3-1. Measurement of area density

We measured continuously, with a β -gauge, the area density of cotton sateen, twill and poplin woven on different looms. From the thickness irregularity curves thus obtained, we found that each loom produced thickness irregularity peculiar to itself, but found no thickness difference by reason of the structural differences between the fabrics.

To get numerically the respective thickness irregularities of the fabrics just mentioned from the results of the continuous measurements, we used the frequency distribution method⁽¹³⁾ and the method usually used on the Uster sliver evenness tester.

Both methods showed similar numerical results. The fabrics were then desized and their thickness irregularities measured by the same two methods, with the result that their thickness irregularities were found to have increased. In other words, a sized fabric is subject to less thickness irregularity.

2-3-2. Measurement of wet pick-up of fabric

We measured, with a β -gauge, the amount of the wet pick-up of fabrics on a padder. Several continuous measurements were made by varying the pressure of the squeezing rollers of the padder without applying a treating agent to the fabrics experimented with. The difference in

the pressure of the squeezing rollers did not change the respective thickness irregularities of the fabrics.

Next, several continuous measurements were made by changing the pressure of the squeezing rollers of the padder and by applying a treating agent to the fabrics—and the amount of the wet pick-up of these fabrics was measured.

The experiments mentioned in the foregoing two paragraphs showed that a β -gauge would detect the long-term irregularity of the amount of the treating agent if it exceeded $\pm 2.5\%$.

Let it be added that the mass absorption coefficient, strictly speaking, varies with the kind of treating agent used—water, dyestuff pigment, sizing agent; and that, therefore, a calibration curve for each agent must be prepared. We used only one calibration curve previously mentioned, however, believing that variations in the mass absorption coefficient according to treating agents were negligible when unevenness of wet pick-up is represented in percentage.

2-3-3. Measurement of amount of wear

We measured, with a β -gauge, the amount of wear of fabrics and drew a characteristic curve of wear showing the relation between the amount of wear and the duration of use of the fabrics or the frequency of friction between a fabric and a friction tester.

Hitherto the only method to test the wear of a tailored fabric has been by observation of the fabric. It is difficult to find numerically the amount of wear by observation alone. However, a wear test we made with a β -gauge showed the amount of wear accurately in numerical values. Incidentally, by using a β -gauge, we can measure the anti-wear resistance power of a fabric by the initial slope of a characteristic curve of wear, the initial slope being obtainable in a short time after a wear test is begun.

2-3-4 Control of heat-setting of a warp-knit nylon fabric⁽¹⁴⁾

A warp-knit fabric is graded according to its yield. For instance, a lock-knit nylon fabric of 30-denier nylon yarns has a yield of 6.66~10 yd²/lb.

Generally, it is difficult to make a warp-knit fabric uniform in yield merely by adjusting each part of a speed loom. The alternative is to correct yield irregularity by adjusting the tension of the fabric during heat-setting. Hitherto this adjustment has taken a long time, but H. E. Knobil succeeded in keeping a yield irregularity

within $\pm 1\%$ by measuring, with a β -gauge, the area density of a fabric before heat-setting and by adjusting the speed of the feed rollers of a heat-setting machine.

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