June 1, 1971 W. H. SLOAN ET AL 3,582,453

GROOVED STRAPPING

Filed May 7, 1969 2 Sheets-Sheet 1

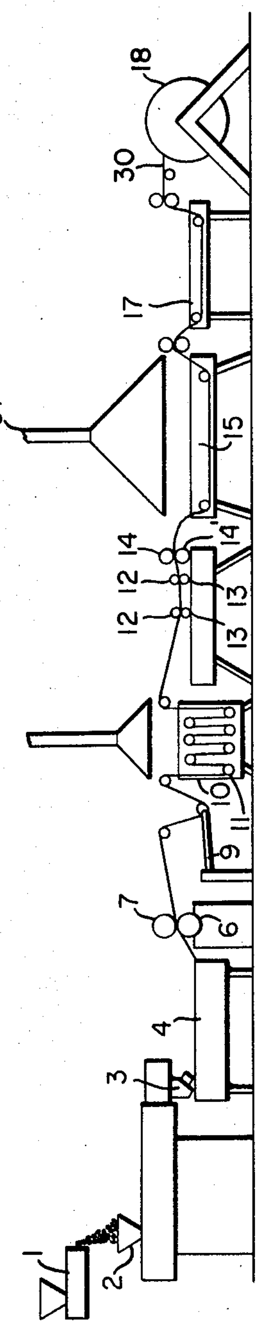

FIG. 1

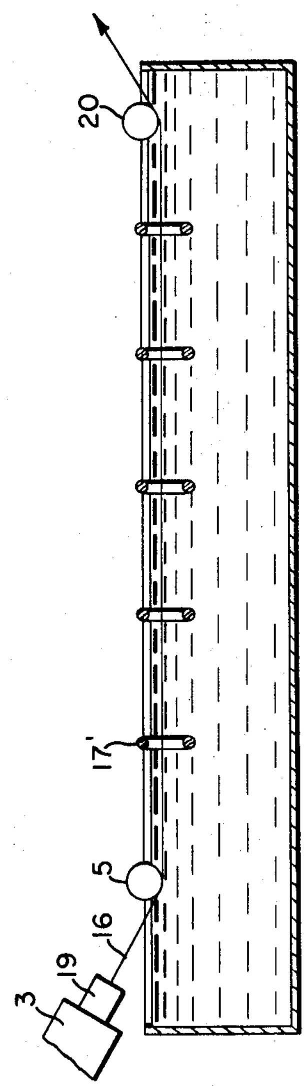

FIG. 2

INVENTORS
WILLIAM H. SLOAN
HOWARD W. STARKWEATHER, JR.

BY Frank C. Hilberg Jr.
ATTORNEY

June 1, 1971 W. H. SLOAN ET AL 3,582,453

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Filed May 7, 1969 2 Sheets-Sheet 2

FIG. 3

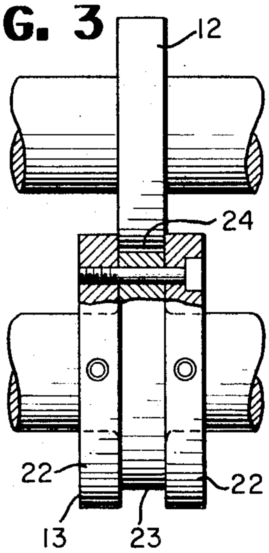


FIG. 4

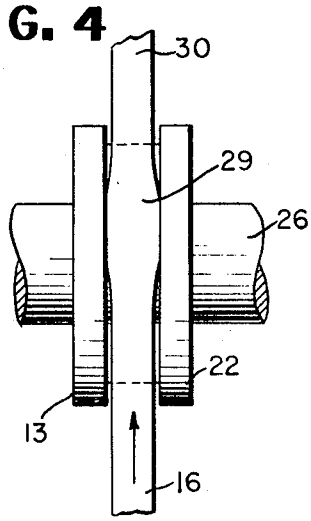


FIG. 5

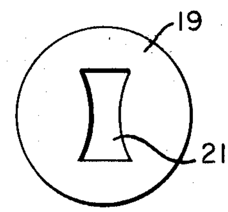


FIG. 6

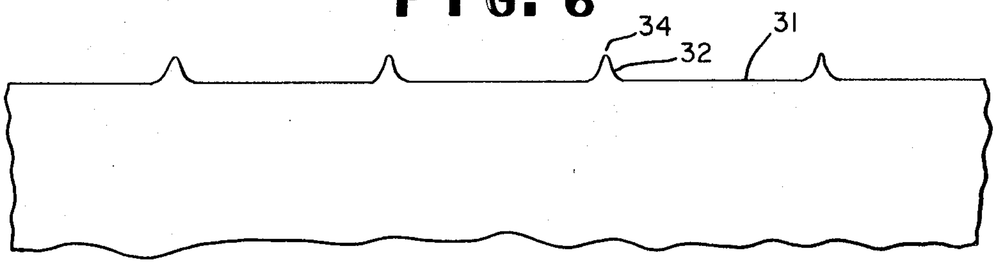


FIG. 7

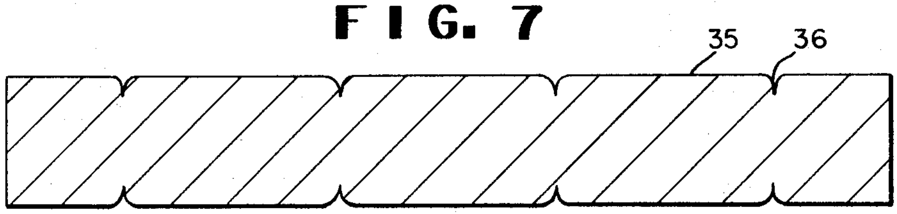
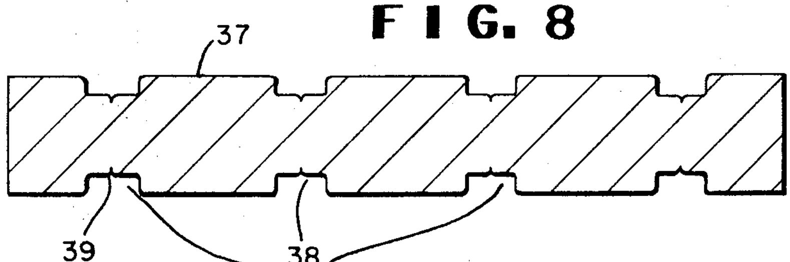


FIG. 8



INVENTORS

WILLIAM H. SLOAN
HOWARD W. STARKWEATHER, JR.

BY Frank C. Hilberg Jr.

ATTORNEY

United States Patent Office

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1

3,582,453

GROOVED STRAPPING

William Henry Sloan, Vienna, W. Va., and Howard Warner Starkweather, Jr., Wilmington, Del., assignors to E. I. du Pont de Nemours and Company, Wilmington, Del.

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Int. Cl. B32b *3/00;* B65d *63/00*

U.S. Cl. 161—123 7 Claims

ABSTRACT OF THE DISCLOSURE

A highly oriented strapping having a series of longitudinal grooves which causes the strapping to split along the grooves rather than across the width of the strapping thereby preventing breaking of the strapping from tearing across the entire width when partially cut under tension, and a multi-step roll orienting process for fabricating such strapping in which the final pair of orienting rolls also form the grooves.

BACKGROUND OF THE INVENTION

The present invention relates to an improvement in strapping such as that described in U.S. Pat. No. 3,354,023 issued Nov. 21, 1967, to Gordon Beale Dunnington and Reuben Thomas Fields. When making strapping in accordance with the teachings of this patent, it is necessary to maintain a fairly high longitudinal splitting tendency in order to avoid a transverse tearing tendency in the strapping. This transverse strength has been obtained when making such strapping by carefully maintaining the width of the strapping close to that of the billet from which it is made and by carefully controlling the degree of longitudinal deformation at a level low enough to provide adequate transverse strength in the strapping. Thus, transverse strength and resultant longitudinal split resistance in the past has been obtained at the expense of the longitudinal strength of the strapping.

SUMMARY OF THE INVENTION

It has now been found that the destruction of the usefulness of the strapping from tearing can be avoided by providing the strapping with a series of longitudinal grooves, of the hereinbelow defined shape. When a tear originates in such a strapping it propagates more or less along the longitudinal dimension of the strapping but generally has some cross propagation as well until such a cross propagation either reaches the edge of the strapping or it reaches one of the longitudinal grooves provided in accordance with the present invention whereupon such tear becomes a split which follows along such grooves rather than across the strapping.

In accordance with the present invention, a crystallizable synthetic polymer is extruded into a billet which is then rolled so as to produce a uniplanar, axial oriented crystalline product. The oriented polymer must be crystalline in order to have the desired mechanical properties and to retain these properties following exposure to moderately elevated temperatures. It is preferred to orient the crystals so that the polymer chains lie within a narrow angle from the direction of rolling in order to obtain the properties most useful as strapping. However, the maximum obtainable deformation may result in undesirable properties such as a tendency to tear, split, fibrillate, or form a hairy surface. Thus, it is necessary to produce a high but carefully controlled degree of deformation. The width of the strapping is preferably from 0.7 to 1.5 times the width of the billet from which it is rolled. To accomplish this objective it has been found that the uniformity of the extruded billet prior to the roll orienting step is of extreme importance to the successful production of a high strength rolled shape. This uniformity relates both to the cross-sectional dimensions of the extruded billet and to any orientation imposed on the billet. If the billet is passed through turns before it has set or cooled sufficiently to have become solid throughout or at least have thick skins on both surfaces, the still fluid material in the interior will become displaced producing a washboard effect or differential strain. Such an irregular billet cannot be roll oriented into a useful high strength strapping because some sections will pass their maximum orientation potential and fibrillate or become hairy before the central sections have been oriented to their optimum. The strapping of this invention is preferably from 10 to 50 mils thick and from ¼ to 1½ inch wide although wider widths can be made and are desirable for some purposes such as helically wrapping large diameter pipe, and widths as narrow as ⅛ inch are useful. The billet is therefore preferably at least 40 mils thick and at least ¼ inch wide.

2

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a schematic side view of the entire apparatus;

FIG. 2 is a detailed side view of the extruder head and quench bath;

FIG. 3 is a detailed end view of one of the orienting rollers;

FIG. 4 is a view of the strapping as it passes through one of the grooved orientation rolls;

FIG. 5 is an end view of the extrusion die showing the shape of the die opening;

FIG. 6 is an enlarged cross-sectional of one of the orientation rolls showing the groove-forming members; and

FIG. 7 is a cross-section of a grooved strapping produced in accordance with the present invention.

FIG. 8 is a cross-section of a grooved strapping produced in accordance with the present invention illustrating grooves of an alternate configuration.

In carrying out the process of this invention, polymer powder or flake is fed by means of flake metering feeder **1** into the extruder hopper **2**, and is extruded through extruder head **3** into a quench bath **4**. The billet, thus formed, is drawn out of the quench bath by rolls **6** and **7**, and is fed across dancer arm **9**, into preheater **10**, wherein it is passed back and forth across rollers **11**.

The temperature of the billet is from ambient temperature to 15° C. below the crystalline melting point of the particular polymer being roll-oriented. Although the billet can be roll-oriented at room temperature the operation is performed more smoothly and with a substantial reduction in power consumption when an elevated temperature is used. It should be further noted that even though water is preferably used in the quench bath because of its ready availability and high specific heat, the billet is preferably in an anhydrous condition as it is fed into the orienting rolls. This is because the heat developed in the orientation rolls by the rearrangement of the polymer molecules in the billet may cause vaporization of any water or other low boiling liquid present, and thereby, create voids or other flaws in the strapping. The preheated billet is then fed through one or more pairs of orienting rolls by means of tension rolls **14, 14'**, passed through heat conditioner **15**, equipped with exhaust **31**, through wash tank **17** and finally is taken up onto spool **18**.

In FIG. 2 the billet **16** is shown as it comes from the extrusion head and is passed under guide roll **5**, through guide pins **17**, and under roll **20** and out of the quench bath. It is preferred that the angle between the extrudate leaving the extruder head **3** and the path the billet follows through the quench bath be small. The preferred angles are from 8 to 15°. Because of the problems involved in removing the billet from the quench bath due to said billets high stiffness, it is also preferred to have a small angle of arc as the billet passes under roll **20** prior to leaving the quench bath. Therefore, the billet must run substantially parallel to the surface of the quench bath and leave the bath at an angle with the bath surface which also preferably falls within the range of from 8 to 15°. It is also preferred to have the extrusion head as close to the quench bath as possible. When using a low melt strength polymer such as the polyamide of Example I, the distance between the opening **21** and die **19** and the quench bath must be less than 2 inches and preferably less than 1 inch. The path of the billet **16** is preferably parallel to and from ½ to 2 inches below the surface of the liquid in the quench bath. Guide pins **17** are necessary to keep the billet from "snaking" or forming loop-like irregularities. The billet should be guided both vertically and laterally.

FIG. 3 shows the construction of the orienting rolls. It is to be understood that while two pairs of orienting rolls are shown in FIG. 1, any desired number of rolls may be used. As can be seen from FIG. 3, each pair of rolls is of tongue and groove construction with one roll having flanges **22** bolted to the central portion **23**. This flanged roll can also be formed of integral construction. The function of the flanges **22** is to assist in controlling the width of the oriented strapping by controlling the size of opening **24**. These rolls are driven by means of shafts formed integral therewith. The way in which the flanges **22** assist in controlling the width of the strapping is shown in FIG. 4. The billet **16** enters the nip of the rolls **13** (and **12** not shown for clarity) and expands in width up to the limits of the flanges as at **29**, preferably as to barely miss or lightly contact the flanges, the oriented strapping **30** then passes on either to another pair of orienting rolls or to tensioning rolls **14**. The amount of tension on strapping **22** imposed by tension rolls **14, 14'** controls the amount of decrease in width the strapping undergoes after leaving orienting rolls **12** and **13**. The amount of tension imparted by rolls **14, 14'** varies with the particular polymer being oriented. In general, the tension is only enough to cause the billet to feed uniformly and without any substantial slippage at the nip of the orienting rolls. The strappings of this invention are distinguished from films in that they are over 10 mils thick. The amount of stretch or necking down of the strapping on leaving the orienting rolls must be accurately controlled since the width of the final strapping is preferably within ±0.005 inch of the width being sought or the strapping cannot readily be fastened with commercially available fasteners. These fasteners generally are heavy gauge metal seals or clips which fit around the strapping joint and are crimped with a machine similar to that commercially used to join steel strapping, such as those illustrated in U.S. Pat. 3,028,281, except preferably with straight sides or edges. Clips or seals require width tolerances. In order to obtain a uniform rectangular billet it is necessary to have the corners of the extrusion die somewhat oversize as is illustrated in FIG. 5. By using a die of this shape the tendency of the extrudate toward becoming round is overcome and a billet of truly rectangular cross-section can be obtained. If a rectangularly shaped die opening is used the billet will have a nearly oval cross-section and excessive cross orientation will be imposed by the orienting rolls thereby lowering the amount of length deformation which can be imposed on the strapping which in turn lowers its ultimate strength and usefulness.

Preferably the rolling takes place in two or three steps. In the final step which may or may not contribute to longitudinally extending the strapping, one or both of the rollers **12** and **23** are shaped as shown for roller **31** in FIG. 6. The peripheral surface of roller **31** is provided with a series of projections **32**. Projections **32** generally

vary in height above the principal surface of the roller from 10 to 35 percent and preferably from 25 to 30 percent of the thickness of the oriented product. While the segment of the projection which adjoins the principal surface of the roller may be curved as shown, it may be a flat surface with an angle between it and the roller surface. The sharp point **34** on the projection should have a radius of curvature no greater than 0.003 inch and preferably no greater than 0.001 inch or the equivalent. For this purpose, a flat point 0.002 inch wide is considered equivalent to a 0.001 inch radius of curvature.

The strapping **35** produced by using a pair of opposing rollers as shown in FIG. 6 is shown in FIG. 7. While strapping **35** has grooves on both sides with the grooves arranged in opposed relationship which is the preferred structure, the grooves can be provided only on one surface of the strapping or alternating from surface to surface across the transverse dimension of the strapping. The grooves **36** in strapping **35** have the dimensions complementary to the shape of the projections **32**. Namely, they are from 10 to 35 and preferably from 25 to 30 percent the thickness of the oriented product in depth and have an effective radius of curvature no greater than 0.003 inch and preferably no greater than 0.001 inch. FIG. 8 shows a strapping **37** having grooves **38** with the grooves having a small effective radius of curvature at the bottom **39** of the grooves **38** but which grooves **38** are wide at the top so as to permit cross flexing of the strapping **37**. Generally from 4 to 12 grooves are provided per surface on the strapping. In forming such strapping the billet preferably is rolled in two or three steps only the final one of which utilizes rolls having the groove forming projections.

As has been pointed out above, the polymers suitable for use in this invention are crystalline. Polyethylene terephthalate is amorphous as extruded but can be converted to a crystalline form which will yield straps or tapes of sufficient strength. Preheating such a billet at from 30 to 80° C. before rolling will cause amorphous polyethylene terephthalate to convert to the crystalline form upon rolling.

The preferred polymers for use in the present invention are polyamides and polyesters. Of these the polyamides such as polycaprolactam, polyhexamethylene adipamide and polyhexamethylene sebacamide are preferred. These polyamides should be oriented from 3.9 to 4.5 times their original length. The polyamides may advantageously contain from 0.2 to 5 and preferably 0.5 to 1 weight percent of a plasticizer. Polyhexamethylene adipamide, polycaprolactam and polyhexamethylene sebacamide are all suitable polyamides for use in such plasticized polyamide straps. The plasticizers which are useful in modifying the polyamides with respect to this invention are those plasticizers which are compatible with polyamides, and melt below 150° C. and boil above 200° C. Such suitable plasticizers include 2-ethyl hexane diol-1,3-tetramethylene sulfone, N-ethyl toluene sulfonamide-o&p, p-toluene sulfonamide, di-n-butyl malate and n-butyl tartrate. Straps made of such plasticized polyamides can consistently be made to have tensile breaking strengths of over 70,000 p.s.i. The addition of plasticizer to the polyamides also results in improved processability of the billet into strapping. This improvement greatly reduces the number of breaks encountered when orienting the strapping. The strappings of the present invention have tensile strengths in excess of 40,000 p.s.i.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In each of Examples 1 and 2, the strapping was made on the apparatus above described using two pairs of three-inch diameter orienting rolls. The second pair of rolls which had the projections were 0.525 inch wide and had the center of the outer projection 0.1125 inch from the edge and the center of the remaining projection 0.100 inch apart to give a total of four projections. The projections of the rolls were 0.005 inch high and their bases had a 0.005 inch radius departing from the surface of the roll. The radius of curvature of the peak of the projections was 0.001 inch. In all of the examples the die head was maintained at less than one inch from the quench bath. The quench bath was water maintained at ambient temperature of 50° C. in all cases. The tensile strength and modulus data were obtained in a conventional test machine equipped with slotted mounting rolls with a one inch per minute loading rate and a five inch separation between rolls. The test results are all based on the original dimensions of the strapping. In Table I, R.V. stands for relative viscosity which for the polyamides was obtained in accordance with A.S.T.M. D–789.

TABLE I

			Strap dimensions		Deformation ratio			Tensile strength, p.s.i.			
Ex.	Material	Billet speed, ft./min.	Width, in.	Thickness, mils	Length	Width	Rolling temp., ° C.	Longitudinal	Transverse	Elongation at break, percent	Tangent modulus, p.s.i.
1	Polyhexamethylene adipamide RV 50	3.1	0.510	31.0	4.20	1.078	161	47,900	6,360	10	633,000
2	do	3.1	0.505	21.1	4.23	1.068	163	55,000	6,410	9.9	705,000

EXAMPLE 3

A billet 0.135" x 1.29" was prepared by continuous molding from polyhexamethylene adipamide of relative viscosity 50 containing 0.125% carbon black. It is passed between a pair of orienting rolls to extend its length about 3.9-fold to give an oriented strap 0.034" x 1.31". When this strap is notched on one edge, it could easily be torn across its width.

EXAMPLE 4

The strap of Example 3 is passed between the pair of grooving rolls the same width as the strap each of which had eleven evenly spaced ridges. The ridges were 0.010"±0.001" high and had concave sides of radius 0.010". The separation between the centers of the ridges was 0.109". When this product is notched on one edge, it cannot be torn across the width. Instead, a very severe tearing force results in longitudinal splitting along one of the grooves.

EXAMPLE 5

A billet of 66 nylon is oriented by rolling to extend its length 4.4 to 4.5-fold. The product is 1.25" wide and 0.033" thick. The tensile strength is 60,000 p.s.i., the elongation at break is 13%, the tangent modulus is 600,000 p.s.i., and the transverse strength is 6400 p.s.i.

EXAMPLE 6

The oriented product of Example 5 is subjected to the grooving process of Example 1. The resulting product has a tensile strength of 54,000 p.s.i., an elongation at break of 11%, a tangent modulus of 600,000 p.s.i., and a transverse strength of 2100 p.s.i. Because of the reduced transverse strength of the grooved product, it tends to split longitudinally when an edge of a specimen under tension was notched rather than tearing across the entire width.

In Examples 7 to 12, a billet of 66 nylon 0.099" x 0.473" was used. In these experiments, the grooves were formed during rolling, rather than in a separate step. The rolls were designed to form grooves 0.005" deep, 0.010" wide at the bottom, having 45° sides, and a separation between centers of 0.100". This groove design was intended to give greater transverse flexibility.

	Example					
	7	8	9	10	11	12
Rolling process:						
1st stage:						
Ribs on upper roll	0	4	0	4	4	0
Ribs on lower roll	0	4	0	0	0	0
2d stage	None			None	None	
Ribs on upper roll		0	5			5
Ribs on lower roll		0	4			4
Deformation ratio	4.1	4.05	4.1	4.0	4.3	4.15
Thickness, mils	21.5	20.7	21.0	21.3	19.8	22.0
Width, in	.505	.502	.505	.501	.502	.502
Tensile strength, p.s.i	54,000	57,000	50,000	53,500	56,500	54,000
Elongation, percent	17	10	8	11	8	12
Tangent modulus, p.s.i	633,000	1,009,000	714,000	830,000	932,000	549,000
Transverse strength, p.s.i	8,600	6,800	7,700	7,900	8,400	6,400

The term "uniplanar, axial orientation" employed in defining the product of this invention may be fully understood from the following discussion.

"Axial," "uniplanar, axial orientation" employed in types of crystal orientation in high polymeric materials. "Axial" orientation means that is given crystal axis (frequently the polymer chain axis) is parallel to a macroscopic axis (e.g., the machine direction in an extruded object). For example, prior art materials which had been drawn in only one direction (e.g., fibers or one-way stretched films) generally exhibit an appreciable degree of axial orientation in which the polymer chain axes are aligned parallel to the stretched direction. "Planar" orientation means that a given crystal axis is parallel to a macroscopic level plane. Conventional two-way stretched films for example generally exhibit a degree of planar orientation in that the molecular chain axes lie approximately parallel to the surface of the film although said axes are arranged at random within this plane. "Uniplanar" orientation means that a given crystal axis is parallel to a macroscopic axis and a given crystal plane is parallel to a macroscopic plane. In the rolled, extruded shapes discussed here the molecular chain axis is generally in the direction of rolling and a certain crystal plane is parallel to the rolled surface. As used here the terms "axial," "planar," and "uniplanar" orientation refer not only to perfect alignment of the types discussed but also to structures in which there is a preferred orientation even though there may be some angular distributions about the preferred orientation. Roll-oriented polymers generally exhibit "uniplanar, axial orientation" but in certain cases, for example, polypropylene axial orientation may be indicated.

X-ray diffraction furnishes a convenient technique for observing the type of orientation in the objects of this invention. A sample is mounted on an instrument such as a Single Crystal Orienter which has the ability to rotate the sample in the X-ray beam about two mutually perpendicular axes. Since a crystalline material will diffract X-rays only when the X-ray beam, the detector, and suitable crystalline planes within the sample are arranged in the manner described by Bragg's Law, it is possible to determine the crystal orientation within the sample by studying the variation in the intensity of the diffracted X-rays as the sample is rotated. This intensity will pass through a maximum as the angular orientation of the sample reaches a value corresponding to the most populous orientation of the crystals within the sample. The breadth of the distribution of crystal orientations may be characterized by the width of a plot of X-ray intensity vs. the angular orientation of the sample at an intensity value equal to one-half of the peak maximum. Further aspects of the definition of the types or orientation and of techniques for determining the distribution of crystal orientation in synthetic polymers are described in a paper by C. J. Heffelfinger and R. L. Burton in the Journal of Polymer Science, volume 47, pages 289–306 (1960).

In an extruded, rolled shape made from polyhexamethyleneadipamide, the uniplanar axial orientation is such that the polymer chains tend to be in the direction of rolling and the (010) crystal planes tend to be parallel to the rolled surface. The angular width at the one-half maximum corresponding to the tilting of the polymer chains from the roll direction toward the thickness direction is less than 23° in the preferred structures. The tilting of the polymer chains from the roll direction toward the transverse direction is characterized by an angle of less than 23°. The tilting of the (010) planes about the roll direction away from parallellity with the roll surface is characterized by an angle of less than 35° in the preferred structures. These angles correspond to those obtained for uniplanar axial orientation in polyhexamethylene adipamide which has been rolled to increase its length at least fourfold. The other polymers useful in this invention will have corresponding angles for the deviation of polymer chain axes from the direction of rolling equal to or less than those cited. However, the uniplanarity may be less sharply defined in other useful polymers. The half maximum tilting of the chains from the roll direction toward the thickness or the transverse direction is preferably less than 23° for all resins.

It is well known in the art that controlled deformation of a crystalline polymer results in an improvement in the physical properties of the polymer in the direction of deformation. This is most highly developed in the case of fiber and filaments where very marked improvement in tensile strength and modulus with an axial orientation is obtained by cold drawing of the extruded fiber of filament. Attempts to obtain equivalent improvement in physical properties in more massive plastic shapes with triaxial symmetry such as tapes, straps, sheets, angles, tees, and the like have not been successful, although significant improvement has been obtained in many cases. Failure to obtain the enhancement in physical properties equivalent to high quality fibers can probably be traced to the failure to obtain the required perfection and type of structure in these more massive objects with triaxial symmetry. The above examples illustrate the achievement of the required perfection of structure with crystalline polymers and copolymers by careful control of the polymer and the processing at high nondestructive deformations.

These unique plastic materials are characterized by a high perfection in the structure, high tensile strength combined with high modulus, and excellent recovery from high load. These same properties are exhibited by high quality fibers which have uniaxial orientation with circular symmetry. These new materials differ in being relatively massive with multiaxial orientation.

This degree of perfection in the structure can be measured in several ways. One well recognized in crystallography is the measurement of the sharpness of the X-ray diffraction pattern obtained along the various axes of the object.

Strapping must have a high tensile tangent modulus in order to be of great utility. It is the nature of crystalline

polymers that when pulled or stretched that their tensile load rises sharply to a plateau upon a relatively small elongation, this plateau extends for a deformation of several "×" (times) the original dimension and then again rises sharply. It is necessary to exceed the deformation represented by the point at which this plateau ends and the tensile strength vs. deformation starts to rise sharply again in order to obtain an extremely useful strapping. If this point is not reached the strapping upon being stretched or tensioned will not return to its original longitudinal dimension but will remain permanently elongated and loose about what ever container it has been used to bind. It is preferred that a strapping upon being stretched will return to within 2% of its original longitudinal dimension. As illustrated in the examples only highly oriented strappings return to within 2% of their original dimension after receiving a substantial stress such as a 35,000 p.s.i. pull.

A high tangent tensile modulus is an indication that the strapping has been oriented or deformed to a point where it will not permanently nor unduly stretch or deform when tensioned about a package. The minimum modulus representative of the preferred strapping of this invention is 1.75 times that of the undeformed or oriented polymer of which the strapping is fabricated which for polyamides such as polyhexamethylene adipamide, polyhexamethylene sebacamide and polycaprolactam requires a longitudinal orientation deformation of at least 4.0.

We claim:

1. A strapping having a tensile strength greater than 40,000 p.s.i. formed of a crystalline, synthetic thermoplastic resin, said strapping being at least 10 mils thick, at least one-quarter inch wide, and of uniform cross-section along the length thereof, in which the resin has a substantially uniform axial orientation in the longitudinal axis of said strapping, and at least one surface of said strapping is provided with a plurality of grooves from 10 to 35 percent of the thickness of said strapping in depth the bottom of which grooves have an effective radius of curvature of less than 0.003 inch.

2. The strapping of claim **1** wherein the resin is a polyamide.

3. The strapping of claim **2** wherein both of the surfaces of the strapping are provided with the grooves.

4. The strapping of claim **3** wherein the surfaces each have from 4 to 12 grooves.

5. The strapping of claim **4** wherein the grooves are arranged in opposing pairs on opposite surfaces of the strapping.

6. The strapping of claim **5** wherein the bottom of the grooves have an effective radius of curvature of less than 0.001 inch.

7. The strapping of claim **6** wherein the polyamide is polyhexamethylene adipamide.

References Cited

UNITED STATES PATENTS

3,066,366	12/1962	Wyckoff et al.	264—210X
3,320,225	5/1967	Bradbury	260—93.7
3,470,286	9/1969	Weber	264—167
3,488,415	1/1970	Patchell et al.	264—284X

WILLIAM A. POWELL, Primary Examiner

U.S. Cl. X.R.

18—4, 10, 35; 24—16; 161—124, 165, 402; 264—167, 210, 284, 288, 291