

An Investigation of the Behavior of Thin Places in Ring Spun Yarns

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ABSTRACT

A thin place in a spun yarn with less number of fibers contains more twist and should result in higher cohesion between the fibers. Still a yarn generally fails at thin place. To study the behavior of thin places during tensile testing, ring spun yarn with three different composition and two counts were produced at three different twist levels. The effect of mass variation on twist and tensile behavior was studied. Yarn thin places in which the mass was 30%, 40%, and 50% less than the mean mass of the yarn were taken for the study. There has been a significant change in the overall and local twist with variation of mass. The composition of the yarns and change in their diameter were found to influence the tensile behavior of the yarns.

Keywords: thin place, yarn diameter, yarn twist, breaking load, breaking extension, yarn failure

1. INTRODUCTION

The strength, uniformity and faults of a spun yarn are important parameters to characterize its quality. In order to get better processing performance, a yarn should not only be uniform in mass distribution but also be strong, and free from faults as far as possible. A yarn fails when processing tension exceed and its strength. The strength of a yarn is largely dependent on the arrangement of fibers, mass & mass distribution, twist & twist variation along its length and presence of faults. The nature of its failure indirectly reflects the breakage and/or slippage of constituent fibers and degree of simultaneity and non-simultaneity of their breaks. The coherence of constituent fibers in a yarn is maintained by twist and it has a prominent role in deciding the stress strain behavior of the yarn. As a general rule at higher twist, a yarn fails predominantly

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through fiber breakage with a possibility of simultaneity of breaks. While a low twisted yarn may fail predominantly through slippage and non-simultaneity of fiber breakage. Presence of any fault in the yarn would result in deviation from expected nature of failure and cause a variation in yarn strength. Hearle *et. al.*, (1969) has reported that in a normal yarn, fibers in the outer layers slip while those in the central layer break when the effect of migration is ignored. A low twisted yarn fails predominantly due to slippage of fiber, a moderately twisted yarn fails through combination of slippage and breakage and a highly twisted yarn fails primarily through sharp breakage of constituent fiber (Ghosh *et. al.*, 2005; Ishtiaque *et. al.*, 2005; Mogahzy *et. al.*, 1992; Pan, 1992). Presence of yarn fault of any kind will present a

significant obstacle in achieving desired quality and performance.

Failure of spun yarn is also influenced by raw material characteristics, twist & its variation in yarn apart from the presence of yarn fault (thick or thin faults). The fiber cross-section irregularities form only a small fraction of the yarn unevenness and are due mainly to the difference in the number of fiber per yarn cross-section (Zhang *et. al.*, 1998). Such variation in the number of fibers in cross-section may lead the variation in twist distribution along the length of yarn (Sustman, 1956). A thin place containing less number of fibers forms a potential weak point affecting the strength of the yarn, economy of production and also the aesthetics of the final product (Kilic, 2006). So it is necessary to keep the number of thin places at minimum level for cost reduction and improved post spinning efficiency. In the present study, an attempt has been made to investigate the variation of the strength of

a yarn at thin places despite having higher inter-fiber cohesion due to twist concentration and how far the mass reduction is compensated by twist accumulation in thin places. Such study may help in exploring the possibility of widening the acceptable limits of thin places in a yarn.

2. MATERIALS AND METHODS

Indian cotton (J-34 variety 29.2 mm 2.5% span length and 1.65 denier) and polyester (32 mm length and 1.4 denier) were used to produce 100% polyester, 100% cotton and 50/50 polyester cotton blended yarns of two different counts (30 tex, and 20 tex). These yarns were processed on a conventional ring spinning line. Three different tex twist multipliers 37.1 for cotton, 26.6 for polyester, 34.2 for blend [which are normally used for commercial yarn production] were used to produce the yarns. The physical characteristics of the yarns are given below in the Table 1.

Table 1: Yarn physical characteristics

Material	Diameter of yarn and thin portion (mm)								
	30 tex					20 tex			
	T.M of Yarn (tex)	Parent yarn	-30%	-40%	-50%	Parent yarn	-30%	-40%	-50%
Cotton	37.05 (3.8 T.M in N_e)	0.272 (13.9)	0.177 (2.9)	0.155 (4.8)	0.131 (6.2)	0.206 (13.4)	0.141 (4.5)	0.121 (3.9)	0.104 (2.2)
Polyester	26.6 (2.9 T.M in N_e)	0.265 (10.9)	0.177 (3.4)	0.152 (4.3)	0.126 (4.8)	0.227 (10.4)	0.144 (1.97)	0.131 (4.8)	0.112 (4.9)
PC blend	34.2 (3.6 T.M in N_e)	0.235 (11.6)	0.155 (2.6)	0.137 (5.4)	0.115 (5.5)	0.205 (9.9)	0.134 (3.0)	0.120 (4.3)	0.098 (6.9)

Collection of thin region of yarn

Uster Evenness Tester-5 (S-800) was used for the detection and collection of thin places while the instrument was run on inspection stop mode. In this mode collection of thick places, thin places and neps are possible by selecting the

appropriate option. The visible thin places were cut to length of more than 500mm, ensuring the presence of thin portion preferably at the central portion of the sample, when subjected to tensile testing. Both cut ends of the yarn were gripped firmly in the cardboard to avoid untwisting of yarn ends.

Yarn testing

- Conditioning of yarn

The parent yarn and the yarn containing thin places were conditioned under standard tropical atmosphere of 65% ± 2% RH and 27°C ± 2°C temperature for 24 hours.

- Measurement of yarn diameter

Diameter of the parent yarns and that at thin places was measured using Leica image analyzer. Minimum 100 readings were taken to calculate mean diameter of yarn.

- Estimation of twist

The twist in the yarn and that at the thin places was measured using the formula $TPM = \frac{\tan \alpha}{\pi d} \times 1000$ where 'TPM' is twist per meter, d, the mean diameter of yarn in mm and α is the twist angle (Ibrahim, 1992).

- Tensile test

After the measurement of diameter and twist at thin portion, thin portion was marked with the help of marker to locate the failure location during tensile testing. Zwick universal tensile tester was used to measure the tensile properties. Parent yarn and yarn with marked thin portion were tested for breaking load and breaking elongation. The tensile test was conducted at 120 mm/min (ASTM, D1425) extension rate with a gauge length of 500 mm. A minimum of seventy readings were taken to have 95% confidence limits.

3. RESULTS AND DISCUSSION

Yarn diameter

The diameter of the parent yarn and that of the thin places is given in Table 2. Although cotton was spun at marginally higher twist multiplier than polyester cotton blended yarn but diameter of the later is less for coarser count while it is similar for finer count. Higher bending rigidity of cotton fiber might have hindered the packing and be responsible for giving higher diameter.

Polyester yarn spun at lower twist multiplier has almost similar diameter as compared to cotton yarn spun at higher twist multiplier. Circular cross-section and better migration behaviour of polyester might have helped the fibre packing resulting better compactness of fibers as compared to cotton yarn.

In case of polyester cotton blended yarn the differential response of the two components to twist may help in getting more compacted structure. Polyester component due to its flexibility may be able to help cotton component to get integrated in the structure in a better manner leading to a more compacted structure. Polyester having better migratory behavior might also have helped packing of the cotton component.

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Table 2: Diameter of yarn

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Value shown in parenthesis indicate cv%

Yarn Twist in thin places

The variation of twist, with mass reduction is represented in Figure 1 (a)-(c). It is observed that the twist in thin places increases as the yarn becomes finer. Among the thin places under consideration the twist at -30% thin places is the minimum and it reaches a maximum for -50% thin places, irrespective of the composition of the yarn. It has also been observed that with decrease in diameter of yarn due to the presence of thin place the increment in local twist for all the yarns shows steady increase. The rate of increase in twist with change in count has been found to be more after 40% reduction in diameter for both polyester and polyester-cotton blended yarn. The rate of increment in twist after similar reduction in diameter is relatively less for cotton yarn in spite of using higher twist multiplier. For polyester-cotton blended yarn, the difference in twist increment with change in yarn count reduces as compared to the difference observed for cotton and polyester yarn.

Twist in a yarn is the resultant of the applied torque and its distribution along the length of the fiber assembly. The torque translation in the fiber mass takes place through the constituent fibers. So, any variation in the fiber mass distribution is likely to affect the twist and its distribution and retention in the fiber mass. The retention of twist in the fiber mass may be influenced by many factors viz; the number of fibers, flexibility of the fiber assembly, fiber surface property and torsion behavior of fiber assembly etc. The twist is expected to be more in a thin place than in a thick place due to difference in

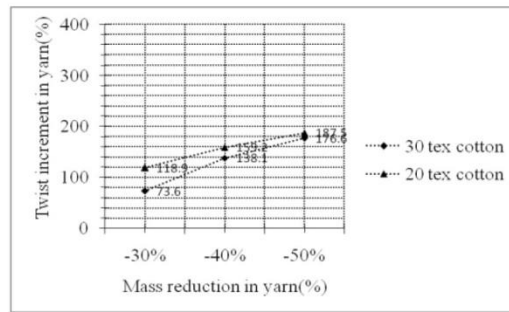
rotation. The relationship between the applied torque and the rotation of the fiber assembly can be expressed in analogy with the angle of rotation of a shaft when subjected to a torque and as shown in Eq. (1) (Khurmi, 2012):

$$\theta = \frac{32 \times T \times L}{\pi \times C \times D^4} \quad \text{Eq. (1)}$$

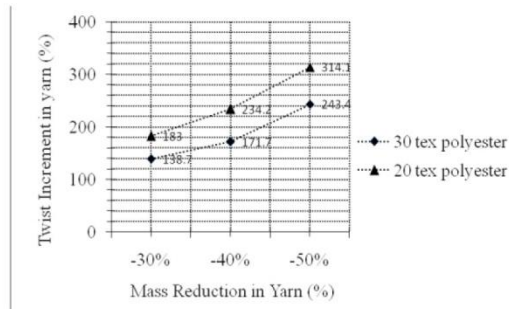
Where, θ = Angle of twist in radians, T = Applied torque in Nm, L = Length of shaft in meter,

C = modulus of rigidity in Newton per square meter, D = Diameter of shaft in meter. When, T, L and C are kept constant, the angle of rotation is inversely proportional to D^4 . This means that when D is small the angle of rotation of is more, implying generation of more twist at a place of low diameter.

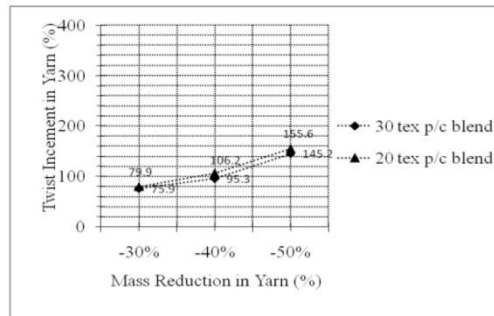
The twist and its flow in the fiber assembly are also likely to be influenced by the number of fibers in the cross-section. Any variation in the number of fibers in the cross section influences the twist flow through it. In a uniformly cylindrical assembly of fibers, the twist translation and distribution is also expected to be uniform. Where diameter is less, the applied twist will have a tendency to concentrate. Such concentration of twist in a yarn leads to initiate snarl at the thin place. In the present study, it was found that snarl formation initiated at the thin place for more than 80% cases.



(a)



(b)



(c)

Figure 1: (a)-(c) Variation of twist with change in mass of yarn

The measured twist in a yarn is the resultant of applied and retained twist. When the number of fibers in the cross section reduces the capability of retention of twist by the fiber mass also reduces. Rigidity of fiber mass, on the other hand, can also play a negative role. Rigidity of cotton is higher than that of polyester and in the polyester cotton blend one can expect a differential behavior of the component fibers. A reduction in diameter implies a fall in number of fibers in the cross section which leads to less increment of twist in cotton yarn as compared to polyester while a differential behavior of the components

might be the reason of less change in twist increment for polyester cotton yarn.

Location of failure region

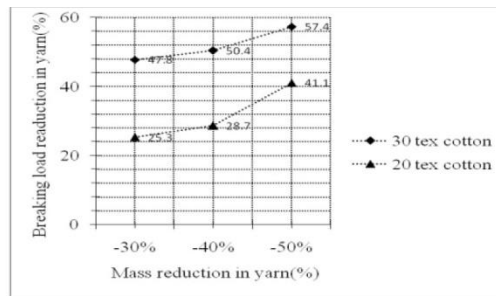
The failure location of the yarns with thin places was recorded and it was observed that the majority of the breakage took place at thin region of yarn. On an average 80% of breakages occurred in thin region of the yarns.

4. TENSILE BEHAVIOR

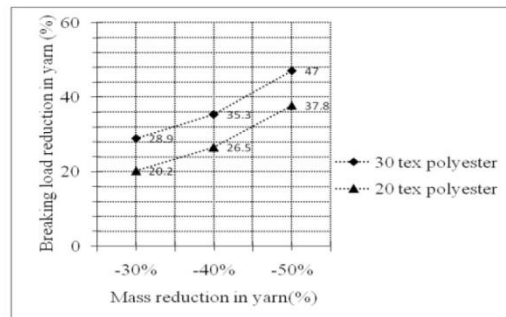
Breaking load

Figure 2 (a)-(c) show the change in breaking load of thin portion with respect to normal yarn. It is seen that the yarn breaking load drops significantly due to the presence of thin places. The drop in breaking load increases when the dimension of thin place increases from -30% to -50%. The drop in breaking load is more for coarser count yarns. The drop for cotton yarn is more than that for the polyester yarn, while it somewhat takes an intermediate position for

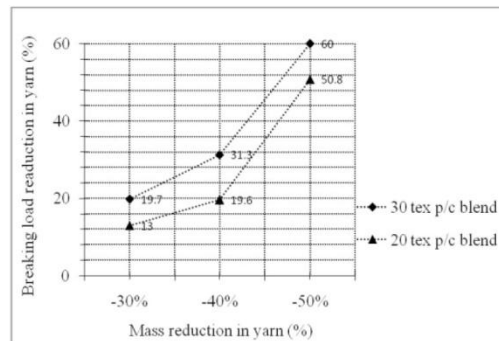
polyester-cotton blended yarn. For -30% thin places the reduction is minimum for polyester-cotton blended yarn while at -50% thin place the reduction of breaking load is minimum for polyester yarn. At a thin place, reduction in the load bearing component is responsible for reduction in breaking load despite having higher inter-fiber cohesion due to higher twist. For coarser count, reduction in diameter leads to more reduction in the absolute number of fibers in the cross section. Such a reduction in load bearing component leads to higher drop in breaking load.



(a)



(b)



(c)

Figure 2: (a)-(c) Variation of beaking load with change in mass of yarn

In the polyester cotton blended yarn the cotton fibre is coarser than the polyester component and so the number of polyester fibre is expected to be more in the cross section. Finer polyester generally predominates the inner region of the yarn thereby maintaining integrity in spite of the reduction in the number of fibres. When the mass reduction is 50%, due to higher interfibre friction polyester yarn succeeds to sustain certain load while low inter fiber friction for cotton and differential frictional characteristic of polyester cotton fibre in blend leads to more reduction in breaking load.

Breaking extension

The variation of breaking extension with mass reduction in the yarn is represented in Figures 3 (a)-(c). It is observed from the figure that the breaking extension (%) decreases consistently for all yarns irrespective of count and composition as the yarn diameter decreases. For -30% thin places, maximum reduction in breaking extension has been observed in case of cotton yarn which continues as the yarn becomes thinner. Reduction of breaking extension in polyester yarn is marginal up to -40% thin places. The reduction in breaking extension is the maximum when the

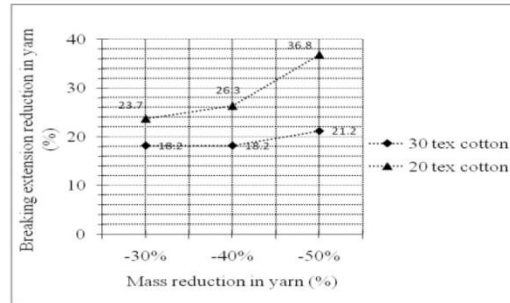
diameter of thin segment changes from -40% to -50% than from -30% to -40%. The breaking extension behavior of polyester cotton blended yarn is following an intermediate path.

- The number of fibers in cross-section and their arrangement in it.
- Amount of inserted twist and its variation which alters the compactness of the structure and hence inter-fiber cohesion. Variation of twist will cause differential compactness along the length of the yarn. The resistance to slippage may also be influenced due to change in migratory behavior of fibers for any change in twist.

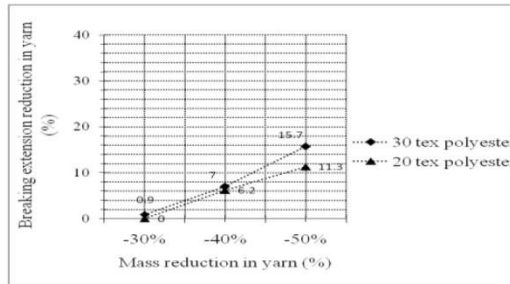
When a yarn is subjected under any load the developed stress in the yarn will be distributed in the yarn. Such a stress distribution is dependent on the local diameter of the yarn. Developed stress will have a tendency to concentrate at thin place

($Stress \propto \frac{1}{area}$) (Morten *et. al.*, 2008). The

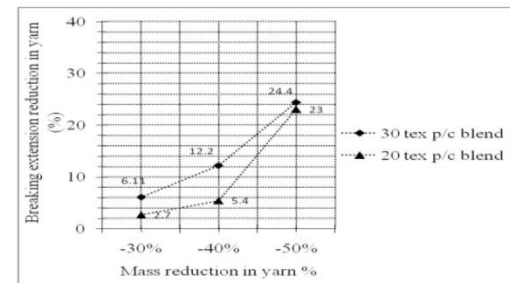
presence of less number of fibers and the tendency of stress to concentrate at the thin place leads to early disintegration of the structure which is manifested as low value of breaking extension.



(a)



(b)



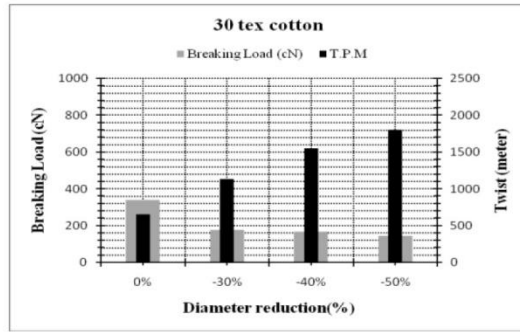
(c)

Figure 3: (a)-(c) variation of breaking extension with change in mass of yarn

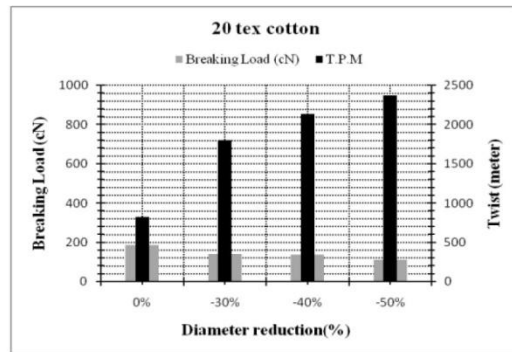
Diameter-strength relationship

Figure 4 (a)-(f) depicts the change in breaking load with change in diameter of yarn. It is observed that as the diameter of the yarn decreases from -30% to -50%, though the twist increases with a possibility of providing higher inter fiber cohesion, the breaking load of the yarn falls consistently. Strength reduction in coarser count is more as compared to the finer count, although the increase of twist in finer count is much higher. When the yarn is coarse, a thin place is associated with a reduction in more number of load bearing component, and obliquity effect too, plays its role due to increase in twist leading to the fall in

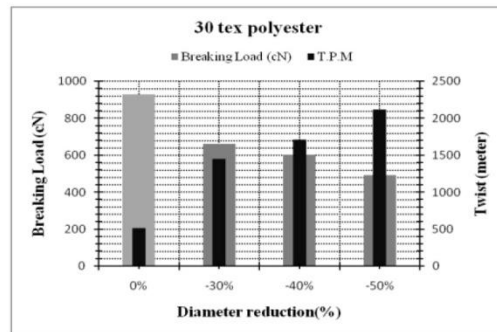
strength of the yarn. Twist has been found to be maximum when the diameter reduction is maximum. The strength has also been found to be minimum at this point. In case of finer count in spite of same twist multiplier the resultant twist per meter is higher as compared to the coarser count. Hence coarser count with more reduction of load bearing component and less twist to hold the structure exhibits more reduction of strength as compared to the finer count. The change in breaking load with change in diameter has been found to be fiber specific. The composition of the yarn has been found to influence the variation of breaking load of yarns.



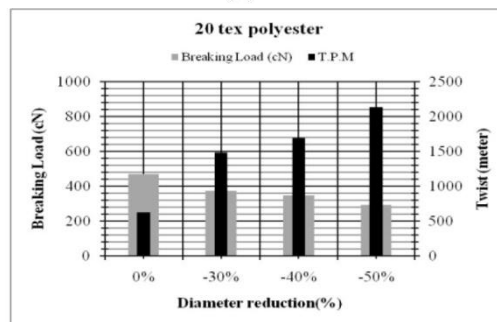
(a)



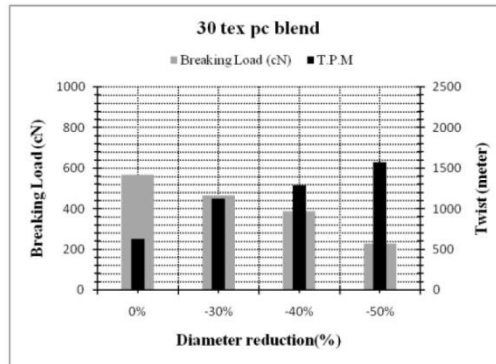
(b)



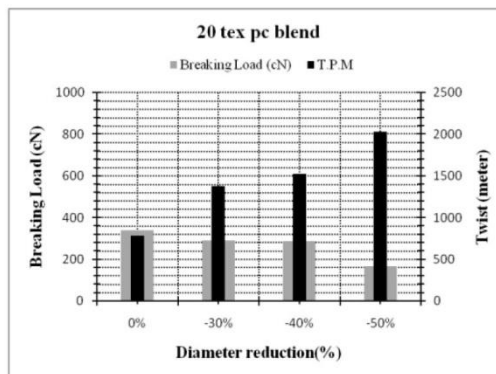
(c)



(d)



(e)



(f)

Figure 4 (a) - (f): Diameter, Twist and strength relationship

5. BREAKING MECHANISM

The distribution of twist in yarn of varying diameter is such that the number of twist turn in the yarn is approximately inversely proportional to the number of fibers and consequently an unequal distribution of twist takes place leading to unequal distribution of stress. Migratory behavior, depending on the spinning tension and the number of fiber in cross-section, however, may help in influencing the resistance to failure. When a staple fiber yarn is subjected to tensile loading, the constituent fibers will experience variable tension according its radial position. This developed tension will apply transverse pressure on the rest of the fibers providing them resistance to slippage.

When a stress is applied to a staple yarn, any possibility of re-adjustment of position of the fibers might help in improving compactness and hence, resistance to slippage of the fibers. When re-adjustment

possibility is less in a well compacted structure the yarn may fail predominantly due to fiber rupture. In a thin place with higher twist, possibility of readjustment of fiber position is less due to higher compactness and presence of less number of fibers. Frictional resistance and entanglement of fibers in the structure may help in better transfer of local stress. Such a transfer of stress may initiate individual fiber failure and influence the breaking mechanism of yarn. The nature of failure in the present study has been found to be influenced by the composition of the yarns and the extent of mass reduction in a thin place.

CONCLUSION

In this study an attempt was made to study the effect of mass reduction on tensile properties, and breakage behavior of yarn. Yarn of three different compositions was taken for the study. Based on the results, it is

concluded that with reduction of mass, local twist shows a significant increase, irrespective of count and composition of yarn. There is successive reduction of breaking load and breaking extension of yarn with reduction of yarn mass. There has been a reduction in strength with reduction in yarn diameter and coarser count yarn shows more reduction in breaking load as compared to finer count yarn. It has been observed that about 80% failure took place at thin region of the yarns. When there is maximum mass reduction, the failure of the yarns was mainly due to fiber slippage, but for other cases failure was completed through a combination of slippage and breakage of fibers. The mechanism of yarn failure was found to be influenced by the dimension of the thin place and the composition of the yarns.

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