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(54) IMPROVEMENTS IN AND RELATING TO BINDING STRAP

(71) We, SIGNODE CORPORATION, a Corporation organised under the laws of the State of Delaware, USA, of 3600 West Lake Avenue, Glenview, Illinois 60025, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to fusible sheetform articles and particularly but not exclusively to fusible plastics binding strap that can be joined by friction fusion, hot knife techniques, or other thermal means.

Plastics strap is a convenient and relatively inexpensive strapping material that has been used for a wide variety of tying and packaging operations. For many applications plastics strap is uniquely suited by virtue of the inherent elasticity thereof, for example for tying packages subject to dimensional change, or to handling situations whereby shock conditions may be imposed upon the strap loop that surrounds the package. Tying usually is accomplished by forming a strap loop about the package, shrinking or reducing the former loop to a snug fit about the package, and thereafter joining overlapped ends of the strap loop by means of a wrap-around seal or a fused joint.

Wrap-around seals for plastics strap are generally formed in a manner analogous to steel strap, for example by crimping a deformable metal band around overlapping strap ends so as to form a mechanical interlock. Such wrap-around seals are not completely effective, however, because plastics strap has inherently low shear strength which restricts the crimping and interlocking techniques normally utilised with wrap-around seals.

As an alternate strap sealing approach, strap joints have been formed by melting and fusing overlapping portions of thermoplastic strap so as to form a joint. For this purpose heated pressure jaws, high frequency dielectric heating means, ultrasonic welders, and friction fusion devices have been used. None of the foregoing joint-forming means is capable of producing routinely and consistently, and in an economic manner, a seal that exhibits a joint strength that is not considerably less than the plastics

strap tensile strength. It is very desirable, however, to have joint strengths that approach the tensile strength of the strap more closely.

According to one aspect of the present invention, a sheetform, crystalline thermoplastic polymer article of substantially uniform thickness and having improved heat-weldability comprises a laminar composite in which a major thickness portion is constituted by said polymer having a first average molecular weight and a minor thickness portion is constituted by the same polymer having a second average molecular weight which is higher than the first, the minor thickness portion being unitary with the major portion and defining a heat-weldable face of the article, and both portions having substantially similar planar crystalline orientation.

According to a second aspect of the present invention, a fusible binding strap of substantially rectangular and uniform cross-section formed of an oriented crystalline synthetic thermoplastic polymer and defined by a pair of opposed major faces and a pair of opposed minor faces comprises a base layer comprising said polymer having a first average molecular weight and a generally planar surface layer unitary and contiguous with said base layer, defining at least one said major face and comprising the same polymer having a second average molecular weight which is higher than the first, the strap having substantially similar axial crystalline orientation along the longitudinal dimension of said strap throughout the cross-section thereof.

The present invention also comprehends a segment of the binding strap as defined above in the second aspect of the invention, which has overlapping opposite end portions fused together so as to define a joint, the joint comprising a central fused region which contains said polymer of a relatively higher average molecular weight than the same polymer which is adjacent to the central fused region.

According to a third aspect of the present invention, a method of producing a sheetform, crystalline thermoplastic polymer article which is a laminar composite of substantially uniform thickness comprises coextruding distinct melt layers of the same crystallizable polymer but having different average molecular weights to

form a laminar sheet so as to provide a minor thickness portion constituted by the polymer having a relatively higher average molecular weight and a major thickness portion constituted by the polymer having a relatively lower average molecular weight, solidifying the formed sheet, and then mechanically working the solidified sheet so as to provide substantially similar planar crystalline orientation in both of said thickness portions.

Thus the invention may be said to reside in improving the fusibility of plastics sheetform articles, such as binding strap and the like, by forming the articles from a crystalline synthetic thermoplastic polymer as a laminar composite in which the laminas or layers are constituted of the same polymer, i.e. having the same repeating unit or units in the structural chain, but of a different average molecular weight. In the laminar composite, the polymer on at least one fusible face of the produced article has a relatively higher average molecular weight than the same polymer in the body of the article so that the ultimately formed joint is in a fused region which contains the relatively higher average molecular weight polymer. Stated in another way, the intrinsic viscosity and relative viscosity of the polymer constituting the fusible face or faces is higher than the intrinsic viscosity and relative viscosity of the polymer in the body of the article. If melt index is used as the primary measurement of the molecular weight, then the melt index of the polymer constituting the fusible face is lower than the melt index of the polymer in the body of the article.

It will be realised that there may be a minor thickness portion which is made up of the same polymer but having a relatively higher average molecular weight on each side of the article. Then, each minor thickness portion of the article has a thickness that is less than the thickness of the major thickness portion but the sum of the thicknesses of the individual minor thickness portions on opposite sides of the article may be greater than the thickness of the major thickness portion. The terms "sheetform" and "sheet" as used herein and in the appended claims designate an article of manufacture having a thickness greater than 10 mils.

The minor thickness portion of the article defines a fusible face of the article. Both the major thickness portion and the minor thickness portion of the article are constituted of the same polymer type, and both portions have substantially similar planar crystalline orientation.

For the purposes of the present invention, suitable crystalline synthetic thermoplastic polymers include polyamides, polyesters and polyolefins. Preferred polymers for strapping are polyethylene terephthalate, polypropylene, polyhexamethylene adipamide (Nylon 66), and polycaprolactam (Nylon 6).

The invention may be carried into practice

in various ways but a number of binding straps and their method of production in accordance with the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a binding strap segment embodying the present invention;

Figure 2 is a schematic representation of an extrusion assembly suitable for fabricating the strap illustrated in Figure 1 and showing an enlarged portion of the extruded strap;

Figure 3 is a perspective view of another binding strap segment made in accordance with this invention;

Figure 4 is a schematic representation of an extrusion assembly suitable for fabricating the strap illustrated in Figure 3 and showing an enlarged portion of the extruded strap; and

Figures 5A and 5B are sectional elevations of fused strap joints formed utilising a composite strap of the present invention.

When sheetform thermoplastic polymer articles are joined to one another, overlapping face portions of the articles are fused together to define a joint. In the case of thermoplastic polymer binding strap, a strap segment forms a loop which encircles a package to be bound, and the end portions of the strap segment are overlapped and fused together at an interface region therebetween. As a result, a closure joint unitary with the strap is produced having a relatively thin central or interface region or layer of fused, i.e. merged and resolidified, strap surface portions. The average overall thickness of the produced central fused region is between 0.001 inch (0.025 mm) and 0.004 inch (0.1 mm) using friction fusion techniques. The thickness of the fused region is somewhat greater if a hot knife technique is used.

It has now been discovered that the tensile strength of the formed joint (joint strength) can be substantially increased, and in an economically advantageous manner, by introducing into the central fused region, as a unitary part of the sheetform article, a polymer having a relatively higher average molecular weight while surrounding or adjacent unfused strap regions comprise a polymer having a relatively lower average molecular weight. This condition can be readily accomplished by providing the article, e.g. binding strap, on at least one face thereof, with a unitary facing layer of a polymer having a relatively higher average molecular weight than that of the polymer which constitutes the major portion of the article itself. In this manner the strap, or any other sheetform article that has to be joined by means of a fused joint, for example using friction fusion, hot knife or similar techniques, can be fabricated primarily of a relatively lower cost, relatively lower molecular weight polymeric material and still provide improved joint strength by virtue of the presence of a relatively higher molecular weight polymeric material which provides a relatively high-strength joint interface.

To produce sheetform articles embodying the present invention, most if not all crystallizable thermoplastic polymers the crystals of which can be oriented by mechanical working can be used, including polymers that are amorphous as extruded but which can be converted to a crystalline form by mechanical working, e.g. drawing. Crystalline polymers, of course, are those which exhibit crystallographic reflections when examined with X-rays in a known manner. The polymers may or may not contain plasticizers that enhance the processability thereof into sheetform articles. However, the thermoplastic polymers that constitute the sheetform article embodying the present invention should have substantially the same crystallizability, i.e. the nature and degree of crystallinity that is achieved upon mechanical working after extrusion should be substantially the same in the major and the minor thickness portions of the produced article. Thus, it is preferred that the composition of the extruded polymer mass forming the major and minor thickness portions of the sheetform article be substantially the same except that the molecular weight of the thermoplastic polymer itself is different in these portions as stated hereinabove.

Some thermoplastic polymers, such as polyesters, if solidified in a crystalline state immediately after extrusion, tend to be brittle and are more difficult to orient by subsequent mechanical working. Accordingly, in such instances it is preferable to select the extrusion conditions so that the extruded composite sheetform article initially solidifies in a substantially amorphous state from which it is then subsequently converted to a crystalline state and oriented during mechanical working.

Illustrative of the types of crystalline or crystallizable thermoplastic polymers that can be used in the practice of this invention are the polyesters such as polyethylene terephthalate, copolyesters or terephthalic acid and isophthalic acid with cyclohexanedimethanol, and the like, the polyolefins such as polyethylene, polypropylene, and the like, and the polyamides such as polycaprolactam, polyhexamethylene adipamide, polyhexamethylene sebacamide, and the like.

The difference in the average molecular weights between the major and the minor thickness portion (or portions) varies depending on the type of polymer that is used and also on the increase in the joint strength that is desired. Preferably, the average molecular weight of the polymer in the fusible minor thickness portion exceeds the average molecular weight in the core portion by at least 20 percent, and more preferably by at least 50 percent.

Inasmuch as commercially available polymer supplies are polydisperse, i.e. the polymer is present in a range of molecular weights, the selection of the polymer for practising the

present invention is based on the average molecular weight for that polymer. The term "average molecular weight" as used herein refers to the weight average molecular weight of the crystallizable polymer in the supply used for practising the present invention and can be determined according to various techniques known in the art, for example light scattering, ultracentrifugation and the like. It is not necessary to make an absolute determination, rather reliance can be had on other well known expedients such as a determination of intrinsic viscosity, relative viscosity or melt index of the polymer.

The intrinsic viscosity of a polymer is directly related to the molecular weight of the polymer and is usually obtained from experimentally determined specific relative viscosity values for a polymer solution (flow time of the polymer solution through a capillary viscometer divided by the flow time of the solvent) at several concentrations of the polymer. The obtained values are plotted and the resulting curve is extrapolated to infinite dilution (zero concentration) to obtain the value for the intrinsic viscosity. Inasmuch as the slopes of the viscosity-concentration curve for the commercially available extrudable polymers in the usual solvents therefor are known in the art, it is possible to ascertain the intrinsic viscosity of a polymer from a single value of relative viscosity. Accordingly, it is the customary practice to measure only a single value of relative viscosity and from the measured value to ascertain the intrinsic viscosity by referring to the standard plots thereof.

The melt index of a thermoplastic polymer is also related to its molecular weight and viscosity and is an indication of the amount of the thermoplastic polymer that can be forced through a given orifice at a specific temperature and in a given time period using a constant force of known value. The melt indices reported herein are determined according to ASTM Standard D1238-73 at 230°C and using a 2160-gram force.

In the case of polyesters, for example polyethylene terephthalate, for manufacturing composite binding strap embodying the present invention the intrinsic viscosity of the polyester forming the fusible, minor thickness portion of the strap preferably is greater than 0.7 and exceeds the intrinsic viscosity of the polymer forming the core portion of the strap preferably by at least 20 percent, and more preferably by at least 50 percent.

Binder strap or a similar sheetform article of manufacture providing the foregoing advantages is illustrated in Figure 1. The binder strap segment 10 comprises a major thickness portion 11 which is made up of a crystallizable thermoplastic polymer, for example polyethylene terephthalate, having a relatively lower molecular weight and a unitary minor thickness portion 12 which is made up of the same polymer but

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having a relatively higher molecular weight. Portions 11 and 12 are of substantially the same composition but for the molecular weight of the polymer. The minor thickness portion 12 provides a generally planar surface layer contiguous with and intimately bonded to the major thickness portion 11, which forms the base layer of the strap, and defines a fusible face. The minor thickness portion 12 should be at least one mil (0.001 inch; 0.025 mm) thick, and usually comprises between 1 and 25 percent of the strap thickness, preferably between 3 and 20 percent of the strap thickness.

Binder strap of the form illustrated in Figure 1 can be fabricated using the coextrusion assembly schematically depicted in Figure 2. The extrusion assembly 15 includes a die 16, a single-side feed block 17 and an extruder adapter 18. The polymeric material which ultimately forms the major thickness portion 11 of the extruded strap is fed to the die 16 from a first extruder (not shown) via a feed conduit 19, and the polymeric material which ultimately forms the minor thickness portion 12 is fed to the die 16 from a second extruder (not shown) via a feed conduit 20. These two melt layers of the same polymer but of different average molecular weights merge within the die cavity 21 and exit from the die orifice, without commingling, as a single melt stream constituted by distinct melt layers. The melt stream is then solidified, intimately bonding the coextruded layers to one another. Preferably the polymer in each thickness portion is maintained in an amorphous state upon solidification. Thereafter the produced laminar sheet of predetermined configuration can be hot drawn or otherwise worked to impart the desired crystallinity, crystalline orientation, and physical characteristics to the finally produced product.

To produce binder strap of the form illustrated in Figure 3, i.e. having a base layer or core 22 flanked on each side by a generally planar, contiguous surface or facing layer 23, 24, an extrusion assembly 25 shown in Figure 4 can be utilized. More specifically, a die 26 is provided with a double-sided feed block 27 and an extruder adapter 28 which together form a unitary assembly. A feed conduit 29 is defined by apertures in the adapter 28, the feed block 27 and the die 26, and serves to convey to the die cavity 31 the molten polymeric material which, upon extrusion and solidification, forms the aforesaid base layer or core 22 of the extruded strap segment. Feed conduits 30 and 32 are provided in the feed block 27 for supplying the relatively higher molecular weight polymeric material which ultimately forms the surface layers 23 and 24. Streams of molten, relatively higher molecular weight polymeric material exiting into the die cavity 31 from the feed conduits 30 and 32 merge without commingling with the molten polymeric material exiting from the feed conduit 29 so as to produce a single, three-layer melt stream

which is extruded from the die cavity 31 and solidified. The coextruded, multi-layer ribbon of polymeric material can be hot-drawn, rolled, or otherwise worked to impart thereto the desired degree of crystallinity and crystalline orientation.

For binding strap having the polymer of relatively higher molecular weight on both major faces thereof, the thickness of the facing layers can be relatively small because when the strap portions to be sealed are overlapped, the total thickness of the desired polymer of relatively higher molecular weight that is available for fusion is doubled.

Binding strap can be coextruded as a ribbon which is reduced to the desired thickness and width dimensions of the ultimate strap product upon mechanical working; however, it is usually more expeditious to coextrude a sheet of substantial width that is mechanically worked to achieve the desired thickness and subsequently cut to produce binding strap having the desired width.

A weld or joint produced in a loop formed by thermoplastic strap similar to the strap produced in Figure 4 is shown in Figures 5A and 5B. The strap is provided on both faces thereof with respective minor thickness portions 23 and 24 of a polymer having a molecular weight at least 20 percent higher than the molecular weight of the polymer which constitutes the major thickness portion 22. The strap loop is formed so that for overlapping strap ends 34 and 35 the minor thickness portions 23 and 24 are contiguous with one another. Upon joining of the strap ends 34 and 35 by insertion of a hot sealing blade between the contiguous minor thickness portions 23 and 24, or by rubbing the minor thickness portions against one another as in friction fusion joint-forming techniques, the contiguous regions thereof in the joint area are softened or become molten and, upon cooling while under pressure, fuse together to form a central, fused interfacial region 36 which is primarily, and in some cases exclusively, constituted by the polymer of relatively higher molecular weight and which region is substantially surrounded by the polymer of relatively lower molecular weight in the unfused major thickness portions 22. In Figure 5A the interfacial region includes also some of the polymer of relatively lower molecular weight and in Figure 5B the interfacial region is made up only of the polymer having relatively higher molecular weight. The thickness of the central fused region can be between 1 and 20 percent of the thickness of the overlapping strap ends 34 and 35.

For optimum joint strength it is desirable that the binder strap welding conditions, as well as the thicknesses of the contiguous minor thickness portions, are selected so that the central fused region is maintained solely within the minor thickness portions.

During joint formation, the original crystal-

line orientation of the polymers present in what ultimately becomes the central fused region of the joint is modified or obviated, and thus the crystalline orientation of the central fused region is usually different from the crystalline orientation of the strap portions adjacent thereto.

The present invention is further illustrated by the following examples.

10 **EXAMPLE I: Composite Polyethylene Terephthalate Strap**

A half-inch wide and 0.020 inch thick polyethylene terephthalate strap was produced by coextrusion and subsequent crystallization and orientation of polyethylene terephthalate having an intrinsic viscosity of about 0.6 with the same polymer having an intrinsic viscosity of about 1.1. Coextrusion was carried out so that the polymer having the relatively higher intrinsic viscosity formed a surface layer about 0.0015 inch thick on one major face of the extruded strap. All layers of the extruded strap were crystalline and had substantially similar planar crystalline orientation.

25 Segments of the produced strap were joined utilizing a conventional hot knife technique to produce joint strengths in excess of about 80 percent of strap strength. Consistently high joint strengths were obtained by fusing the layer of relatively higher intrinsic viscosity, i.e. molecular weight, to the layer of relatively lower intrinsic viscosity, i.e. molecular weight, as well as by fusing together both layers of relatively higher intrinsic viscosity.

35 **EXAMPLE II: Composite Polyethylene Terephthalate Strap**

Polyethylene terephthalate having an intrinsic viscosity of about 0.8 was coextruded with polyethylene terephthalate having an intrinsic viscosity of about 1.2 to produce, after drawing, strap about 5/8 inch wide and about 0.020 inch thick and so that the polyethylene terephthalate having the relatively higher intrinsic viscosity formed a surface layer about 0.001 inch thick on one major face of the extruded strap. After coextrusion, the extruded article was crystallized and oriented to provide substantially similar planar crystalline orientation in all layers thereof.

50 Segments of the produced strap were formed into loops, and the ends thereof were overlapped and joined by friction fusion. Joint strengths in excess of about 85 percent of strap strength were obtained.

55 **EXAMPLE III: Composite Polypropylene Binding Strap**

Oriented polypropylene binding strap having a thickness of about 0.030 inch was produced by coextrusion and subsequent drawing of polypropylene having an average melt index of about 0.2 and polypropylene having an average melt index of about 6 into a sheetform article that was subsequently cut into ribbons about one-half inch wide and suitable as binding strap. Coextrusion was effected so that the poly-

propylene having the relatively lower melt index formed a surface layer about 0.003 inch thick on each side of the sheetform article produced after drawing. All layers of the produced strap were crystalline and had substantially similar planar crystalline orientation.

EXAMPLE IV: Composite Polyethylene Terephthalate Binding Strap

Polyethylene terephthalate having intrinsic viscosities of about 0.6 and about 1 was coextruded and subsequently crystallized and oriented by drawing under tension so as to produce one half-inch wide strap having a thickness of about 0.020 inch, and having a minor thickness portion which was a layer of the polymer having an intrinsic viscosity of about 1 on each major face of the strap. Each of the minor thickness portions in the produced strap was about 0.002 inch thick, and all strap portions had substantially the same planar crystalline orientation.

Control strap of substantially the same overall dimensions was produced in a similar manner and with similar planar crystalline orientation, but using only polyethylene terephthalate having an intrinsic viscosity of about 0.6.

Segments of the strap having major and minor thickness portions were superposed, so that a face of one segment was contiguous with a face of the other segment, and were then welded together using a torsion bar type laboratory friction fusion welder at a welding time of about 0.004 second and welding pressure of between 10,000 and 13,000 pounds per square inch (p.s.i.). The produced welds were contained within the layers of the relatively higher intrinsic viscosity material. Segments of the control strap were similarly welded.

Upon testing for joint strength, the following was observed:

	Control Strap	Composite Strap	
joint strength %	55	80	110

EXAMPLE V: Composite Nylon Binding Strap

Polyhexamethylene adipamide (Nylon 66) binding strap having a thickness of about 0.020 inch was produced by coextrusion and subsequent crystallization and orientation of Nylon 66 having a relative viscosity of about 225 and Nylon 66 having a relative viscosity of about 50. The coextrusion was performed so that a surface layer about 0.004 inch thick and constituted by the Nylon 66 of the relatively higher viscosity was provided on each major face of the produced strap. All layers of the produced strap were crystalline and had substantially similar planar crystalline orientation.

Segments of the produced strap were formed into loops and joined by friction fusion so as to produce a weld within contiguous layers of the Nylon 66 having the relatively higher relative viscosity. The welds, when tested for joint strength, exhibited a joint strength of about 60

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percent of strap strength. This compares favourably with a joint strength of only about 40% that was attained under the same conditions using Nylon 66 strap having a relative viscosity of about 50.

EXAMPLE VI: Composite Polyethylene Terephthalate Binding Strap

In a manner similar to Example IV, oriented crystalline binder strap was produced with each face of the strap defined by a 0.0036 inch thick layer of the polyethylene terephthalate having the relatively higher intrinsic viscosity.

Control strap having substantially the same overall dimensions and crystalline orientation was produced from polyethylene terephthalate having the relatively lower intrinsic viscosity (i.e., I.V. = 0.6).

Upon testing for joint strength, welds produced in the same manner on the same equipment as in Example IV, the following was observed.

	Control Strap	Composite Strap
joint strength, %	57	92

WHAT WE CLAIM IS:—

1. A sheetform, crystalline thermoplastic polymer article of substantially uniform thickness and having improved heat-weldability comprising a laminar composite in which a major thickness portion is constituted by said polymer having a first average molecular weight and a minor thickness portion is constituted by the same polymer having a second average molecular weight which is higher than the first, the minor thickness portion being unitary with the major portion and defining a heat-weldable face of the article, and both portions having substantially similar planar crystalline orientation.

2. An article as claimed in Claim 1 in which the second average molecular weight is at least 20 percent higher than the first.

3. An article as claimed in Claim 1 in which the second average molecular weight is at least 50 percent higher than the first.

4. An article as claimed in Claim 1 or Claim 2 or Claim 3 in which the polymer is a polyester.

5. An article as claimed in Claim 4 in which the polyester is polyethylene terephthalate.

6. An article as claimed in Claim 1 or Claim 2 or Claim 3 in which the polymer is a polyolefin.

7. An article as claimed in Claim 6 in which the polyolefin is polypropylene.

8. An article as claimed in Claim 1 or Claim 2 of Claim 3 in which the polymer is a polyamide.

9. An article as claimed in Claim 8 in which the polyamide is polyhexamethylene adipamide.

10. An article as claimed in Claim 8 in which the polyamide is a polycaprolactam.

11. An article as claimed in any of the preceding claims in which the minor thickness portion is at least 1 mil thick.

12. A fusible binding strap of substantially rectangular and uniform cross-section formed of an oriented crystalline synthetic thermoplastic polymer and defined by a pair of opposed major faces and a pair of opposed minor faces which comprises a base layer comprising said polymer having a first average molecular weight and a generally planar surface layer unitary and contiguous with said base layer, defining at least one said major face and comprising the same polymer having a second average molecular weight which is higher than the first, the strap having substantially similar axial crystalline orientation along the longitudinal dimension of said strap throughout the cross-section thereof.

13. A fusible binding strap as claimed in Claim 12 in which both major faces are defined by substantially planar surface layers comprising the second polymer.

14. A fusible binding strap as claimed in Claim 12 or Claim 13 in which the polymer is a polyester.

15. A fusible binding strap as claimed in Claim 14 in which the polyester is polyethylene terephthalate.

16. A fusible binding strap as claimed in Claim 14 or Claim 15 in which the intrinsic viscosity of the polyester in the generally planar surface layer exceeds the intrinsic viscosity of the polyester in the base layer by at least 20 percent.

17. A fusible binding strap as claimed in Claim 14 or Claim 15 in which the intrinsic viscosity of the polyester in the generally planar surface layer exceeds the intrinsic viscosity of the polyester in the base layer by at least 50 percent.

18. A fusible binding strap as claimed in Claim 12 or Claim 13 in which the polymer is a polyolefin.

19. A fusible binding strap as claimed in Claim 18 in which the polyolefin is polypropylene.

20. A fusible binding strap as claimed in Claim 12 or Claim 13 in which the polymer is a polyamide.

21. A fusible binding strap as claimed in Claim 20 in which the polyamide is polyhexamethylene adipamide.

22. A fusible binding strap as claimed in Claim 20 in which the polyamide is polycaprolactam.

23. A fusible binding strap as claimed in any of Claims 12 to 22 in which both of the major faces are defined by generally planar surface layers comprising the polymer having the second average molecular weight.

24. A fusible binding strap as claimed in any of Claims 12 to 23 in which the thickness of the or each generally planar surface layer is at least 1 mil.

25. A fusible binding strap as claimed in any of Claims 12 to 24 in which the thickness of the or each generally planar surface layer is

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percent of strap strength. This compares favourably with a joint strength of only about 40% that was attained under the same conditions using Nylon 66 strap having a relative viscosity of about 50.

EXAMPLE VI: Composite Polyethylene Terephthalate Binding Strap

In a manner similar to Example IV, oriented crystalline binder strap was produced with each face of the strap defined by a 0.0036 inch thick layer of the polyethylene terephthalate having the relatively higher intrinsic viscosity.

Control strap having substantially the same overall dimensions and crystalline orientation was produced from polyethylene terephthalate having the the relatively lower intrinsic viscosity (i.e., I.V. = 0.6).

Upon testing for joint strength, welds produced in the same manner on the same equipment as in Example IV, the following was observed.

	Control Strap	Composite Strap
joint strength, %	57	92

WHAT WE CLAIM IS:—

1. A sheetform, crystalline thermoplastic polymer article of substantially uniform thickness and having improved heat-weldability comprising a laminar composite in which a major thickness portion is constituted by said polymer having a first average molecular weight and a minor thickness portion is constituted by the same polymer having a second average molecular weight which is higher than the first, the minor thickness portion being unitary with the major portion and defining a heat-weldable face of the article, and both portions having substantially similar planar crystalline orientation.

2. An article as claimed in Claim 1 in which the second average molecular weight is at least 20 percent higher than the first.

3. An article as claimed in Claim 1 in which the second average molecular weight is at least 50 percent higher than the first.

4. An article as claimed in Claim 1 or Claim 2 or Claim 3 in which the polymer is a polyester.

5. An article as claimed in Claim 4 in which the polyester is polyethylene terephthalate.

6. An article as claimed in Claim 1 or Claim 2 or Claim 3 in which the polymer is a polyolefin.

7. An article as claimed in Claim 6 in which the polyolefin is polypropylene.

8. An article as claimed in Claim 1 or Claim 2 of Claim 3 in which the polymer is a polyamide.

9. An article as claimed in Claim 8 in which the polyamide is polyhexamethylene adipamide.

10. An article as claimed in Claim 8 in which the polyamide is a polycaprolactam.

11. An article as claimed in any of the preceding claims in which the minor thickness portion is at least 1 mil thick.

12. A fusible binding strap of substantially rectangular and uniform cross-section formed of an oriented crystalline synthetic thermoplastic polymer and defined by a pair of opposed major faces and a pair of opposed minor faces which comprises a base layer comprising said polymer having a first average molecular weight and a generally planar surface layer unitary and contiguous with said base layer, defining at least one said major face and comprising the same polymer having a second average molecular weight which is higher than the first, the strap having substantially similar axial crystalline orientation along the longitudinal dimension of said strap throughout the cross-section thereof.

13. A fusible binding strap as claimed in Claim 12 in which both major faces are defined by substantially planar surface layers comprising the second polymer.

14. A fusible binding strap as claimed in Claim 12 or Claim 13 in which the polymer is a polyester.

15. A fusible binding strap as claimed in Claim 14 in which the polyester is polyethylene terephthalate.

16. A fusible binding strap as claimed in Claim 14 or Claim 15 in which the intrinsic viscosity of the polyester in the generally planar surface layer exceeds the intrinsic viscosity of the polyester in the base layer by at least 20 percent.

17. A fusible binding strap as claimed in Claim 14 or Claim 15 in which the intrinsic viscosity of the polyester in the generally planar surface layer exceeds the intrinsic viscosity of the polyester in the base layer by at least 50 percent.

18. A fusible binding strap as claimed in Claim 12 or Claim 13 in which the polymer is a polyolefin.

19. A fusible binding strap as claimed in Claim 18 in which the polyolefin is polypropylene.

20. A fusible binding strap as claimed in Claim 12 or Claim 13 in which the polymer is a polyamide.

21. A fusible binding strap as claimed in Claim 20 in which the polyamide is polyhexamethylene adipamide.

22. A fusible binding strap as claimed in Claim 20 in which the polyamide is polycaprolactam.

23. A fusible binding strap as claimed in any of Claims 12 to 22 in which both of the major faces are defined by generally planar surface layers comprising the polymer having the second average molecular weight.

24. A fusible binding strap as claimed in any of Claims 12 to 23 in which the thickness of the or each generally planar surface layer is at least 1 mil.

25. A fusible binding strap as claimed in any of Claims 12 to 24 in which the thickness of the or each generally planar surface layer is



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- between 1 and 25 percent of the thickness of the strap.
26. A fusible binding strap as claimed in any of Claims 12 to 24 in which the thickness of the or each generally planar surface layer is between 3 and 20 percent of the thickness of the strap.
27. A segment of binding strap as claimed in any of Claims 12 to 26 having overlapping opposite end portions fused together so as to define a joint, the joint comprising a central fused region which contains said polymer of a relatively higher average molecular weight than the same polymer which is adjacent to the central fused region.
28. A binding strap segment as claimed in Claim 27 in which the thickness of the central fused region is between 1 and 20 percent of the thickness of the overlapping end portions of the strap.
29. A binding strap segment as claimed in Claim 27 or Claim 28 in which the central fused region has crystalline orientation that is different from the crystalline orientation of strap portions adjacent thereto.
30. A binding strap segment as claimed in Claim 29 in which the central fused region exhibits less crystalline orientation than strap portions adjacent thereto.
31. A segment of binding strap as claimed in Claim 12, made of oriented polyethylene terephthalate having overlapping opposite end portions fused together so as to define a joint, the joint comprising a central fused region which contains polyethylene terephthalate having an intrinsic viscosity of at least 0.7.
32. A method producing a sheetform, crystalline thermoplastic polymer article which is a laminar composite of substantially uniform thickness, the method comprising coextruding distinct melt layers of the same crystallizable polymer but having different average molecular weights to form a laminar sheet so as to provide a minor thickness portion constituted by the polymer having a relatively higher average molecular weight and a major thickness portion constituted by the polymer having a relatively lower average molecular weight, solidifying the formed sheet, and then mechanically working the solidified sheet so as to provide substantially similar planar crystalline orientation in both of said thickness portions.
33. A method as claimed in Claim 32 in which the polymer is a polyester and in which the laminar sheet is solidified, maintaining the polymer in each thickness portion in a substantially amorphous state, and in which the mechanical working of the solidified sheet converts to a crystalline state and orients the crystallized polymer in each thickness portion.
34. A method of producing a sheetform crystalline thermoplastic polymer article, as claimed in Claim 32 and substantially as described herein with reference to Figures 1 and 2 or Figures 3 and 4 of the accompanying drawings.
35. Composite binding strap as claimed in Claim 12 and substantially as described herein with reference to any one of the foregoing Examples I to VI.
- KILBURN & STRODE
Chartered Patent Agents
Agents for the Applicants