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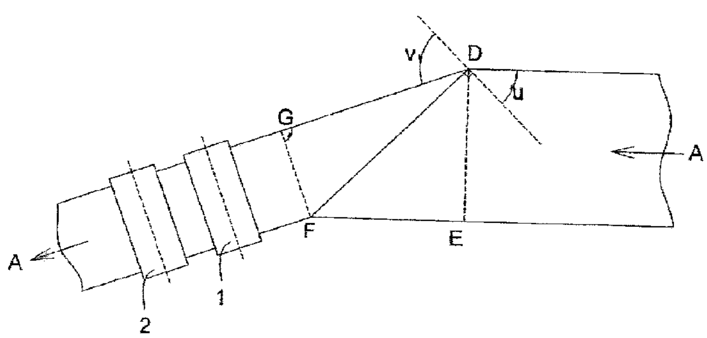
(54) Title: METHOD OF AND APPARATUS FOR MANUFACTURE OF A LAMINATE COMPRISING AN ORIENTED AND FINE-WAVED FILM, AND RESULTANT PRODUCTS

Fig. 1



(57) Abstract: In a method of manufacturing a laminate of an oriented and waved film (A) and a film or web (B), at least film (A) consisting of orientable, crystalline polymer material, the film (A) is stretched in an angular arrangement by being gripped by a linear nip (D-F) formed between rollers or bars, while being conveyed to this nip in a direction which forms an acute angle (u) to a plane perpendicular to the linear nip, and subsequently being pulled off by pulling means (1 and 2) under an acute angle (v) to the said perpendicular plane, as measured on the opposite side of this plane, (v) being greater than (u) but smaller than 85°, hereby producing elongation and uniaxial molecular orientation, the stretching ratio (GD to FE) and the angles (u) and (v) are selected such that the angle of orientation of the stretched film (A) deviates less than 15° from its longitudinal direction, and a reduction of film width is established, which measured in direct line is greater than the width reduction caused by the longitudinal elongation so as to form a longitudinally extending waving and the said waving is stabilised before meeting the pulling means (1 and 2), and film (B) is laminated to film (A) after film (A) has left the nip (D-F), while maintaining the fluting of (A). Suitably the films are formed of polyethylene.

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Method Of and Apparatus for Manufacture of a Laminate Comprising an Oriented and Fine-Waved Film, And Resultant Products

The objective of the invention appears from the title. Corrugated boards of thermoplastic sheet material has been known for more than 40 years. The uses of these known products are generally similar to the uses of corrugated cardboards since both provide a high stiffness against bending in one direction. However more recent inventions aim at low wavelengths of the fluting to make the laminate loose the character of board and give it the character of a flexible but stiffened film, at the same time as orienting and preferably also crosslaminating technologies are used for improvement of several properties. In particular tensile strength, yield tension and tear propagation resistance.

Thus WO02/102592 Rasmussen concerns laminates, preferably crosslaminates, in which one ply, preferably oriented in the machine direction, has been supplied with longitudinally extending flutes of wavelength 3 mm or lower. Another ply is without fluting, and has preferably been supplied with a transverse orientation.

In another publication, WO04/54793 Rasmussen, an aim is to achieve stiffness against bending in each direction, and to this end one ply of the laminate has been supplied with flutes along its machine direction, another ply with flutes transverse hereto, and in at least one of these plies the wavelength of the fluting is 5 cm or less, preferably much less.

In both of the above mentioned Rasmussen publications the establishments of the m.d. fluting takes place by means of rollers with circular grooves. These grooved rollers are mutually intermeshing, and the laminating takes place between a grooved roller and a smooth, rubbercoated roller. The grooved roller for laminating is in exact registration with the grooved rollers for fluting, and since the first mentioned grooved roller has a temperature which is higher than that of the last mentioned grooved rollers, the pitch of grooving must be mutually different when referring to ambient temperature. In the examples in both publications the pitch of grooves on the laminating roller has been 1.0 mm, but it is mentioned in both publications that the pitch of the machine direction (m.d.) flutes in the final laminate has been brought down to 0.8 mm by shrinkage of the transversely oriented film subsequent to the bonding.

The second above mentioned Rasmussen publication mentions several methods of forming flutes perpendicular to the m.d.. In the most practical method (see claim 67) the film to get transverse flutes is line-bonded to an m.d. oriented film on a laminating roller which is supplied with longitudinal grooves in a fine pattern (i.e. the grooves are perpendicular to the m.d.) and after stabilisation of the bonding the m.d. oriented film is brought to shrink. Hereby the non-bonded regions of the other film bend and form flutes.

Prior to the conception of the present invention the inventors have intensively searched the market for application of the technologies in the above mentioned Rasmussen publications. The second above mentioned Rasmussen publication mentions that "for textile-like applications of the flute wavelength in both plies should preferably be as low as possible, having hereby also regard to the economy of the manufacturing process". Now it has clearly turned out that the interest in the market place clearly favours low gauge laminates in which the wavelength of fluting is about or lower than 0.5 mm, so that the fluting becomes almost invisible or looks like a fine textile structure

Following that line, the inventors found that the above mentioned method of producing a perpendicular fluting can be applied without much difficulty to make the transverse flutes of a pitch lower than 0.5 mm (see in this connection Examples 2 and 3 of the present specification). However, calculations and experimentation re the application of the above mentioned technology for m.d. fluting of wavelength lower than 0.5 mm, has shown that although this will be industrially applicable, the width of the laminate will be limited to about 30-50 cm due to the limitations in temperature control of the rollers and accuracy in machining of the extremely fine pattern of grooves. That strictly limits the possibilities to obtain a precise "registration" between the flute-forming grooved rollers and the grooved laminating roller. In conclusion there is a strong need to devise an entirely different process for forming and laminating a film with fine flutes which extend in the m.d.

It should be mentioned in this connection, that to the knowledge of the inventors, the shortest known wavelength of corrugated paper laminate is about 1.8 mm. This is disclosed in US6139938, Lingle et al.

The present invention is based on a technology known from US2505146 (Ryan) which issued in 1950. The method steps stated in the introduction to the present claim 1 is known from that Patent, but in the present invention special conditions are selected, and a lamination step is added, as it appears from the characterising part of claim 1. For understanding of the claim language it is recommended to study Fig. 1 and the corresponding description.

The present invention is primarily conceived with a view to the manufacture of a laminate, in which (B) also is a thin film consisting of crystalline orientable polymer material, but for the sake of completeness it is mentioned that the film (B) is not limited so, but may e.g. be a paper film, a metal foil or a textile web.

Ryan has focused on the formation of a molecular orientation on the bias, and in his preferred execution of his technology the angle (v) is smaller than the angle (u), which is in contrast to the use of the technology in the present invention. However, in Figs. 6 and 17 and corresponding descriptions in columns 25 and 32, Ryan does describe that the angle (v) can be bigger than the angle (u), but he has not disclosed that his technology can be applied to form an even and stable longitudinal waving in a film. A study of the present Fig. 4 of this present Application will also show that the fineness and uniformity of the waves formed by use of the present invention is surprising, and could hardly have been anticipated by Ryan.

Reference is further made to US3491158 (Rasmussen), which issued in 1966. This deviates from the Ryan Patent in that the nip, which holds the film back during the stretching, is formed by a normal set of nip rollers, i.e. the angle (u) is zero, but it is similar to Ryan by the feature that the film is pulled off from the nip under an angle (v) while it is being stretched. This stretching takes place at an elevated temperature. In this old Rasmussen method there are actually formed fine, longitudinally extending pleats or waves. As in the present invention, this is done by reducing the width of the film in excess of the reduction in width which is obtained by stretching the film. However, the shape of these fine pleats or waves is not stabilised and is not maintained for manufacture of a corrugated laminate. To the contrary, the pleats are compressed flat and used to enhance a final longitudinal stretching for the purpose of making twine or technical yarn, e.g. by fibrillation.

For special purposes this old modification of the Ryan technology can also be applied in the present invention, provided compression of the waved structure is avoided, the waves are stabilised and the final stretching step is left out. However, in the said old Rasmussen method the angle (v) is 70-85°, (see claim 3) at the same time as the angle (u) is zero, and this causes a very high reduction of the width, which for most applications of the present invention is unsuitable.

Going back to claim 1 of the present invention, the stated selections of angles and stretching ratio will, as already mentioned, be better understood by a study of Fig. 1 and the connected description. Reference is also made to the extensive mathematical treatments in the Ryan Patent. As regards "the width reduction caused by the longitudinal elongation", this is a factor which can be determined in the laboratory. Laboratory determination can be carried out on narrow (e.g. 2 cm wide) continuous film samples, which are stretched at the temperature and velocity selected for the industrial process.

While claim 1 provides that the direction of orientation in film (A) as it leaves the nip (D-F) deviates less than 15° from its longitudinal direction, this deviation is preferably less than 10°, and more preferably less than 5°.

An apparatus particularly suited for carrying out the feeding of the film (A) into the nip (D-F) under an angle (u) is described in GB1078732 (Rasmussen), which issued in 1967. This apparatus makes use of "Segmental Rollers", i.e. the nip is formed between a pair of rotating rollers (5) each with its surface composed of a number no less than 3 of axially movable segments (6), and these segments are brought to reciprocate along the axial direction in coordinates with the rotation of the rollers, such that the film constantly is fed to the nip (D-F) under the same angle (u).

The mentioned British Patent concerns splitting of strongly oriented film to obtain a fibrous network. The rubber belts used in that fibrillation process are not necessary in connection with the present invention, but the segments on at least one of the rollers must be rubber coated to form the nip. Since the surfaces of the rollers normally must be heated, e.g. to 60-80°C, and since a low friction is preferable, the rubber is preferably a silicone rubber.

As it will appear from Fig. 1 and the connected description, there will be a fixed relation between angle u, angle v, stretching ratio EF to DG and the achieved reduction of width DE to GF. When a high stretching ratio combined with a deep waving or pleating is desirable, the film to be fed into the nip (D-F) may need to be in a state of uniaxial orientation preferably coinciding with or deviating at the highest 20° from its longitudinal direction, or with an unbalanced biaxial orientation having a main direction coinciding with or deviating at the highest 20° from its longitudinal direction. A strong melt orientation may be sufficient.

The stabilisation, which is needed before the waved film meets the pulling devices (rollers) is in the simplest form carried out by heating the film before it meets the nip, and the nip is then also heated. The heated film must again be cooled, normally by air, before it meets the pulling means (1) and (2), preferably immediately as it leaves the nip. A surprising stability of the waves can be achieved by an adequately high film temperature during the formation of the waves, followed by the mentioned cooling. In special cases the stabilisation may be produced by irradiation.

Alternatively or supplementarily, the stabilisation can be established by carrying out the laminate of the films (A) and (B) after (A) having left the nip (D-F) but before it meets the pulling means (1) and (2). However, the normal sequence is that the laminating takes place when film (A) has left the pulling means. It may be carried out on a different production line.

In any case the bonding is established as a line bonding or spot bonding limited to the crests on one side of film (A). There may also be laminated a third film (C) to the opposite side of film (A). In the simplest form, film (B) and/or film (C) is formed by extrusion coating and is oriented only by stretching in molten state.

However, to produce a film with good strength in all directions, the laminate is preferably a crosslaminate, i.e. film (B) has been oriented under an angle to the longitudinal direction of film (A). The bonding can be formed by extrusion lamination or between coextruded lamination layers on film (A) and film (B). It is important that the waves of film (A) are efficiently stabilised to avoid any significant flattening of the waves during the lamination. Nevertheless it is important to carry out the lamination under a very low laminating pressure, as it further shall be described in connection with Figs. 3 and 3a.

Prior to laminating, the film (B), when it consists of crystalline, orientable polymer material, is preferably supplied with a uniaxial or unbalanced biaxial molecular orientation, which gives the film a main direction of strength which is transversely extending, in other words forms an angle with the m.d. This angle is preferably between 40-90°, most preferably 90° when practical consideration (including cost of machinery) allows it. Transverse orienting at 90° can be carried out with a conventional tenterframe e.g. at about 80-90°C, preferably while a free longitudinal contraction is permitted during the expansion of the width.

In the apparatus which performs the biased stretching, the angle (v) is preferably made adjustable. The angle (u) cannot be made adjustable, except that the devices which control the reciprocation of the segments may be exchangeable. As herein before mentioned, (u) can in very special cases be zero. In other extreme cases it can be close to 90°, e.g. about 85°. However, normally it should be within a range from about 15° to about 60°.

Cam arrangements to transfer the rotation of the "Segmental Rollers" into the reciprocation of each segment are explained in the above mentioned British Patent. However, if the angle (u) is bigger than about 50°, it may be necessary to supplement such cam devices with pneumatic or hydraulic pistons, one acting on each segment.

A suitable method of forming transversely extending waves in film (B) and subsequently laminating it to film (A) without losing these waves, appears from claims 10-13 and is further described in connection with Figs. 3 and 3a.

No matter which embodiment of the invention is used, suitable compositions for each of the films (A) and (B) comprise HDPE, LLDPE or crystalline PP, to form at least 50% of each film.

A third film (C) may be laminated to film (A) on the side opposite to film (B).

Protection is also claimed for any combination of apparatus herein described and suitable for carrying out the method of the invention. Furthermore the invention comprises any product manufactured by this method.

The invention shall now be described in further detail with reference to the drawings of which:

Fig. 1 is a principal sketch serving to clarify claim 1,

Fig. 2 is a sketch of the "Segmental Rollers" which establish the nip where the waving is formed, and which are adapted to convey the film (A) to this nip under an angle (u) to the perpendicular to their axes,

Fig. 3 is a sketch showing how an m.d. oriented and finely fluted film (A), is line-bonded to a flat film (B) without distribution of the flutes (A), and how a t.d. fluting of (B) is developed by m.d. shrinkage of (A),

Fig. 3a is a microphoto of a laminating roller shown in Fig. 3 and actually made for Examples 2 and 3 and other laboratory trials. It is seen from one of its ends thereby showing the fine pattern grooves, which makes the bonding limited to a pattern of lines,

Fig. 4 is a microphoto of the film produced as described in Example 1, showing the cross section with even and fine waves.

In Fig. 1 the film (A), which already may have received a relatively strong orientation in its longitudinal direction, is pulled into the nip (DF) under an angle (u) to the perpendicular to the nip. The nip is formed between the two "Segmental Rollers" shown in Fig. 2. Each consists of a core part (5) and segments (6), the latter supplied with a rubber coating (7). The segments (6) are axially moveable on the core (5), running in tracks. The apparatus comprises curved tracks positioned at at least one end of the rollers and corresponding with cams on the segment, the curvature of the track being such that the segments are reciprocated longitudinally as they rotate relative to the track. These tracks are here shown in a simplified construction, while in practice they normally should comprise special roller bearings. When the "Segmental Rollers" are rotated, the segments are brought to reciprocate, one time "forward" and one time "backward" during one revolution. As mentioned this is normally arranged by means of cams at one end of each roller, see the drawings in the above mentioned British Patent. However, the cams can be substituted by or supplemented with suitable pneumatic or hydraulic means installed on the rollers, which means are controlled by or which control the rotation of the rollers.

Going back to Fig. 1 the film (A) is pulled off from the nip (DF) by the roller pair (1) and the roller pair (2), and is hereby extended, both moving at the same circumferential velocity. This pulling off takes place under an angle (v) bigger than (u) between a plane normal to the nip and the pulling direction.

When exact longitudinal orientation is wanted, a straight line, drawn on film (A) under 90° to its longitudinal direction, such as the line (DE), before film (A) meets the nip, must after passage of the nip remain a straight line which is perpendicular to the then existing longitudinal direction of film (A), such as the line (GF). In that case a circle, drawn on the film before the latter meets the nip, will be transformed to an ellipse with its main axis parallel with the new longitudinal direction of the film, and a straight line drawn perpendicular to the m.d. will in essence remain as a straight line perpendicular to the m.d.

When the point (E), (if drawn on the film) has moved to the point (F) (on the nip), the point (D), (if drawn on the film), will have moved to the point (G). Thus the stretching ratio, i.e. the ratio between the ingoing and outgoing velocities, will be (DG) divided by (FE). In Fig. 1 the film (A) is shown as if it moved in the same plane before and after the nip DF which localises the stretching. In actual fact film (A) should preferably but not necessarily, over a certain arc e.g. 10-20°, follow the surface of one of the "Segmental Rollers". This is helpful in order to avoid creasing of the film. However, it would have been rather complicated to show this in a drawing. Having left the nip, the film may again follow one of the roller surfaces over a small arch, but that has no positive effect. In the situations where film (A) follows a roller surface before and/or after the nip DF, Fig. 1 should be understood as an unfolded representation.

These considerations are based on the conditions that essentially all stretching takes place in or immediately after the nip DF. To secure this, this film is efficiently air cooled right at the exit from the nip. This can conveniently be carried out by applying an air die which ends in a wall of microporous material, localised immediately after the nip and with this wall parallel with and almost touching the film.

The inherent tendency in the film (A) to contract, can be established exactly by laboratory experiments as mentioned in the general description. On basis of

a) this inherent contraction ratio multiplied by a factor for wanted depth of waving,
b) the angle (u), and
c) the stretch ratio,

the angle (v) can easily be calculated on trigonometric basis. Thus,
stretching ratio DG/FE = sin v/sin u,
and total t.d. contraction ratio, composed of the inherent contraction and the extra waving:
DE/GF = cos u/cos v
See also the calculations in Example 1.

It should be understood, but it is not shown in Fig. 1, that the film (A) passes in "S-path" over each of the two pulling roller pairs (1) and (2). During this passage a ruining of the waved configuration must be avoided, thus each of these 4 rollers may be coated with a soft rubber, and the two rollers (1) may not form a nip against each other. The roller pair (2) may form a nip, but should exert almost zero nip pressure. Having left these pulling rollers, the film (A) may be spooled up or may proceed directly to the lamination, which e.g. may take place as shown in Fig. 3.

In Fig. 3 the thin film (B) has been coextruded and thereby supplied with a lower melting lamination layer. It may be oriented in any direction but preferably substantially perpendicular to the m.d. It may come from a reel or directly from a t.d. stretching apparatus such as a conventional tenter frame.

An alternative technology to obtain 90° orientation of a film is described in US5361469 (Rasmussen) col. 4 ln. 39-col. 5 ln 6. Here a tubular film is supplied with orientation under an angle (e.g. 30°) by relative rotation between the circular exit orifice and the haul off rollers, and subsequently it is helically cut under an angle (in the example 60°) to form 90° orientation. This will be melt orientation only, but nevertheless this method is very suitable in connection with the present invention

The direction of orientation in (B) is not necessarily about 90° to the m.d. but should conveniently not be lower than about 40°. Such angles of orientation can be formed by helical cutting of an m.d. oriented tube

It is noted that the formation of flutes extending under an able of 90° to the m.d. – which shall be described below – has no connection with the direction of orientation in (B). Film oriented e.g. at 40° to the m.d., can be brought to form fine flutes extending at 90° to the m.d. Film (B) is guided under a very low tension (control means not shown) to the rubber coated roller (8). This has ambient temperature, while the following laminating roller (9) which it contacts is heated to a temperature to melt or semi-melt the lamination layer. There are fine axial grooves (12) on the surface of roller (9). These grooves are showed in the microphoto Fig. 3a.

The fine grooves limit the bonding to a fine pattern of bonding lines with unbonded spaces between. The pitch(es) of the pattern of grooves may be as low as 0.3 mm as it appears from the microphoto.

The thin film (B) becomes almost instantly heated to the temperature selected for lamination. If (B) consists of HDPE, LLDPE, LDPE or crystalline PP, supplied with a lower melting lamination layer, a suitable temperature will be between about 80-110°C depending on the lamination layer, and if film (B) is in strongly oriented state in the t.d., it must have been properly stabilised at a similar or higher temperature before it is fed to the apparatus, to avoid transverse shrinkage. Such stabilisation is described in WO04/54793 (Rasmussen) in connection with Fig. 5.

The film (B) is laminated with film (A) as this comes out of the "Segmental Rollers" stretching process supplied with longitudinally extending flutes. Film (A) is also supplied with a lower melting lamination layer. The two pairs of pulling rollers (1) and (2) in Fig. 1 are in the Fig. 3 substituted by 3 rollers (10) all coated by a soft rubber, and all driven at the same velocity, which is adjusted as explained in connection with Fig. 1. They have ambient temperature. The line bonding takes place when the two films meet on laminating roller (9). Film (A) is not heated before meeting film (B). At this step film (A) still has the same longitudinal tension as when it left the "Segmental Rollers". To preserves its fluted shape it only follows the hot laminating roller over a short adjustable arc, e.g. about 20°. Thereby only a small portion of each flute is flattened and heated.

The lamination of (A) and (B) passes over a pressurised air film, formed through microporous material on the air die (11). The air has ambient temperature and acts to cool and lubricate the films.

The tension in the laminate is maintained by the two driven pull-rollers (12) and the idling nip roller (13). Both rollers (12) are coated with a soft rubber, and (13) is coated with foam rubber.

The three pull rollers (10), the laminating roller (9) and the two pull rollers (12) are all driven with the same circumferential velocity, and thus film (A) is still under a high longitudinal tension when it meets nip roller (13). Having left the nip (A) relaxes on its way to winding, while the unbonded spaces in (B) bend and form flutes, provided all adjustments are correct.

Of particular importance is the tension in film (B) when it meets the idling rubber coated nip roller (8). If this tension is high, it is clear that the shrinkage of (A) will not cause (B) to form flutes. If it is close to zero, the heating on laminating roller (9) will cause an expansion in the m.d., which partly brings film (B) out of contact with the roller. Therefore the tension when film (B) meets roller (8) must be very exactly adjusted. Electrostatic charging of film (B) by means of a corona discharge is a helpful means to keep film (B) in good contact with roller (9) at low tensions.

Important is also the choice of arc over which film (A) follows the laminating roller (9). To this end the position of the cooling die (11) is made adjustable.

While the tension in film (A) normally is sufficient to produce the pressure needed for bonding, this may under circumstances be supplemented by the action of a pressurised air film, formed through microporous material and acting on the side of film (A) which is opposite to film (B). This is not shown in the drawing.

EXAMPLE 1

A 3-layer tubular PE film is extruded from a 1.5 mm circular exit slot, with blow-up ratio (BUR) 2:1 and in gauge 0.017 mm. The composition is as follows:
Middle layer, 60% of total: plain high mol. wgt. HDPE,
Outer surface layer: an ethylene copolymer starting melting at 80°C,
Inner surface layer: plain LLDPE of melt flow index 1.

An experimental "Segmental Rollers" apparatus (see claim 3 and Fig. 2) is used, which was constructed for the developments resulting in the above mentioned old British Patent. In this apparatus the angle (u) is 17°, and it would have been a substantial work to change this angle. Pulling rollers (see Fig. 1, ref. numbers 1 and 2) are installed such that the angle (v) and the stretching ratio easily can be varied.

20 cm wide longitudinal tapes are cut from the extruded tubular, flattened film and are stretched in different ratios at 70°C. This is the temperature chosen for the stretching in the "Segmental Rollers" apparatus. It is hereby found that break occurs at a stretch ratio of 3.0:1 and that the width of the tape immediately before break is 1.1 mm, i.e. the inherent transverse contraction ratio is 2.0:1.1 – 1.8:1.

The low ultimate stretching ratio is due to a high melt orientation in the starting film. This high melt orientation is an advantage for the invention, and without this it might have been necessary to pre-orient the film, in conventional manner e.g. at 70°C. The reason for this is that a strictly longitudinal orientation and waving is preferable in the final film and then, as calculated in the description of Fig. 1, the stretch ratio will be sin v/sin 17° - sin v/0.29. In the very ultimate case when (v) approaches 90°, this sets a limit of 1:0.29 – 3.4:1 for the stretching ratio in the "Segmental Rollers" apparatus if the angle u = 17°.

To safeguard against break, the stretch ratio 2.6:1 is chosen. By the stretching trials carried out at 70°C on 20 mm wide tapes, it is found that the stretching in this ratio inherently reduces the width from 20 mm to 14 mm. This means that the inherent contraction ratio is (2.0:1.4):1 = 1.43:1.

Tentatively the angle (v) = 60° is chosen. According to a formula in the description of Fig. 1, this will give a total width reduction in the ratio cos 17°/cos 60° - 0.95:0.5 = 1.90:1. Since the inherent contraction ratio is 1.43:1, there will be left a ratio of 1.90/1.43 = 1.33:1 to make the waving, and this is considered acceptable.

On the other hand, the direction of orientation will not become strictly longitudinal. To achieve this, the stretching ratio should have been sin 60°/sin 17° = 0.87:0.29 = 3.0:1.

However, it is considered that the deviation from longitudinal orientation will be very low and the stretching on the "Segmental Rollers" apparatus is then carried out with v=60°, temperature 70°C and stretching ratio 2.6:1. It is hereby confirmed that the deviation from longitudinal orientation becomes negligible.

The obtained waving appears from the microphoto Fig. 4. As already mentioned the waving is surprisingly even. The film can be laminated under a low lamination pressure with a film (B) having similar composition without ruining the waves.

EXAMPLE 2

In this Example there was used a full stretching/laminating line combining the apparatus of Figs. 1, 2, 3 and 3a (with some modifications, see below). Both films (A) and (B) were based on LLDPE. Before the "Segmental Rollers" stretching process film (A) started as an m.d. melt oriented film in the form of a 120 mm wide ribbon, while film (B) before the laminating process started as a 60° melt oriented film in form of a 55 mm wide ribbon. The 60° orientation was achieved by helical cutting of an m.d. melt oriented tube, as this is described in US5361469 (Rasmussen). It is noted that, while the starting orientation in (B) was under 60°, its direction of fluting became perpendicular.

Concerning the laboratory stretching/laminating line:

The two pairs of pull rollers (1) and (2) in Fig. 1 were substituted by the three pull rollers (10) in Fig. 3.

Roller (8) was not yet tried as a nip roller as in Fig. 3. It acted as an idle roller positioned at some distance from the laminating roller (9).

The air-film cooling device in Fig. 3 was substituted by a simple metal block, which at the start of each trial run had about ambient temperature. It needed not be cooled since each trial run was short.

The diameter of the laminating roller (9) was 32 mm, and its length was 52 mm.

With reference to Fig. 1, the angle u was 17° and the angle v was 60°, both like in Example 1.

Concerning the extruded film:

Films (A) and (B) were taken from tubular films which only deviated in gauge. Gauge of the extruded film for (A) was 0.030 mm, and gauge of the extruded film for (B) was 0.015 mm. Both were coextruded from a 3-component die. The composition was as follows:

Main layer extruded as the core and the internal surface was 85% of total and was 100% LLDPE (Dowlex 5056).

Outer surface layer (for lamination) was 15% of total and consisted of an ethylene copolymer of melting point about 80-90°C (Attane SL4102).

The gap of the exit slot in the coextrusion die was 1.5 mm and the blow-up ratio was 1.8:1.

Conditions of stretching/lamination:

The surface of the "Segmental Rollers", which was coated with black rubber, was infrared heated and controlled at 50°C. The laminating roller (9) was heated by circulating hot water and controlled at 80°C.

The stretching ratio of film (A) as measured on the final laminate after relaxation was 3.0:1. This was found to produce exact longitudinal orientation of (A).

The unwinding tension in film (B) was adjusted to make the flutes in film (B) as deep as possible.

By experimentation with the position of the metal block (11) the flattening of the flutes in film (A) was minimised without ruining the bonding between films (A) and (B).

Results:

Film (A) became fluted with wavelength 0.5 mm and depth of flutes 0.23 mm.

Film (B) became fluted with a wavelength corresponding to the pitch on roller (9) and depth of flutes 0.09 mm.

Final gauge for the laminate: 32 grams per sq. m.

Ultimate m.d. tensile strength 24 N/cm width.

Ultimate t.d. tensile strength 7 N/cm width.

EXAMPLE 3

For the two films (A) and (B) the same tubular films were used as in Example 2, of gauges 0.030 mm and 0.015 mm, respectively. In this Example, transverse melt orientation of film (B) was tried. In an industrial process this can conveniently be achieved by the method described in US5361469 (Rasmussen) col. 4 ln 39-col. 5 ln 6. This technology has already been briefly described in the general description of the present invention. However, in the present trial 55 mm wide strips were simply cut out of the extruded tubular film under 90° to its m.d., and several such strips, were joined by means of adhesive tape.

The trial production of the fluted laminate took place exactly as described in Example 2.

Results:

Film (A) became fluted with wavelength 0.5 mm and depth of flutes 0.01 mm.

Film (B) became fluted with wavelength corresponding to the pitch on roller (9) and depth of flutes 0.045 mm,

Final gauge of the laminate: about 30 g/sq. m.

Ultimate tensile strength m.d. 26 N/cm width.

Ultimate tensile strength t.d. 7.3 N/cm width.

CLAIMS

1. A method of manufacturing a laminate of an oriented and waved film (A) and a film or web (B), at least film (A) consisting of orientable, crystalline polymer material, in which the film (A) is stretched in an angular arrangement by being gripped by a linear nip (D-F) formed between rollers or bars, while being conveyed to this nip in a direction which forms an acute angle (u) to a plane perpendicular to the linear nip, and subsequently being pulled off by pulling means (1 and 2) under an acute angle (v) to the said perpendicular plane, as measured on the opposite side of this plane, (v) being greater than (u) but smaller than 85°, hereby producing elongation and uniaxial molecular orientation, characterised in that the stretching ratio (GD to FE) and the angles (u) and (v) are selected such that the angle of orientation of the stretched film (A) deviates less than 15° from its longitudinal direction, and a reduction of film width is established, which measured in direct line is greater than the width reduction caused by the longitudinal elongation so as to form a longitudinally extending waving and further characterised in that the said waving is stabilised before meeting the pulling means (1 and 2), and film (B) is laminated to film (A) after film (A) having left the nip (D-F), while maintaining the fluting of (A).

2. A method according to claim 1, characterised in that (B) also is a film consisting of orientable, crystalline polymer material.

3. A method according to claim 1 or 2, characterised in that said nip is formed between a pair of rotating rollers (5), each with its surface composed of a number no less than 3 of axially moveable segments (6), and said segments are brought to reciprocate along the axial direction in coordination with the rotation of the rollers such that the film constantly is fed to the nip under the same angle (u), while the segments are moved oppositely after their contact with the film.

4. A method according to claim 1, 2 or 3, characterised in that said deviation is less than 10°, preferably less than 5°.

5. A method according to any of the preceding claims, characterised in that prior to the stretching in an angular arrangement, the film (A) is supplied with a uniaxial orientation coinciding with or deviating at the highest 20° from its longitudinal direction, or with an unbalanced biaxial orientation having a main direction coinciding with or deviating at the highest 20° from its longitudinal direction.

6. A method according to any of the preceding claims, characterised in that the film (A) meeting the nip has been heated, and the nip is heated, and the stretched film (A) is cooled before meeting the pulling means (1 and 2), the cooling preferably taking place immediately as it leaves the nip.

7. A method according to any of the preceding claims, characterised in that the bonding is formed by extrusion lamination or between coextruded lamination layers on film (A) and film (B).

8. A method according to claim 2, characterised in that prior to the lamination film (B) is supplied with transversely extending orientation.

9. A method according to claim 8, characterised in that said orientation forms an angle between 40 and 90°, preferably about 90°, to the longitudinal direction.

10. A method according to claims 2, 8 or 9, characterised in that the bonding takes place between mutually facing lamination layers on film (A) and film (B) on a heated laminating roller, film (B) being in direct contact with the roller while film (A) is in longitudinally tentered state, and the bonding is limited to transversely extending lines formed by supplying the laminating roller with longitudinal grooves, and further characterised in that subsequent to the bonding the laminated films are cooled and film (B) is brought to form transverse flutes by elimination of the tension in (A).

11. A method according to claim 10, characterised in that the pitch of the longitudinal grooves is between 0.2 and 1.0 mm.

12. A method according to claim 10 or 11, characterised in that the pressure which causes film (A) and film (B) to bond together is confined to the pressure produced by the tension in (A).

13. A method according to claim 10 or 11, characterised in that the pressure which causes film (A) and film (B) to bond together is confined to the resultant of the pressure produced by the tension in (A) and a pressurised air film applied on the side of film (A) which is opposite film (B).

14. A method according to claim 7, characterised in that the lamination is extrusion lamination by means of a tie film applied at the location where film (A) and film (B) meet each other on a laminating roller.

15. A method according to any preceding claim, characterised in that a third film (C) is laminated to film (A) on the side opposite to film (B).

16. Any combination of apparatus described herein, and suitable for carrying out the method according to the invention.

17. Any product made by the method according to the invention.

18. A method according to claim 2, characterised in that at least 50% of each of the films (A) and (B) consists of HDPE, LLDPE or crystalline PP.

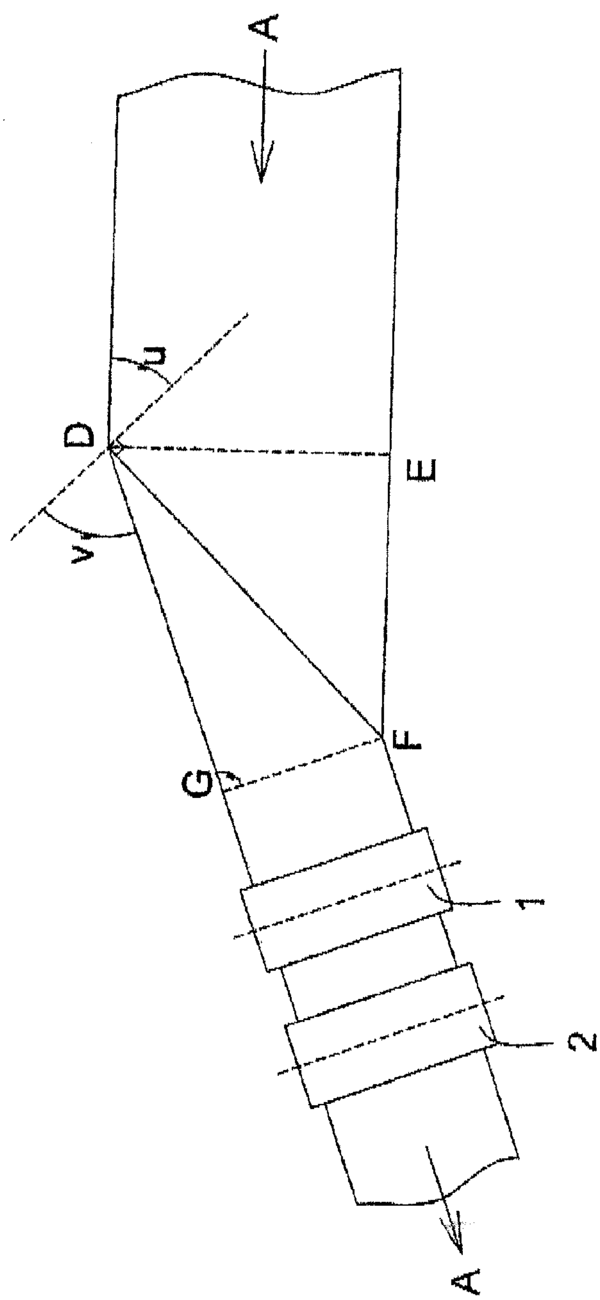

Fig. 1

Fig. 2

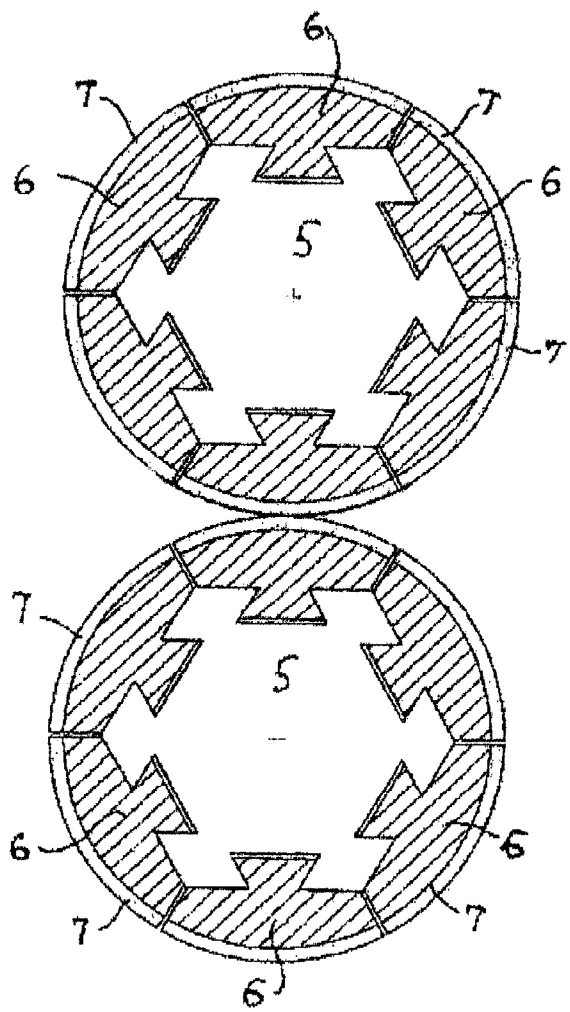

Fig. 3

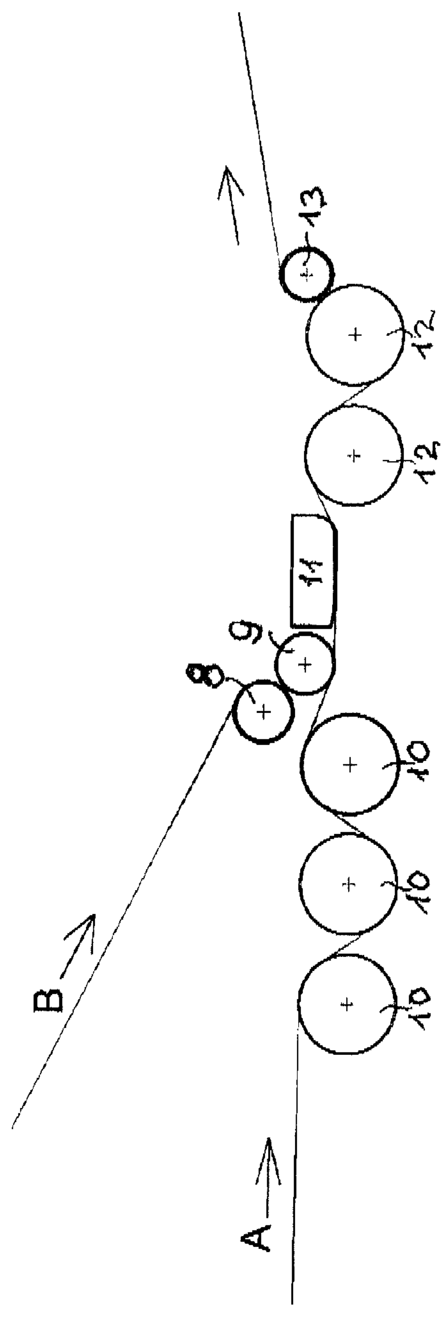

Fig. 3a

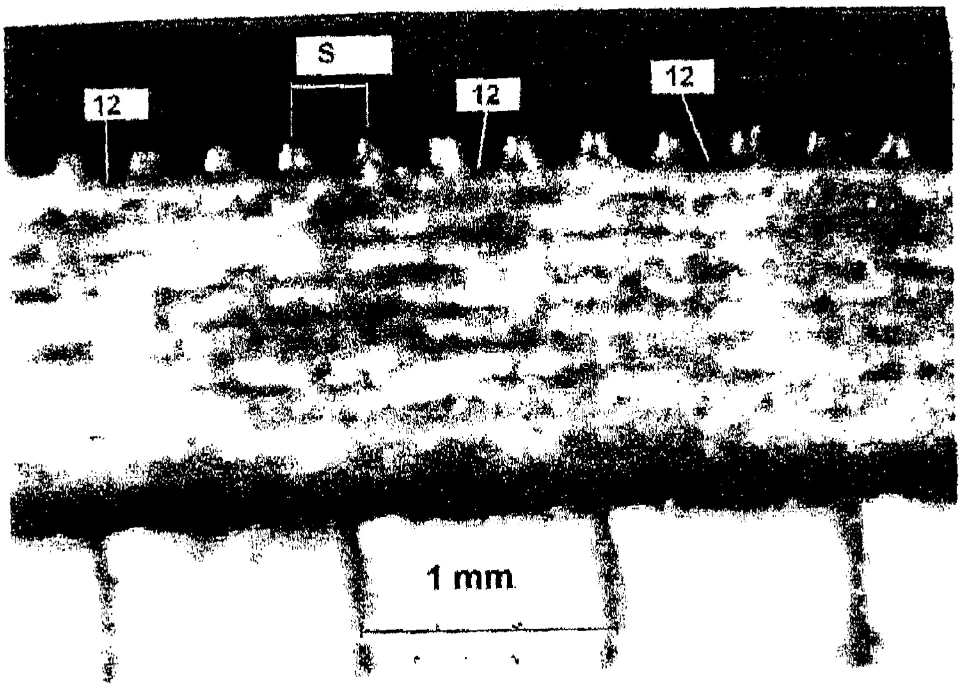

Fig. 4