AN ANALYSIS OF THE AIR-JET YARN-TEXTURING PROCESS PART VII: THE EFFECTS OF PROCESSING PARAMETERS ON YARN PROPERTIES

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ABSTRACT

The properties of the supply yam and the processing parameters together determine the final properties of air-jet-textured yams. An investigation is reported on how variations in overfeed, air-pressure, and texturing speed, wet or dry processing, and the use of an impact element each affect the properties of the yam textured . The test plan and the test methods are described, prior to a report of the test results. It is concluded that the test results agree with the predictions made from the postulated mechanism of loop formation.

INTRODUCTION

The properties of air-jet-textured yarns are affected by both the supply-yarn properties and the process parameters. The effects of process parameters were first investigated nearly 20 years ago by Wray[1], but, in that investigation, pre-twisted supply yarns were used. To-day's texturing technology operates satisfactorily on continuous- filament yarns with little or no twist, and further investigations of the effects of process parameters on the textured-yarn properties are therefore justified. Only one type of yarn was used in the tests in order to eliminate the effects of the supply-yarn properties.

Tests were restricted to measurements of tensile properties, linear density, and instability. Bulkiness tests were omitted because such test methods have not been firmly established and clearly defined. Loop-size and loop-frequency tests demand the counting and measuring of individual loops under a microscope or a microprojector, tedious jobs even for laboratory purposes. Instability tests were based on load- elongation curves obtained on an Instron Tensile Tester rather than on simpler but cruder weight-hanging methods.

FACTORS AFFECTING TEXTURED-YARN PROPERTIES

The physical characteristics of single-end air-jet-textured yarns are affected both by the properties of the supply yarn and by the processing parameters. Although these are not investigated here, the relevant properties of the supply yarn are:

 (a) the type of yarn (including the type of polymer and its physical properties and the spin finish);

 (b) the linear density per filament;

(c) the number of filaments in the yarn; and

(d) the geometry of the filament cross-section.

Air-jet-texturing technology has advanced considerably over the period since Wray's earlier studies[1] so that industry no longer needs to use pre-twisted supply yarns; pre-twist is not therefore among the supply-yarn properties considered.

The process parameters are:

(a) the type of jet;

(b) the overfeed ratio;

(c) the air-pressure;

(d) the production speed;

(e) wet or dry processing; and

(f) the use of an impact element.

Since Rozmarynowska and Godek[2] have shown that the process of air-jet texturing causes no significant changes in the properties of individual filaments, it may be concluded that any changes in yarn properties result only from the formation of the bulked (textured) structure as determined by the processing parameters and the properties of the supply yarns. Consequently, no attempt was made to determine the properties of the individual filaments after texturing, and all the changes in the yarn properties are believed to result from the texturing process only. It is the purpose of this paper to report a study of the effect of process parameters on one particular type of yarn, the properties of which are summarized in Table I.

Table I

Type of yarn	Flat polyester-fibre
Source of the yarn	ICI Fibres, U.K.
Linear density	175 dtex
Number of filaments	66
Breaking load	670 gf (6.57 N)
Breaking elongation	28%
Tenacity	3.83 gf/dtex (0.38 N/tex)

TEST PLAN

The textured yarns were produced by using Heberlein's standard-core HemaJet on the single-position texturing machine built to facilitate adjustment of the process variables. These process variables were: overfeed ranging from 10 to 30% by increments of 5% production speed ranging from 200 to 600 m/min by increments of 100 m/min; and air-pressure ranging from 0.5 to 0.9 MPa (gauge) by increments of 0.1 MPa.

Processing conditions of 20% overfeed, 400 m/min production speed, and 0.8 MPa (gauge) air-pressure were chosen as standard parameters. Whenever one of the parameters was varied, the others were kept at their standard levels. For the

first set of tests, the supply yarn was wetted during texturing, and no impact element was used with the nozzle. Two other sets of yarns were produced to investigate the effects of using an impact element and to compare the effects of wet and dry texturing on the yarn properties. For these further tests, only the overfeed was varied in order to keep the testing programme within reasonable time limits.

TEST METHODS

Instron-tester load elongation curves were obtained, from which the breaking loads and breaking elongations and hence the tenacities of the yarns could be obtained. The linear density of each yarn was found by weighing a measured length. Load-elongation curves from the Instron tester were also used to determine the instabilities of the yarns. Instability, or the tendency for the loops to be removed by applying tension, is affected by the process parameters and supply-yarn characteristics[1]. Conventional instability tests depend on hanging weights on a skein of yarn and measuring the extension after a certain time has elapsed. These tests depend on the duration of the applied loads, and human errors in the test results are inevitable. An alternative test method that was used for the work at present under consideration reduces duration dependence and human errors inherent in the weight-hanging methods. Instron-tester load-elongation curves were obtained and elongations under loads corresponding to those normally used in other instability tests were read off. The loads used were 0.01 cN/dtex (lower limit) and 0.5 cN/dtex (upper limit). The difference in elongations corresponding to these loads provides a measure of the instability of the yarn.

A yarn with a low loop frequency may have a very low instability owing to the smaller number of loops that can be pulled out under an applied tension; such a yarn may not be acceptable as textured yarn. On the other hand, a satisfactorily textured yarn with a high loop frequency may have very high yarn instability if loops are likely to be pulled out under applied tensions. Yarn instability is affected not only by the instability of the loops but also by the structure of the core of the yarn. Hence any measure of instability that is not related to the frequency and size of the loops and the yarn-core structure will not necessarily reflect the suitability of the yarn for particular end-uses.

Several test methods have been suggested to assess the physical bulk of the textured yarn, e.g., a package-density method 1, a water-absorption test[3], and a test designed to measure the apparent volume of a skein of yarns and compare it with the theoretical volume[2]. Each has considerable disadvantages, and there is no unique method that has a wide acceptance; it was therefore decided not to attempt any assessment of the physical bulk of the yarn.

Other important properties are the surface properties of the textured yarn, such as loop size and loop frequency. The measurement of these properties involves the tedious work of counting the loops, assessing their sizes, and estimating the over-all and core diameters of the yarn. Research has, to date, been confined to a visual impression of yarns wrapped on blackboards, the tedious time-consuming loop-size and loop-frequency assessments having been excluded owing to the lack of rapid methods for their accurate measurement.

RESULTS AND DISCUSSION

Test Results and Visual Examination

Test results for tenacity, breaking elongation, linear density, and instability for varying process parameters are shown in Figures 1-4. In general, these indicate that the strength and extensibility of the textured yarn are both reduced when compared with the corresponding properties of the raw supply yarn (see Table I), and its linear density is increased as expected.

Visual inspection of the experimental yarns when wrapped on blackboards showed a substantial increase in yarn voluminosity (bulk), and those textured yarns that were seen to have greater numbers of loops also had greater instability values than those having fewer loops. The strength of the air-jet-textured yarn is reduced mainly because the looped filament portions do not contribute to the carrying of applied loads; such loads are largely borne by the straighter filament portions usually located in the core of the yarn. Yarns with higher numbers of loops are thus generally weaker and less extensible. Such findings are consistent with those reported by Wray[1] for air-jet- textured pre-twisted yarns.

Effects of Overfeed

Figures 1 and 2 show that tenacity and breaking elongation both decrease with increasing overfeed. It has been observed that, at high overfeeds, because there are adequate extra lengths of filaments available for loop formation, the number of loops formed increases at the same time as the size of the loops becomes enlarged. Following from the argument in the preceding paragraph, the tenacity and the breaking elongation of the yarn are both reduced as the overfeed is increased.

Fig. 3 shows that, as expected, the linear density of the textured yarn increases with increasing overfeed. Not all of the loops are firmly fixed in the yarn core, as is indicated by the increasing yarn instability with increasing overfeed (see Fig. 4). This is due to the increased number of loops at high overfeeds, which in turn increases the probability that some of these loops will be removed on elongating the yarn and thereby result in greater yarn instability.

Effects of Air-pressure

The effects of the air-pressure on the tenacity and breaking elongation, as shown in Figures 1 and 2, are similar to those of the overfeed ratio. As the pressure increases, the air velocity at the exit, the degree of non-uniformity in the velocity distribution, and the turbulence all increase; the filament separation and the longitudinal displacements of the filaments with respect to each other become more effective, and filaments travel and change their positions at a greater rate. Hence a better loop formation and texturing can be achieved, this resulting in lower tenacities and breaking elongations. Although the excess lengths of the filaments are unchanged for a constant overfeed, the linear density of the textured yarn increases with increasing air-pressure (Fig. 3). This could be due to the more effective entanglement of the filaments, which causes more loops to become fixed in the core of the yarn and gives rise to the increased linear

density. Fig. 4 shows that the yarn instability increases slightly with the increasing air-pressure, again owing to increased numbers of loops, because the greater the number of loops, the more likely is the yarn to elongate under loads applied in instability tests.
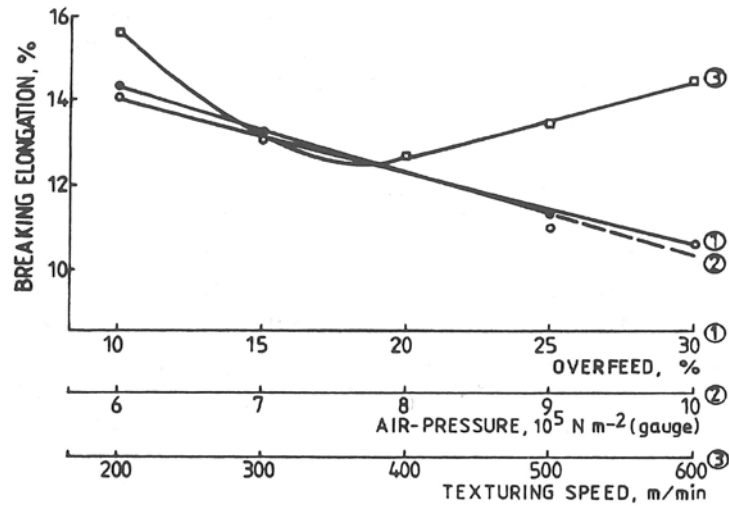

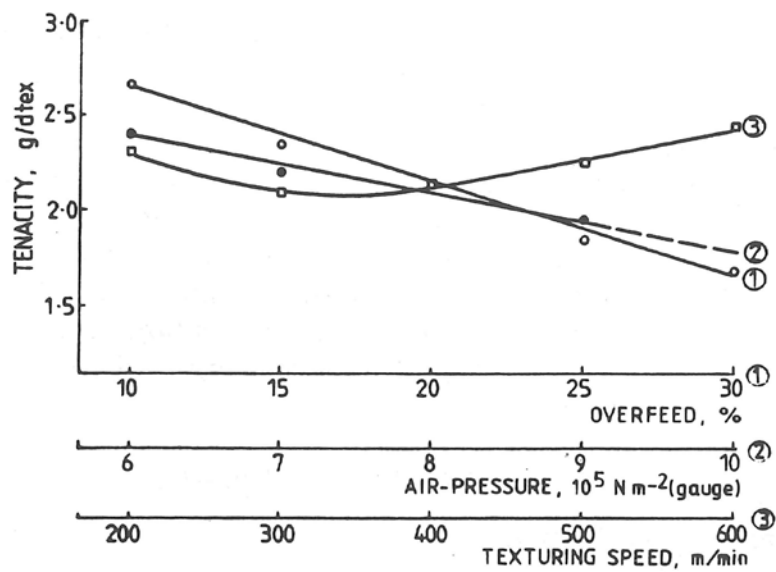Fig. 1. Yarn breaking elongation for various process parameters

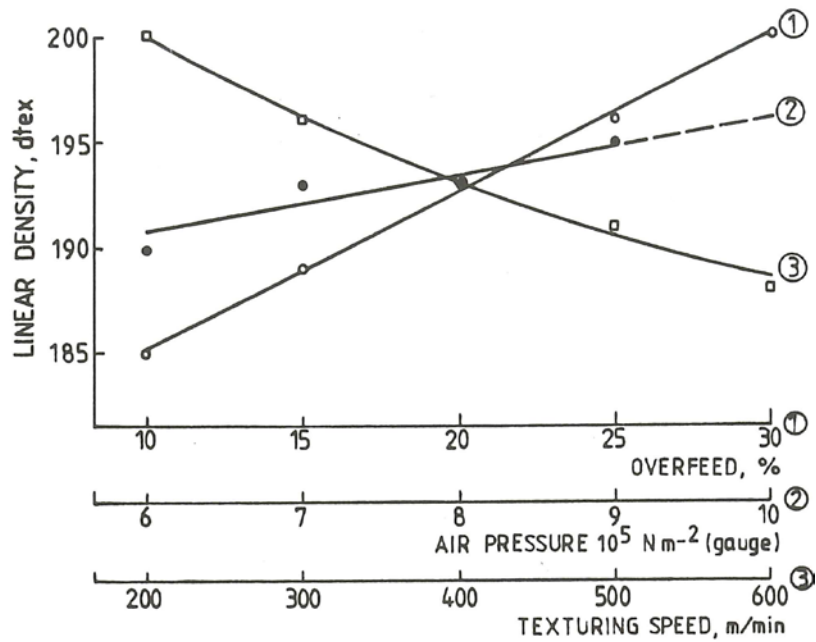Fig. 2. Yarn tenacity for various process parameters

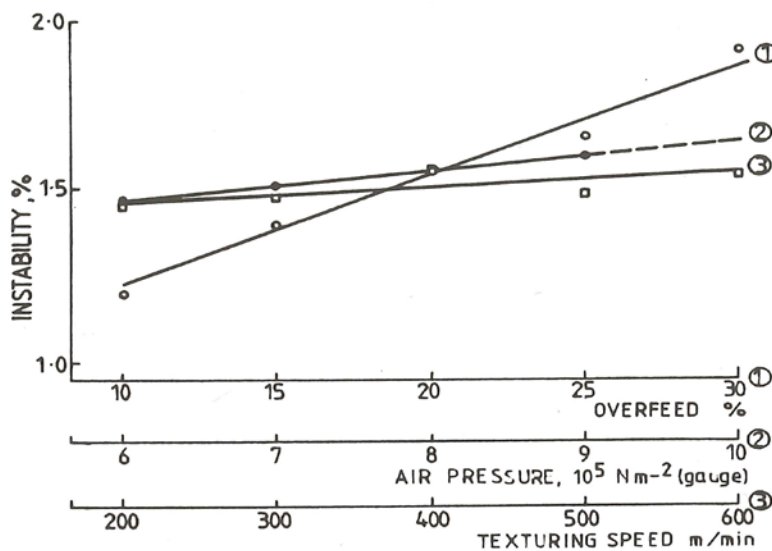Fig. 3. Yarn linear density for various process parameters

Fig. 4. Yarn instability for various process parameters

Effects of Texturing Speed

Since it is known that better texturing is obtained at lower texturing speeds, and that this in turn reduces the strength of the yarn, it is to be expected that the strength will gradually increase with increasing texturing speed. Contrary to this expectation, tenacity and breaking elongation do not increase with increasing texturing speed at the lower end of the speed range (Figures 1 and 2) but decrease to a minimum and then begin to increase. This minimum may depend on the other processing parameters as well as on the properties of the supply yarn; for the particular yarn used in the tests, the critical speed was about 350 m/min when texturing was done under the chosen standard processing conditions.

The texturing speed affects the bulkiness of the yarn, and its structure becomes more closely packed at low speeds. It is reasonable to expect that the inter-filament friction in the core of such yarns becomes higher than that of less compact yarns. The increased inter-filament friction would contribute to the strength of the yarn in a manner analogous to that of the inter-fibre friction in spun yarns and could account for the higher strength and extensibility of the yarns textured at low texturing speeds. As the texturing speed is increased, the yarn structure becomes less compact and consequently inter-filament friction is expected to reduce and so cause the yarn strength to drop. As the texturing speed continues to increase beyond the critical speed at which both strength and extensibility are at a minimum, then texturing becomes less effective and causes less compact structures progressively to occur; the strength and extensibility begin to increase owing to the less compact structure and to the increased number of relatively straight filaments that are available to carry the applied load.

Fig. 5 shows high-speed photographs taken during texturing at various texturing speeds together with inset scanning electron micrographs of the corresponding yarns. These photographs confirm that the yarns produced at lower texturing speeds have very dense, closely packed structures, with smaller over-all diameters and smaller loops. An inspection of Fig. 1 shows that yarns textured at around 150 and 600 m/min possess similar tenacity (strength), although the structures of these two yarns are very different. For yarns produced at the former speed, this strength is attributed to the increased inter-filament friction, whereas, for those produced at the latter speed, it is attributed to the reduced numbers of loops that occur with less effective texturing and therefore with the greater occurrence of relatively straight load-carrying filaments.

With increasing texturing speeds, for a fixed overfeed, the linear density of the textured yarn reduces because of the poor loop formation (Fig. 3); such loops are liable to be removed under the applied tension. Fig. 4 suggests that yarn instability is little affected by increasing texturing speed.
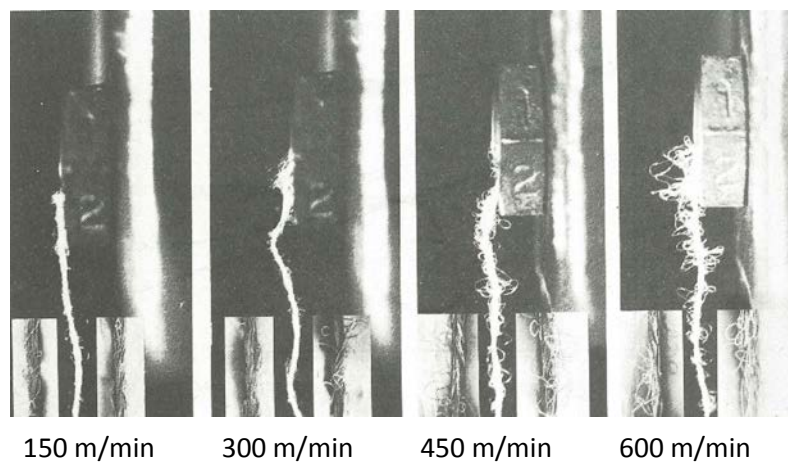

| 150 m/min | 300 m/min | 450 m/min | 600 m/min |

Fig. 5. High-speed photographs of the filaments leaving the jet, taken during texturing at various speeds, and SEM photographs of the correspond mg textured yarns

Effects of an Impact Element and Dry Texturing

Test results for varying overfeed ratio with and without an impact ball and for dry and wet texturing are shown in Figures 6-9. Fig. 6 shows that the introduction of an impact ball has a significant effect on the elongation: It results in approx1mtely constant breaking elongation for the range of overfeeds tested. In contrast, Fig. 7 shows that the tenacity of the yarn is not affected significantly by using an impact ball except at high overfeeds. Dry conditions give rise to substantial increases in both breaking elongation and tenacity owing to less effective loop formation.
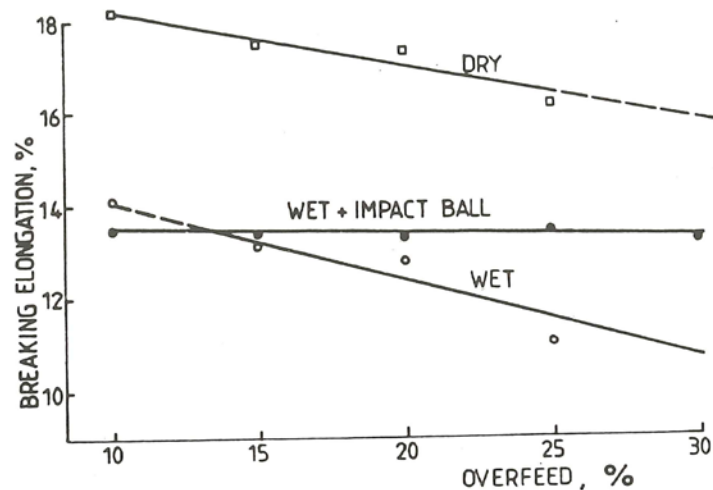

Fig. 6. Comparison of the effects of wet and dry processing and the use of an impact ball on yarn breaking elongation for varying overfeed
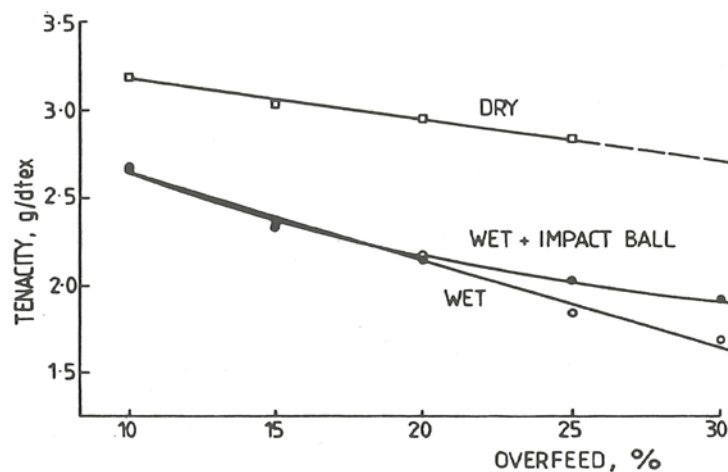

Fig. 7. Comparison of the effects of wet and dry processing and the use of an impact ball on yarn tenacity for varying overfeed

Figures 8 and 9 show that the linear density and instability of the textured yarn are only slightly increased by using an impact element, but they are both considerably reduced in dry texturing, again because of less effective loop formation.
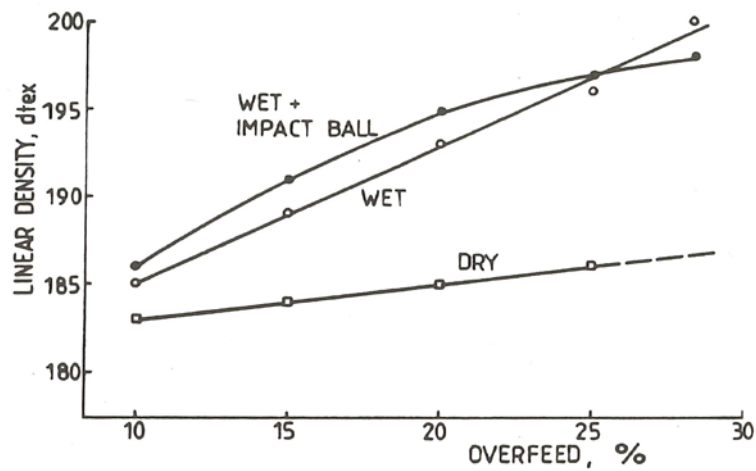
Fig. 8. Comparison of the effects of wet and dry processing and the use of an impact ball on yarn linear density for varying overfeed
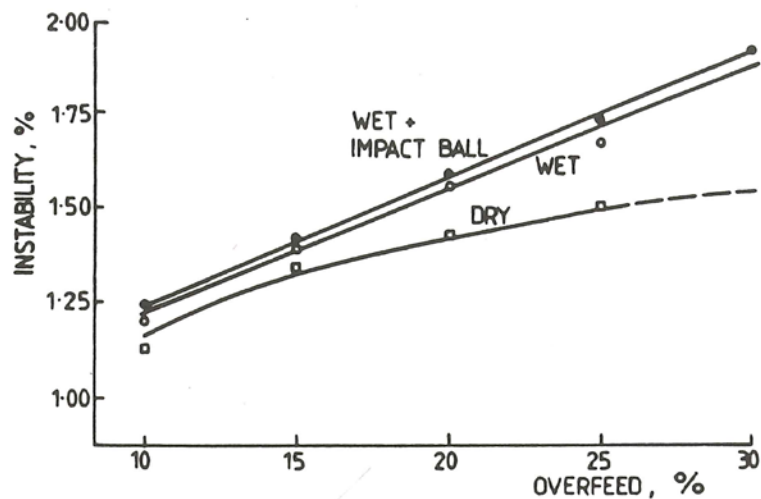

Fig. 9. Comparison of the effects of wet and dry processing and the use of an impact ball on yarn instability for varying overfeed

It can be concluded that the inferior textured yarns produced by dry texturing are caused by the poor texturing conditions arising from high friction between the filaments themselves and between the filaments and the machine parts with which they make contact[4].Wet texturing substantially improves the texturing efficiency. The use of an impact element has a slight effect on the textured-yarn properties. Its only significant effect is on the breaking elongation, especially at high overfeed ratios.

CONCLUSIONS

The results of the yarn tests, in general, showed that the effects of process parameters on the yarn properties can be explained by the postulated loop-formation mechanism described in Part VI[5].

Although these test results may give some indication of certain yarn properties, they afford only a limited indication of the textured yarn's suitability for particular end-uses. For a full a6sessment of the suitability of a yarn, among the other properties that are less easily measurable, surface characteristics such as loop size, loop frequency, and physical bulk and yarn dimensions such as core and over-all diameter have still to be assessed. This is because simple, quick, and reliably accurate methods for determining these properties have yet to be developed.

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