Sept. 24, 1968 G. SHAW ETAL 3,402,416

INTEGRALLY CONNECTED BRUSH FIBRES

Filed Nov. 23, 1966 4 Sheets-Sheet 1

FIG-1

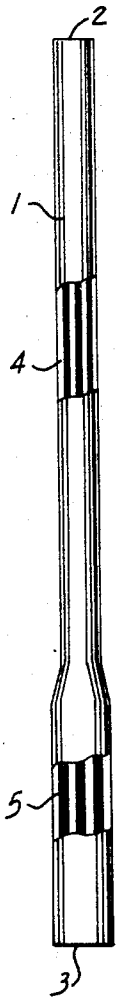


FIG-2

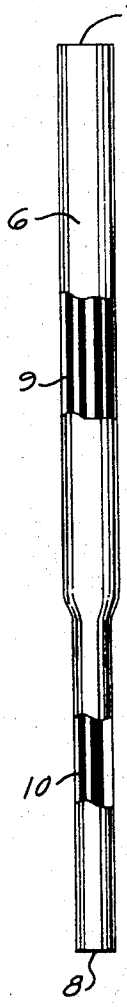
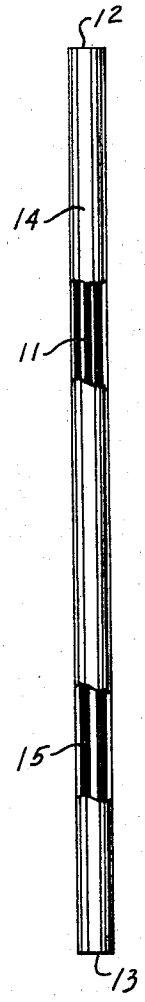


FIG-3



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INTEGRALLY CONNECTED BRUSH FIBRES

Filed Nov. 23, 1966 4 Sheets-Sheet 2

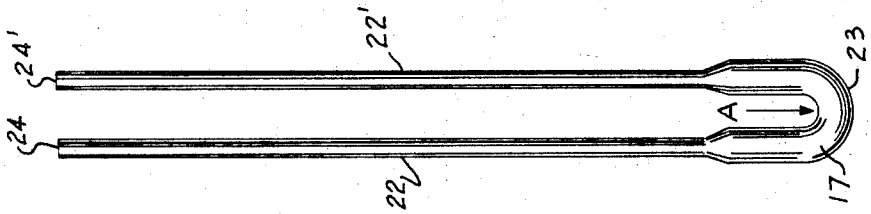


FIG-7

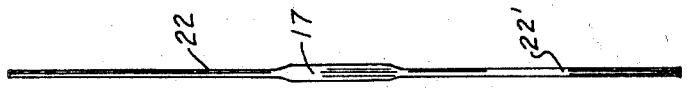


FIG-6

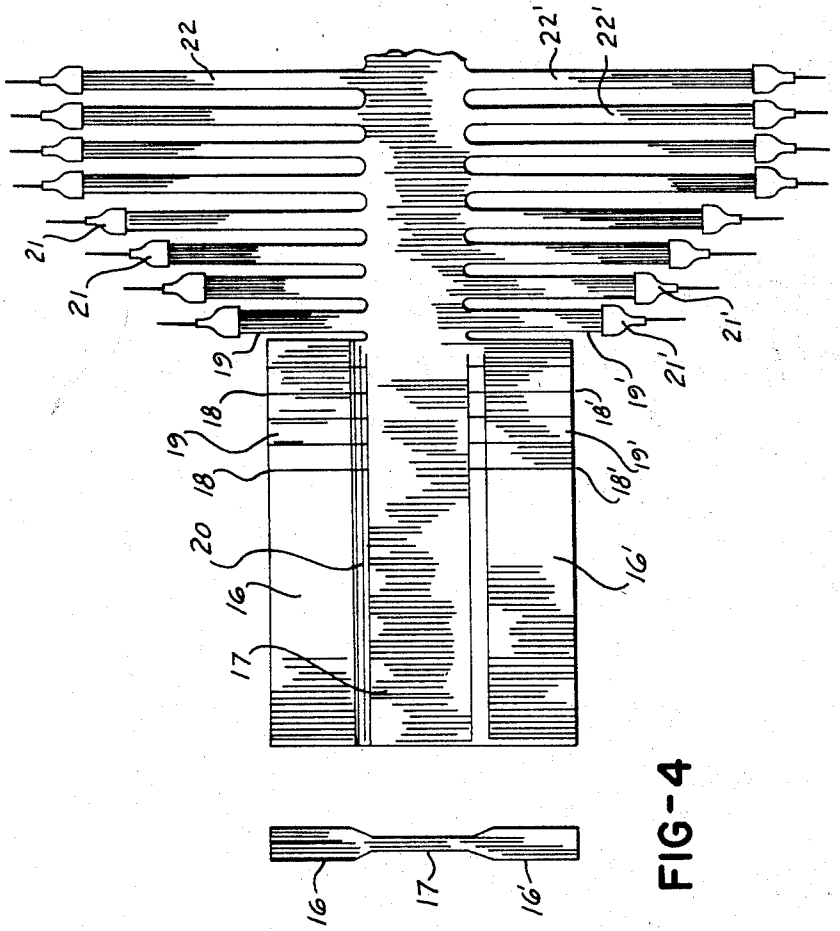


FIG-5

FIG-4

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INTEGRALLY CONNECTED BRUSH FIBRES

Filed Nov. 23, 1966 4 Sheets-Sheet 3

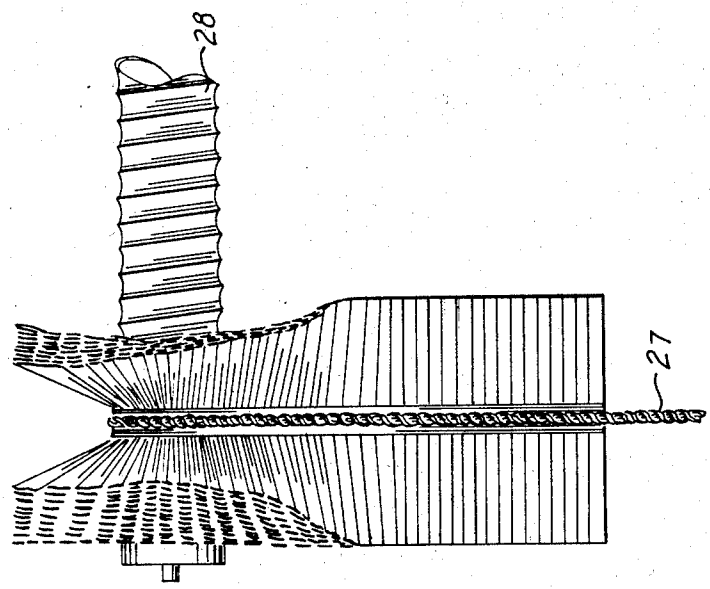


FIG-9

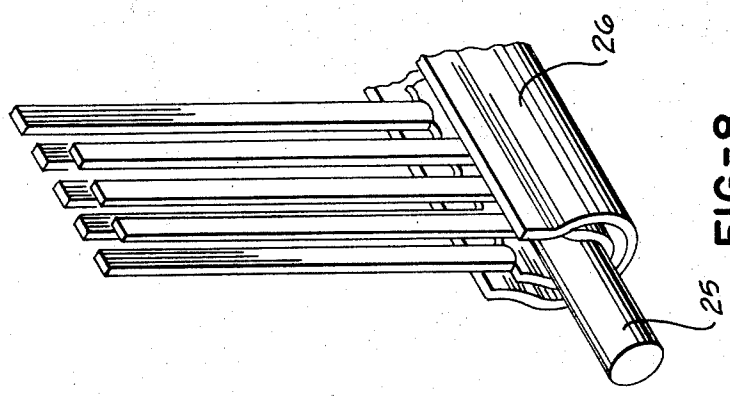


FIG-8

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Sept. 24, 1968 G. SHAW ETAL 3,402,416

INTEGRALLY CONNECTED BRUSH FIBRES

Filed Nov. 23, 1966 4 Sheets-Sheet 4

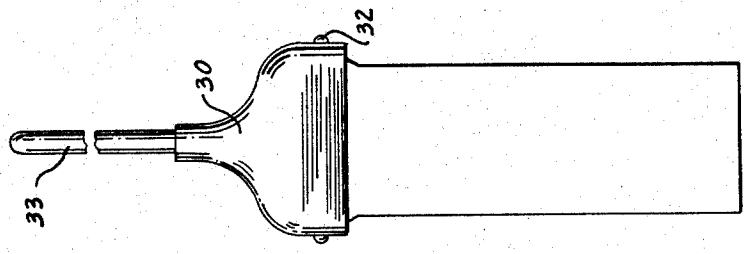


FIG-14

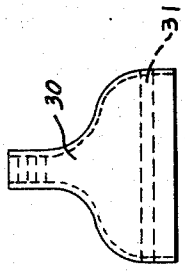


FIG-13

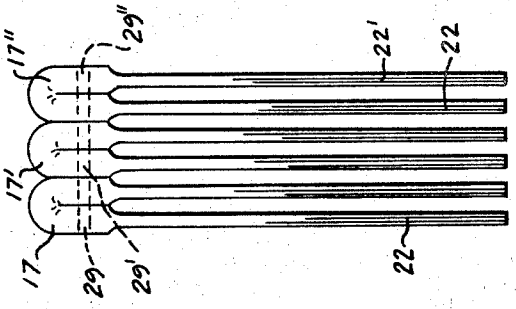


FIG-12

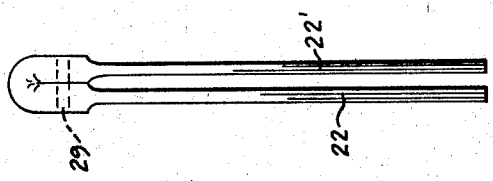


FIG-11

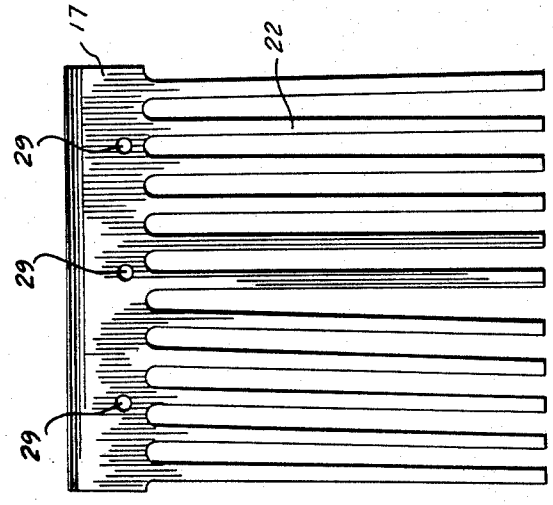


FIG-10

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3,402,416

INTEGRALLY CONNECTED BRUSH FIBRES

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Filed Nov. 23, 1966, Ser. No. 596,492
20 Claims. (Cl. 15—159)

ABSTRACT OF THE DISCLOSURE

This invention relates to thermoplastic brush fibres integrally connected by means of a thermoplastic support having improved characteristics, particularly improved wear resistance, i.e., abrasion resistance or resistance to wear. The invention also includes novel brush constructions employing the fibres of this invention.

The improved characteristics of the brush fibres of this invention are attained by effecting a greater amount of orientation in the fibre section located at or near the working end than the fibre section adjacent thereto.

Prior to this invention, thermoplastic brush fibres have made no use of the degree of orientation within specific fibre sections along the length of a given fibre in order to improve their utility. To date, thermoplastic brush fibres have been produced either as completely unoriented fibres (U.S. Patent No. 3,121,040) or as completely oriented fibres (U.S. Patents Nos. 2,292,905, 2,637,893, and 3,106,442).

It will be apparent in the discussion which follows wherein the novel brush fibres of this invention differ from prior brush fibres and it should also be apparent why the improved brush fibres offer superior wear resistance among other advantages.

Objects and advantages of this invention will be set forth in part hereinafter and in part will be obvious herefrom, or may be learned by practice with the invention, the same being realized and attained by means of the steps, methods, combinations and improvements pointed out in the appended claims.

This invention consists in the novel steps, combinations, and improvements herein shown and described.

An object of this invention is to provide novel brush fibres having improved abrasion resistance at or near their working end because of the greater amount of orientation section of the fibre.

Yet a further object of this invention is to provide a in that section of the fibre than in the adjacent supporting multiplicity of fibres having improved abrasion resistance integrally connected by means of an unoriented portion of thermoplastic material.

Still another object of this invention is to provide a continuous multiplicity of fibres extending laterally from a common segment and integrally connected thereto, said fibres possessing near or at their working ends a greater degree of orientation in the mass than at some other point along their length.

Yet another object of this invention is to provide novel brush constructions employing brush fibres having the qualtities set forth in the foregoing objects.

It has been found that many of the objects of this invention may be realized by forming a fibre comprising a

working zone which has been oriented along the longitudinal axis of the fibre to a comparatively high extent and an integral, adjacent supporting zone which has been oriented to a comparatively low extent. In order to provide high abrasion resistance at the working end of the fibre, it is desirous that the degree of orientation at or near the working end be at least about 4% greater than the degree of orientation in an adjacent portion of the same fibre. It can be appreciated that there can exist a single fibre unit possessing a working area having at or near the working end a high degree of orientation and an adjacent supporting area having little or no orientation. By such construction for a fibre, it is possible to obtain fibres having a good overall balance of abrasion resistance, flexural characteristics and recovery.

FIGURE 1 is a front elevational view of a brush fibre of this invention having a working end possessing a greater degree of orientation providing an abrasion resistant zone having a lesser cross-sectional area of material adjacent to a stem zone possessing a lesser degree of orientation having a greater cross-sectional area of material than the working end.

FIGURE 2 is a front elevational view of a brush fibre of this invention having a working end possessing a greater degree of orientation providing an abrasion resistant zone having a greater cross-sectional area of material adjacent to a stem zone possessing a lesser degree of orientation having a smaller cross-sectional area of material than the working end.

FIGURE 3 is a front elevational view of a brush fibre of this invention having a working end possessing a greater degree of orientation providing an abrasion resistant zone having the same cross-sectional area of material adjacent to a stem zone possessing a lesser degree of orientation.

FIGURE 4 is an end view of an extruded flat band of unoriented thermoplastic material comprising two longitudinal heavy portions of material adjacent to a thinner supporting member.

FIGURE 5 is a top view of an assembly line for producing fibres of this invention in a continuous manner using the band of thermoplastic material as shown in FIGURE 4.

FIGURE 6 is an end view of an interconnected strip of fibres as produced in accordance with the assembly line as shown in FIGURE 5.

FIGURE 7 is an end view of the fibre strip in FIGURE 6 having two working ends possessing a greater degree of orientation providing abrasion resistant zones having lesser cross-sectional areas of material than an intermediate supporting zone doubled through a bend of 180 degrees at about its mid-point.

FIGURE 8 is an isometric view illustrating how the interconnected fibres of FIGURE 6 may be retained by wire in normal strip brush construction.

FIGURE 9 is an isometric view illustrating how the interconnected fibres of FIGURE 6 may be wound on to a broom core.

FIGURES 10–14 illustrate a method of assembling a brush using fibre sections of FIGURE 6. FIGURE 10 is a front view of a section comprising a multiplicity of fibres joined by a common segment. FIGURE 11 is a side view of FIGURE 10. FIGURE 12 is a side view of three sections aligned side by side.

FIGURE 13 is an end view of a cap adapted to be

placed over aligned segments of FIGURE 12 in the manner shown in end view FIG. 14 which shows a finished brush construction with the sections riveted together and a handle screwed into the cap.

In order to describe the invention more fully, reference is now made to the specific embodiments illustrated in the drawings.

The brush fibre **1** shown in FIGURE 1 is of generally circular cross-section and comprises a working end **2** possessing a greater degree of orientation **4**, preferably at least 10% greater, than a stem end **3** possessing little or no orientation **5**. The cross-sectional area of the working end is less than the cross-sectional area of the stem end, which comes about from orienting a portion of material having an original cross-section of uniform area.

A method for obtaining the brush fibre as shown in FIGURE 1 is as follows:

Crystalline isotactic polypropylene having a melt flow of 4.0 dg./min. and a specific gravity of 0.905 was fed into a 1 inch extruder (20–1) fitted with a die having 1 vertically disposed orifice of 0.250 inch. The temperature on both the die and extruder during extrusion was 500 degrees F. The extrudate was removed at the rate of 65 feet/minute through a cold water bath having a temperature of 40 degrees C. The emerging filament was cut into 12 inch lengths.

The resulting unoriented filament (of essentially uniform cross-section along its length) is held at about its mid-point, 6 inches, by two cold anvils (40 degrees C.) having dimensions in the order of 0.5 inch diameter. In a separate operation, a clamp is affixed to one end of the filament and with an even and controlled force, the clamp is extended laterally in order to effect orientation along a portion of the length of the fibre. A reduction in the cross-sectional area of the fibre results as the degree of orientation is increased. The clamp is extended until approximately 3 times the original length is reached (18 inches) which results in about 200% stretch. This stretching operation takes place in the presence of dry heat; the temperature being in the order of 125 degrees C.

The resulting fibre **1**, having a 6 inch stem portion **3** containing little or no orientation **5**, adjacent to an oriented portion **4** having a length of 18 inches and a resulting cross-sectional area of 0.01 square inch, is so formed. It must be appreciated that a small amount of unoriented material must be trimmed off from the oriented end after the removal of the clamp. Thus the working end **2** has a greater degree of orientation present along its length than the stem portion end **3**.

Increased wear resistance can come about by effecting different degrees of orientation at or near the working end. In order to fully understand the varying degrees of orientation that can exist within the fibre length it becomes necessary to define a method for analyzing for a change in orientation.

One such method used is based upon the degree of elongation present in the fibre. When a synthetic fibre is stretched along its length to a given amount, i.e., four times its original length, said stretching aligns the molecules, there exists a definite quantity of elongation. This type of elongation is primary, since it can be demonstrated that before Young's modulus is reached the fibre stretches or increases in length until it acquires a maximum degree of orientation. This measure of stretch (elongation) is approximately constant within a given type of polymer for a given orientation ratio. As the tensile strength of a fibre increases, the elongation decreases, and thusly synthetic fibres possessing high elongations have low tensile strengths. It can be shown that polypropylene fibres which have been oriented to 200% possess elongations in the range of 150–200%. As the orientation percentage is increased, say to 300%, the elongation decreases to the order of 80–90%. Table I shows how the elongation decreases with an increase in the percentage of orientation for polypropylene fibres.

TABLE I

Shape of fibre [1]	Percent orientation ratio	Diameter (in.)	Percent elongation [2]
Circular	100	0.015	196
Do	200	0.015	114
Do	300	0.015	82
Do	400	0.015	82
Do	500	0.015	64
Do	600	0.015	39
Do	700	0.015	36
45% hollow	100	0.015	130
Do	200	0.015	80
Do	300	0.015	64
Do	400	0.015	60
Do	600	0.015	25
25% hollow	100	0.015	206
Do	200	0.015	85
Do	300	0.015	65
Do	400	0.015	60
Do	500	0.015	54
X-shaped	100	0.015	186
Do	200	0.015	85
Do	300	0.015	50
Do	400	0.015	30
Do	500	0.015	22

[1] Material is Bakelite 4500 polypropylene; melt flow 4.0; density 0.905.
[2] Percent elongations are averages of five fibres each in each type of fibre.

A second and somewhat more definite method for determining the degree of orientation in a fibre section is to determine the dichroic ratio for a particular absorption band using infrared spectrophotometry analysis. The dichroic ratio is defined as the ratio of the optical densities of an absorption band measured with radiation polarized respectively parallel and perpendicular to a given direction in the fibre sample.([1])

The fibre sample is mounted in a spectrograph with the direction of orientation parallel to the slit. The absorption spectrum is then recorded for a given micron region and the fibre sample remounted with the direction of orientation perpendicular to the slit, and again the absorption spectrum recorded for the same micron region. The optical densities $I_{\parallel}$ and $I_{\perp}$ for the two orientation directions are then calculated from the resulting band. The ratio R of these densities is the dichroic ratio.([2,3])

$$R\frac{I_{\perp}}{I_{\parallel}}$$

Table II shows how the dichroic ratio changes for a given micron region when the only variable present is the degree of orientation.

TABLE II

Shape of fibre	Percentage orientation	Diameter or thickness (in.)	Dichroic ratio or 11.9 micron band
Hollow [1]	100	0.015	2.2±0.05
Do	300	0.015	2.0±0.05
Do	500	0.015	1.5±0.05
Film [2]	500	0.003	2.1±0.05
Do	600	0.003	1.9±0.05
Do	700	0.003	1.7±0.05

[1] The material used is Bakelite Polypropylene 4500.
[2] The material used is Chevron Polypropylene 9094 (melt flow 2.5; density 0.90).

The data in Table III which follows clearly show the improvement in wear resistance which can be obtained by effectively increasing the degree of orientation at the working end. In obtaining the data in Table III apparatus and procedure used were as follows:

The apparatus used was en end-test apparatus whereby the working end of a fibre was subjected to reciprocating movement (8 inch path, 24 cycles per minute) across the surface of emery cloth held under load of 165 grams throughout. New emery cloth was used for each test. The emery cloth surface was cleaned when wear measurements were taken. Throughout all the tests, wear measurements were taken every 15 minutes. The data reported in Table III which follows bring out a very significant point. Polypropylene fibres can be oriented to any degree

[1] Infrared Spectroscopy of High Polymers, Rudolf Zbinden, Academic Press, New York, 1964, page 7.
[2] Ibid, page 8.
[3] Ibid, page 168.

between 0 and 700%. In so doing, the rate or amount of wear per hour can be regulated by imparting to the working end of the fibre a given percentage of orientation. As an example, a fibre whose working end has been oriented to 400% will wear twice as fast per hour as a fibre whose working end has been oriented to 600%. Likewise, fibres made from copolymers of polypropylene also display increased wear as the degree or percentage of orientation is increased. This fact is pointed out in Table III.

TABLE III

Fibre type	Area of fibres [1]	Percent of orientation [2]	Inches of wear [3]
Propylene [4]	0.020	0	0.240
Do	0.020	300	0.150
Do	0.020	400	0.106
Do	0.020	500	0.060
Do	0.020	600	0.050
Do	0.020	700	0.043
Polyallomer [5]	0.02	200	0.140
Do	0.02	300	0.125
Do	0.02	400	0.109
Do	0.02	500	0.094

[1] Area is in square inches.
[2] The percentage of orientation was measured by using both of the methods as described in Tables I and II.
[3] Wear is measured in inches and is for a total testing time of 2 hours.
[4] The polypropylene used for testing was Bakelite 4500.
[5] The polyallomer used for testing was Eastman Polyallomer 5021A; melt flow 2.5; density 0.905.

FIGURE 2 shows a brush fibre **6** of generally circular cross-section and comprises a working end **7** possessing a greater degree of orientation **9** than a stem end **8** possessing little or no orientation **10**. The cross-sectional area of the working end **7** is greater than the cross-sectional area of the stem **8**. In order to effectively obtain the brush fibre as shown in FIGURE 2, it become necessary to start with an unoriented portion of thermoplastic material having alone its length two different cross-sectional areas. The section of fibre which ultimately will possess the greater degree of orientation **9** and provide a working end **7**, having a larger cross-sectional area of material than the stem end **8**, will before orientation comprise the larger portion of material, and during the process of orientation will become somewhat less in cross-sectional area than when in the unoriented state, yet will not equal the cross-sectional area of the stem section. Also, the length of the working end of the fibre will change markedly as the large portion is oriented to a greater percentage than its original length. The point of attachment of the fibre **6**, to a brush body is at **8**.

FIGURE 3 shows a brush fibre, **14**, of generally circular cross-section and comprises a working end **12** possessing a greater degree of orientation **11** than a stem end **13** possessing little or no orientation **15**. The cross-sectional area of the entire fibre **14**, both working end **12** and the stem end **13**, is essentially the same.

The preferred single fibre of this invention would be the fibre in FIGURE 3 in which the cross-sectional area of the fibre **14** remains constant for both the abrasion resistant zone **12** and the stem zone **13**, yet the abrasion resistant zone **12** possessing a greater degree of orientation **11** than the stem zone **15**. The abrasion resistant zone of such a fibre will outwear the abrasion resistant zone of an unoriented fibre having the same cross-sectional area.

Referring to Table III it can be demonstrated that if the fibre **14** in FIGURE 3 had a diameter equal to an area of 0.02 square inch and the working end was oriented to 600% and the stem end oriented to 400%, there would be present in the working end twice the amount of abrasion resistance as in the stem end. The point of attachment of this fibre **14**, to a brush body is at **13**.

In producing a fibre as shown in FIGURE 3 it is necessary to start with an unoriented portion of thermoplastic material having along its length two different cross-sectional areas, the larger cross-sectional area of such size so as to produce an abrasion resistance zone **11** of the same cross-sectional area as the stem end **13** after it has been oriented to a given percentage of its original length.

The integrally connected brush fibres as shown in FIGURES 5 and 6 comprise a multiplicity of oriented fibres extending laterally from a common unoriented supporting member. A method for obtaining the fibre strip as shown in FIGURES 5 and 6 is as follows:

Crystalline isotactic polypropylene having a melt flow of 4.0 dg./minute and a specific gravity of 0.905 was fed into a 2 inch extruder (20–1) fitted with a slotted horizontal die having a dimension of approximately 0.125 x 2.25 inches. The temperature on both the die and extruder during extrusion was 500 degrees F. The die configuration was such that a flat band of unoriented thermoplastic material comprising two longitudinal heavy portions of material adjacent to a thinner supporting center member was extruded into a water bath (temperature of approximately 40 degrees C.) at the rate of 65 feet per minute. The bath was 20 feet in length. The resulting band was then cut into 18 inch lengths and subsequently processed in the following manner.

A band of fibres (shown in end view in FIGURE 4) comprising two heavy thick portions of unoriented material **16** and **16'** having a common center supporting member **17** is cut laterally to its length as shown in FIGURE 5 by a multiplicity of parallel cuts **18** and **18'**, said cutting resulting in unoriented fibres **19** and **19'** which extend from a non-cut center portion **17** of about 0.250 inch to the respective side edges of the band, the lines of the respective cuts being spaced by a distance of 0.125 inch. The cutting or slicing operation can be carried out by any suitable means.

The resulting sliced band **20** is then held longitudinally from above and below along the 18 inch center member **17** by cold anvils having dimensions in the order of 0.125 x 18 inches. In a separate operation, clamps **21** and **21'** are affixed to the ends of the sliced strips **19** and **19'** and with an even and controlled force, the clamps are extended laterally in order to effect orientation along the length of the cut strip. This operation is performed in the presence of heat, e.g., at 125° C. A reduction in the cross-sectional area of the strips **22** and **22'** takes place as the degree of orientation is increased. The clamps are extended until approximately 2 times the original length is reached (300% stretch). The cross-sectional area per oriented fibre **22** and **22'** is reduced from approximately 0.015 square inch before orientation to 0.0039 square inch. This operation is carried out on all the cut fibre strips in the 18 inch length. A small unoriented portion which is held by the clamp during orientation is subsequently cut from **22** and **22'** leaving an essentially square working end extending four inches from the center of the unoriented band. The resulting fibre strip comprises highly recoverable stiff and abrasion resistant oriented fibres **22** and **22'** all having the same common supporting member **17**.

As shown in FIGURE 7, when the fibre strip **20** of FIGURE 5 is bent 180 degrees around **23** and fastened in the direction A through **23** as in standard brush manufacturing practice, two working ends **24** and **24'** having maximum abrasion resistance and a greater degree of orientation than at portion **23** become available in the same plane to do work.

The embodiment of FIGURE 8 comprises the connected and doubled over fibre arrangements of FIGURE 7, retained by a wire **25**, in a metal channel **26**.

The embodiment of FIGURE 9 comprises the connected and doubled over fibre arrangement of FIGURE 7 retained by a cable **27** on a core **28**. This is normal assembly for rotary-type brushes.

FIGURES 10–14 show how segments with protruding filaments illustrated in FIGURE 7 may be assembled into a finished brush. More particularly, as shown in FIGURES 10 and 11, fibres **22** and **22'** of this invention protrude from a common segment **17**. The common segment **17**, bears holes **29** or other means for attaching it to other similar segments. A side view of this segment is shown in FIGURE 11. In FIGURE 12 three similar segments, **17**, **17'** and **17''**, are placed so that the holes **29** are aligned with similar holes **29'** and **29''** in sections **17'**

and 17''. As shown in FIGURE 13, there is provided a molded cap **30**, with three sets of holes **31**, which are spaced the same as holes **29**, **29'** and **29''** in the corresponding segments **17**, **17'** and **17''**. When cap **30** is placed over segments **17**, **17'** and **17''** as shown in FIGURE 14 and rivet attachments **32** are driven through the matching holes of the cap and the three segments and a handle **33**, is screwed into cap **30**, a finished brush emerges as shown in FIGURE 14.

The magnitude of the fibres described in the invention is such that the maximum cross-sectional area of the fibres is in the range of 0.006 to 0.200 square inch and their minimum cross-sectional area is in the range of 0.003 to 0.150 square inch.

The preferred thermoplastic compositions for making the fibres of this invention are "polypropylene" materials. By polypropylene is meant polymers of propylene and copolymers of propylene wherein propylene is in a major amount, e.g., polyallomers which are propylene-ethylene copolymers. Of particular interest are isotactic polypropylene and crystalline polypropylene and crystalline polyallomer material. By "isotactic polypropylene" is meant polypropylene comprising crystallizable isotactic molecules and up to 15% of amorphous, non-crystallizable macromolecules. Polymers of the aforedescribed type are described in U.S. Patent No. 3,106,442.

It should be appreciated that while the examples set forth herein have dealt with the preferred polymers of propylene and copolymers of propylene, other thermoplastics such as polyamides would give excellent brush fibres of the type covered by this invention. Colorants, extenders, plasticizers and modifiers may be added to these materials as practice dictates.

The invention in its broader aspects is not limited to the specific steps, methods, compositions, combinations and improvements described but departures may be made therefrom in the scope of the accompanying claims without sacrificing its chief advantages.

What is claimed is:

1. A thermoplastic brush fibre having improved abrasion resistance comprising an abrasion-resistant zone of uniform cross-sectional area at the working end oriented along the longitudinal axis of the fibre to a comparatively high extent, and an integral, adjacent supporting zone oriented along the longitudinal axis of the fibre to a comparatively low extent where the extent of orientation in the abrasion-resistant zone is at least 4% greater than the extent of orientation in the supporting zone, the oriented molecules in both the abrasion-resistant zone and the supporting zone being aligned in the same longitudinal direction.

2. A thermoplastic brush fibre according to claim **1** wherein the abrasion-resistant zone and supporting zone are of the same cross-sectional area.

3. A thermoplastic brush fibre according to claim **1** wherein the abrasion resistant zone is of greater cross-sectional area than the supporting zone.

4. A thermoplastic brush fibre according to claim **1** wherein the abrasion-resistant zone is of a lesser cross-sectional area than the supporting zone.

5. A polyproylene brush fibre according to claim **1.**

6. A polyallomer brush fibre according to claim **1.**

7. A polyamide brush fibre according to claim **1.**

8. A brush construction comprising a plurality of fibres according to claim **1** supported at one end by means of a suitable support.

9. A multiplicity of abrasion-resistant thermoplastic brush fibres according to claim **1** wherein the supporting zones of said fibres form a common supporting thermoplastic segment.

10. A multiplicity of abrasion-resistant brush fibres according to claim **9** wherein the supporting segment is non-oriented.

11. A multiplicity of abrasion-resistant brush fibres according to claim **9** wherein the thermoplastic material is polypropylene.

12. A multiplicity of abrasion-resistant brush fibres according to claim **9** wherein the thermoplastic material is polyallomer.

13. A multiplicity of abrasion-resistant brush fibres according to claim **9** wherein the thermoplastic material is polyamide.

14. A multiplicity of abrasion-resistant thermoplastic brush fibres according to claim **9** wherein the common segment integrally connects two fibres in an end to end relationship.

15. A multiplicity of abrasion-resistant thermoplastic brush fibres according to claim **9** wherein the common segment integrally connects at least two fibres in a parallel relationship.

16. A multiplicity of abrasion-resistant thermoplastic brush fibres according to claim **9** wherein the common segment integrally connects in an end to end relationship one row of parallel fibres with a second row of parallel fibres.

17. A brush construction comprising the fibre arrangement of claim **16** wherein the common segment is doubled through a bend of 180 degrees at its mid-point.

18. A strip brush construction according to claim **17** wherein the doubled over segment is maintained in a suitable supporting channel by suitable retaining means.

19. A rotary brush construction according to claim **17** wherein the doubled over segment is retained on a core by suitable cable means.

20. A brush construction comprising a plurality of the fibre arrangements of claim **16** each of the fibre arrangements having its common segment doubled through 180 degrees at its mid-point, said common segments being aligned side by side and being connected together by suitable connecting means.

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