A STUDY OF THE DEGREE OF BREAKAGE OF GLASS FILAMENT YARNS DURING THE WEFT KNITTING PROCESS

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Abstract

In this paper, the degree of breakage of glass filament yarns during the weft knitting process is studied. A quantitative method used for assessing the degree of glass filament breakage is proposed, and the effects of different factors such as cam setting, knitted structures and yarn parameters are analysed. The experimental results show that an optimum cam setting exists at which the degree of filament breakage is minimum.

Key words:

knittability, high-modulus yarns, glass fibres, knitting technology, cam setting

1. Introduction

Knitted fabrics have received great attention as a kind of reinforcement in the composites industry in recent years [1, 2, 3, 6, 7, 8]. This is due to some of their outstanding characteristics such as flexibility in production, knitting to shape, superior resistance to impact, and high ability to conform to complicated forms. In order to obtain high mechanical properties, knitted fabric reinforcements are generally produced from high-performance yarns or filaments such as glass, aramid, carbon, and even ceramics etc. However, these fibres are normally very difficult to process in the knitting process due to their high stiffness and high coefficient of friction. Some of them are even very brittle in bending when a loop is formed. For this reason, establishing a method for efficiently knitting these high performance yarns or filaments is of increasing importance, if more knitted structures are to be used as reinforcements.

Several researchers have investigated the knittability of high-modulus yarns or filaments [4, 5, 9, 10]. According to their investigations, the knittability of a yarn depends on its strength (both tensile and bending) and frictional properties. In order to knit a high modulus yarn efficiently, good yarn input tension control is required. At the same time, the fabric's take-down tension, stitch cam setting, machine speed and yarn lubrication conditions also influence knittability. Besides this, fabric geometry and physical properties and their relationships with cam settings have also been studied in detail. In order to assess the knittability of high modulus yarns, fibre breakage, needle and cam damage during the knitting process were also investigated. However, the analyses of the fibre or filament breakage were qualitative, and only based on observations of microscopic photographs of knitted samples. A quantitative method for assessing the degree of filament breakage is lacking as yet.

In this paper, a quantitative method for assessing the degree of glass filament breakage is proposed. At the same time, the influence of stitch cam setting, yarn type and knitted structure on the breakage degree is also presented.

2. Experimental Conditions and Work

2.1. Materials

Two types of the E-glass multi-filament yarns were used in this work. Their characteristics are shown in Table I.

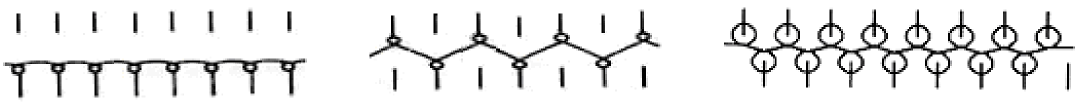
Table I. Characteristics of the glass filament yarns used

Type	Diameter of the filament (μm)	Linear density (tex)	Twist (twists/m)
A	5.5	144	300
B	8.0	144	91.2

2.2. Knitting process

The knitting was carried out on a hand-manipulated V-bed flat knitting machine SGE9007 made in China. The gauge was selected according to the above yarn linear densities used, and was 11 needles per inch. In order to improve feeding conditions for the glass filament yarns, the yarn feeding system was replaced by a yarn tension device used on a Stoll CMS TC-320 flat knitting machine. Also, all contact points on the machine were polished in order to minimise any damage to the yarn by abrasion. During knitting, the yarn input tension and take-down tension were kept constant.

Three kinds of knitted structures were selected. They were single jersey, and two ribs knitted with different needle arrangements as shown in Fig. 1.



(1) (2) (3)

Figure 1. Knitted structures used

(1) Single Jersey, (2) 1×1 Rib I (half needles in action), (3) 1×1 Rib II (all needles in action)

According to previous studies [4, 5, 9], the cam setting is the primary parameter among all machine settings which influences the knittability of high modulus yarns. For this purpose, a series of stitch cam positions from knitting very tight fabrics to very loose ones were set for each structure and yarn. The procedure was as follows: firstly, the stitch cam was adjusted to a position for knitting a loop length at a value as minimum as possible, and then the cam positions were gradually changed to increase the loop lengths until they reached as high a value as possible. The minimumminimum and maximum positions are referred to as the lower limit and upper limit respectively. As the stitch cam positions could not be clearly indicated on a hand flat knitting machine, in the present paper the cam settings are designated by loop lengths. The loop lengths were measured by cutting a specific number of wales out of the structure, unravelling the yarn, measuring its length, and dividing this by the number of stitches; the accuracy of this loop value was 0.1 mm.

2.3. Assessing method and tensile test

The method used for assessing the degree of glass filament breakage is based on the yarn strength loss due to the weft knitting process. It consists in measuring the filament yarn strengths before and after knitting, and calculating their strength loss as a percentage according to the following formula:

$$DFB = (T_0 - T_1) / T_0 *100, \%$$

where DFB (%) is defined as the degree of glass filament breakage as a percentage, and T_0 and T_1 are the yarn breaking forces before and after knitting respectively.

It is evident that the measurement of the breaking force of a yarn after knitting can only be made when it has been unravelled from the fabric which was knitted. In order to reduce possible further filament breakage during unravelling handing, special care must be taken. According to a preliminary microscopic observation, the filament breakage due to unravelling handing was very small and could be counted as negligible in comparison to the breakage of filaments due to the knitting process. Therefore, it could be considered that the unravelling handing had only a little influence on the experimental results.

The glass filament yarns were tested on the HD021 automatic tensile-testing installation according to Chinese National Standard GB/T 7690.3—2000, in which the tested length is 50 cm, and the crosshead speed is 20 cm/min. 10 tests were preformed for each testing case, and the mean value of the breaking forces was calculated. Because the glass filament yarns are brittle, it is very easy to damage them under the action of the clamps. To solve this problem, all yarns tested were coated with the liquid epoxy resin Bisphenol at both ends, in order to avoid yarn breakage at the clamp positions.

3. Results and Discussion

The experimental results of the degree of filament breakage DFB (%) in term of the loop length (i.e. cam setting) for 3 different knitted structures knitted with 2 glass filament yarns are shown in Figures 2-4 respectively. The analyses of the different influencing factors are given as follows.

3.1. Variation trend of the degree of filament breakage with cam setting

It can be seen from Figures 2-4 that all the curves have the same variation trend, in which the degree of filament breakage firstly decreases and then increases with the increase in the loop lengths for all the knitted structures and glass yarns. This means that a minimum value of the degree of filament breakage exists if a suitable stitch cam position is set. This minimum value can be considered as an optimum cam setting position for knitting glass filament yarns. In addition, it was found that the optimum position is closer to the lower limit of the loop length. In order to explain this phenomenon, it is necessary to analyse the degree of filament breakage caused at different knitting steps in the knitting cycle.

In a knitting cycle, from the old loop clearing to the new loop forming, three kinds of force actions (i.e. tension, bending and friction) can result in the breakage of glass filaments. For a glass filament yarn, a single tensile action along with its axe does not readily cause high filament breakage, because a glass yarn normally has high tensile strength. However, during a knitting cycle, as loops are being formed, the yarns are subjected to tension, bending and friction simultaneously. These simultaneous actions can easily cause glass filament yarns to break due to their brittleness in bending and on friction. The degree of filament breakage for a glass yarn can be considered as the sum of the filament breakages caused at different steps in a knitting cycle. However, the degree of the filament breakage caused at each knitting step varies with the cam setting (i.e. loop length). When the loop lengths are proximate to the lower limit, the degree of filament breakage during the loop clearing and knock-over predominates.

Because the loop lengths decrease, higher frictional actions are produced between the yarn/yarn, yarn/needle and high yarn tension in the old loops in the course just knitted. There is no doubt that the higher frictional action will cause considerable filament breakages on the yarn's surface. The lesser the loop length is, the higher the degree of filament breakage is on the left side of the optimum cam setting position. However, as the loop lengths are increased, the degree of the filament breakage at the loop formation step increases. The reason is that when the loop lengths increase, the fabric structures are loosened, and the degree of the filament breakage at the clearing and knock-over steps decreases.

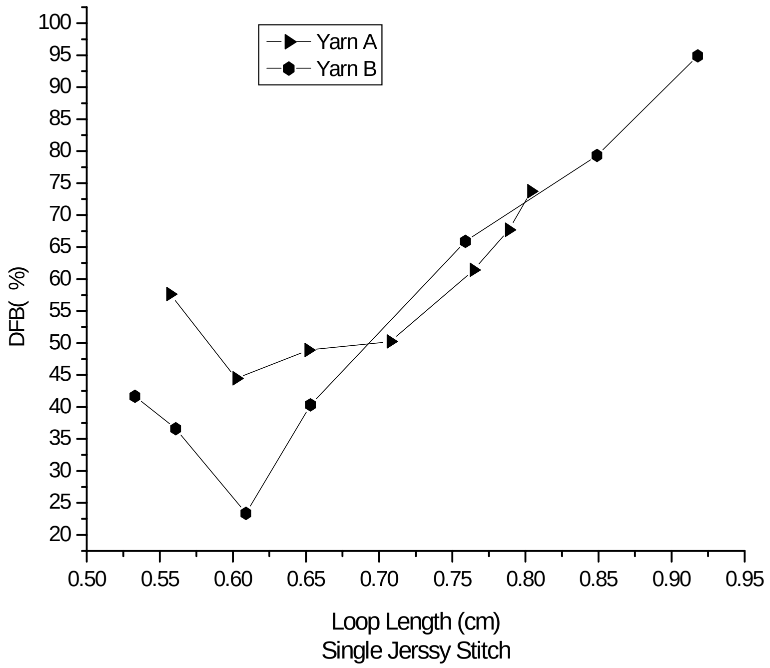


Figure 2. Variation of DFB in term of the loop length for single jersey

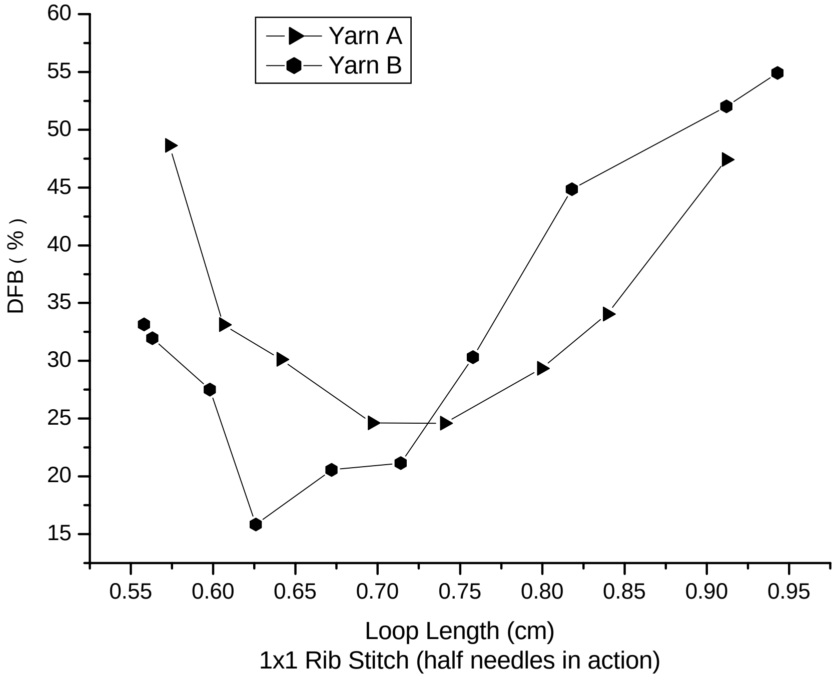


Figure 3. Variation of DFB in term of the loop length for 1 × 1 Rib I (half needles in action)

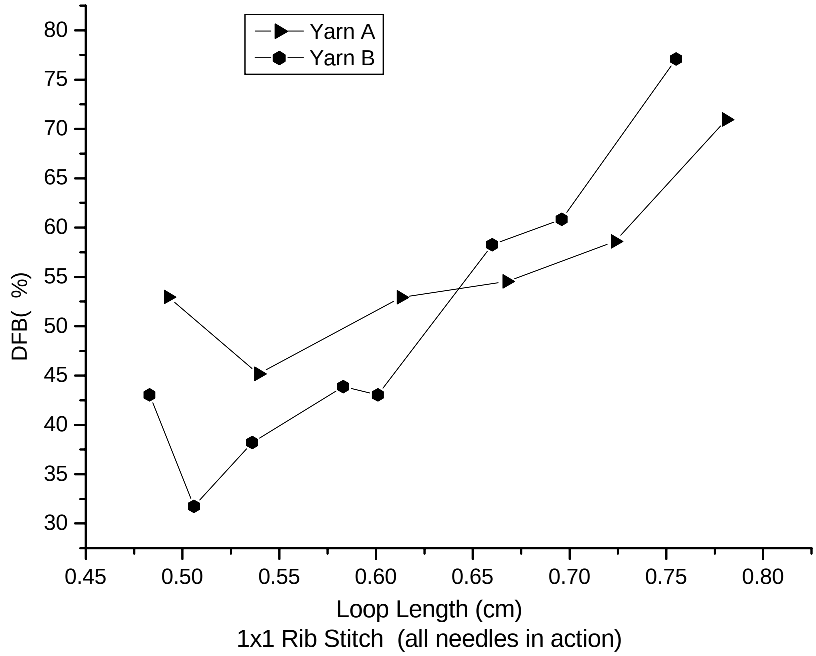


Figure 4. Variation of DFB in term of the loop length for 1 × 1 Rib II (all needles in action)

However, the maximum yarn tension at new loop formation step is increased because the wrapping angles of the yarn with the knitting elements are increased. At the same time, the bending and friction effects of the yarn also increase. When the loop lengths start to increase from the lower limit, the reduction of the degree of filament breakage during the old loop clearing and knock-over is faster than the increase of the degree of filament breakage during the formation of new loops. Consequently, the degree of filament breakage decreases in the zone near the lower limit. However, after a short increase in the loop lengths, the filament breakages accelerate because the increase of the yarn tension during loop formation continues to accelerate. Thus, the degree of filament breakage begins to increase once more. The greater the loop length is, the higher the degree of filament breakage is on the right side of the optimum cam setting position.

3.2. Effects of the knitted structures on the degree of filament breakage

In Figures 2-4, all the curves have the same variation trend. However, the degree of the filament breakage for each knitted structure is different. Knitting single jersey results in higher filament breakage than in knitting 1×1 ribs. The maximum value of the filament breakage degree in knitting a jersey structure can reach over 90%. There are two reasons for this. The first one is that the jersey is only knitted on a needle bed. When a jersey fabric is taken down from the knitting zone, a severe friction effect is produced due to the fabric's contact with the needle bed. As a result, a higher degree of filament breakage is obtained. The second reason is that the yarn in the part of the sinker loops is subjected to more bending action during loop formation. This severe bending can also result in a high filament breakage.

If a comparison is performed between two types of 1×1 ribs, it can be found that the rib knitted with all needles in action has a higher degree of filament breakage than the rib knitted only with half needles in action. This is normal because the tightness of the rib knitted with all needles in action increases. Higher tightness will cause higher friction between yarn/yarn, yarn/knitting elements and high yarn tension during loop formation. Consequently, higher filament breakage is produced.

3.3. Effects of the filament diameter and yarn torsion on the degree of filament breakage

It can be seen from Figures 2-4 that the effects of two glass filament yarns on the degree of filament breakage for 3 knitted structures are very similar. When the loop lengths are at lower values, the degree of filament breakage of yarn B (with bigger filament diameters and lower torsion) is lower than that of yarn A (with smaller filament diameters and higher torsion). However, as the loop lengths increase, the situation changes inversely. This phenomenon can be easily explained as follows; when the loop lengths are at the lower values, the frictional effects during knitting increase due to the higher tightness of the kitted structures. In this case, the yarn with the smaller filament diameter can be more easily damaged by friction. At the same time, higher yarn torsion makes the yarn surface more uneven. The more contact points between the yarn surfaces exist, the more contact points between knitting elements are produced. Consequently, the degree of filament breakage increases. Contrarily, when the loop lengths are at higher values, the simultaneous tension and bending actions to which the yarns are subjected during loop formation is increased. As yarn with a bigger filament diameter can be easily broken in bending, the filament breakage degree is expected to be higher than that of the yarn with a smaller filament diameter. In addition, the lower yarn torsion can also reduce the yarn tensile strength because there is a decrease in the ability of all the filaments to be extended simultaneously .

3.4. Comparison between commonly used knitwear yarns and glass filament yarns

In order to confirm the particular properties of the glass filament yarn in weft knitting, two types of commonly used knitwear yarns, a cotton yarn and a wool/acrylic-fibre blend yarn (wool 30%, acrylic-fibre 70%), were knitted and their strengths before and after knitting were tested under the same conditions as glass yarns. Figure 5 shows a comparison of the degree of fibre breakage between the commonly used yarns and glass yarns for single jersey structure.

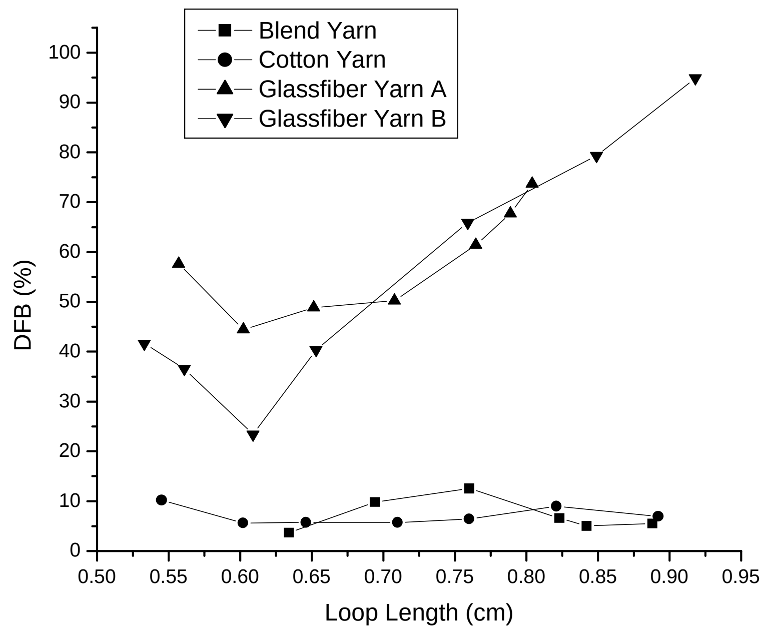


Figure 5. Comparison of DFB between commonly used yarns and glass yarns

It was found that the fibre damage during knitting to the commonly used yarns is very small compared to that to the glass yarns. In addition, no obviously regular variation trends of the degree of fibre breakage in term of loop length are observed. This confirms that knitting glass yarn is more difficult than knitting normal yarn, and choosing a suitable cam setting is very important when a glass yarn is being knitted.

4. Conclusions

A quantitative method for assessing the degree of breakage of filament for the glass yarns during knitting has been proposed in the present work. The influences of different factors such as cam setting, knitted structure and yarn type on the degree of breakage were analysed. According to the experimental results and analyses, the following conclusions have been drawn:

1) The degree of breakage of glass yarns' filaments strongly depends on the stitch cam setting (i.e. loop length). An optimum cam setting exists at which the degree of filament breakage is minimum.

2) Knitting a single-faced structure will cause higher filament breakages than knitting double-faced structures. For the 1×1 rib structure, the needle arrangement has a strong influence on the degree of filament breakage. The 1×1 rib knitted with all needles in action shows a very high degree of filament breakage.

3) The degree of filament breakage also depends on the filament diameter and yarn torsion. The yarn with a smaller filament diameter and higher torsion has a lower degree of filament breakage with higher loop lengths.

4) The fibre damage is very low for the commonly used knitwear yarns compared to that of the glass yarns, which is independent of the cam setting.

The work presented here was carried out on a hand flat knitting machine. Due to the adjusting limit of the machine, other factors such as yarn input tension, machine speed and take-down tension, which could influence the degree of filament breakage, were not investigated. Experimental work about these factors is being carried out on an electronic machine, and the results will be presented in the future.

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