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(54) **METHOD FOR EXTRUDING FOAMED POLYPROPYLENE SHEET HAVING IMPROVED SURFACE APPEARANCE**

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Related U.S. Application Data

(60) Provisional application No. 60/098,958, filed on Sep. 3, 1998, provisional application No. 60/122,129, filed on Mar. 1, 1999, and provisional application No. 60/128,173, filed on Apr. 6, 1999.

(51) **Int. Cl.**[7] **B29C 44/20**

(52) **U.S. Cl.** **264/51**; 264/53; 264/54; 425/461

(58) **Field of Search** 264/51, 53, 54; 425/461

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(57) **ABSTRACT**

An improved coat hanger extrusion die wherein the aperture of the die land widens along the extrusion axis of said die to the die exit opening, thereby forming an expansion zone, and a method for extruding foamed polypropylene sheet having an improved surface appearance.

13 Claims, 2 Drawing Sheets

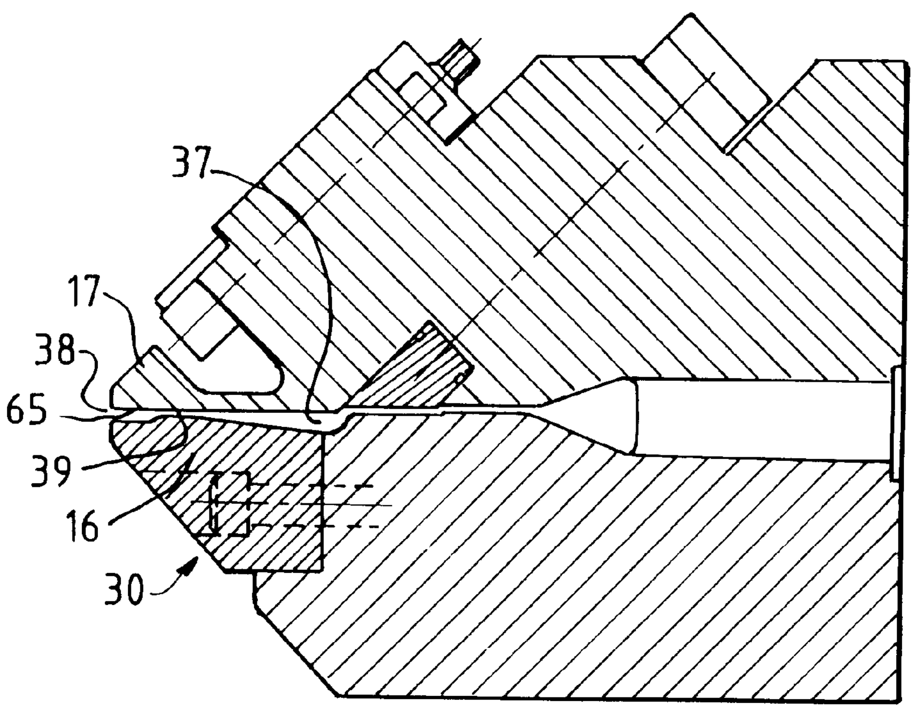


FIG. 1

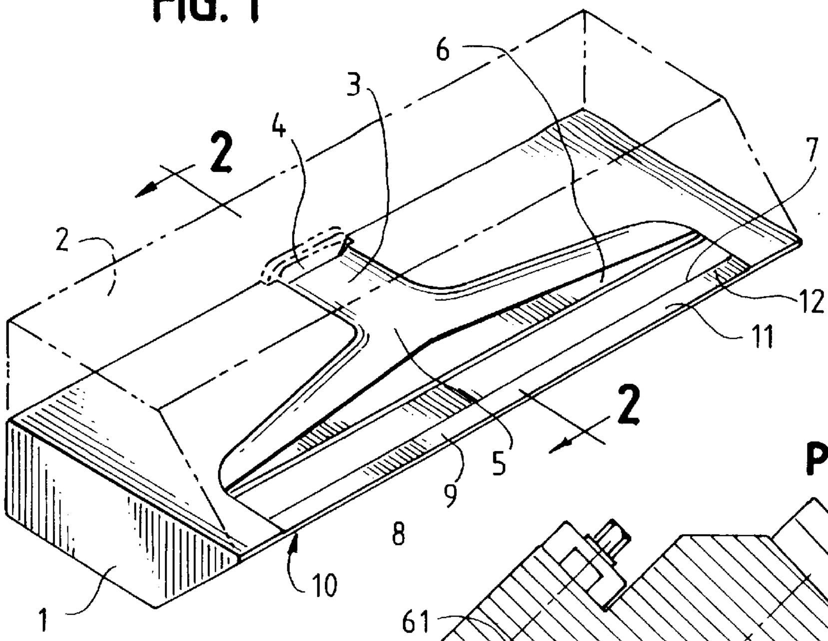


FIG. 2
PRIOR ART

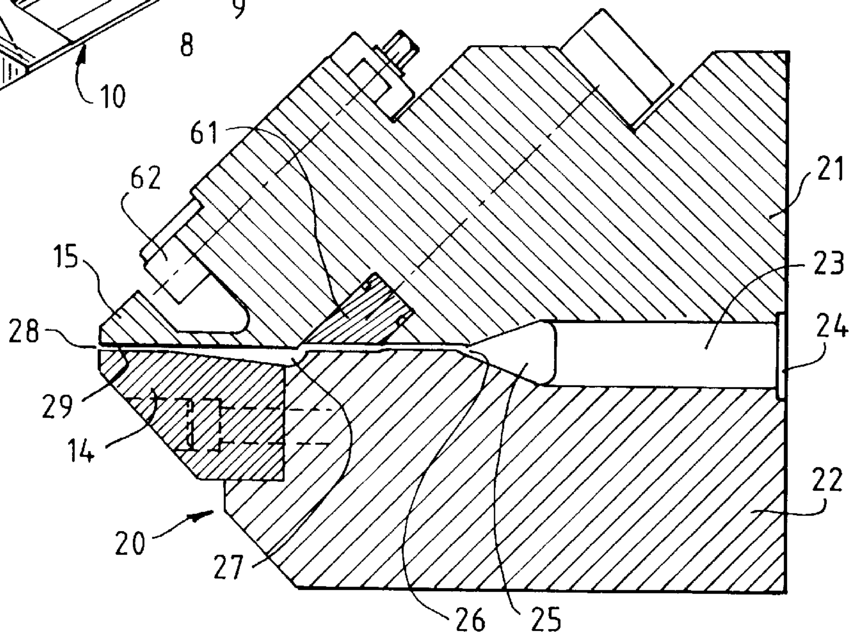


FIG. 3

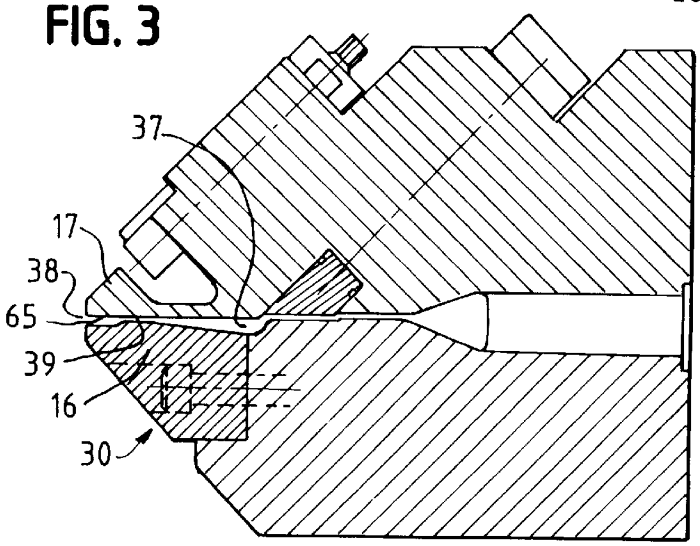


FIG. 4

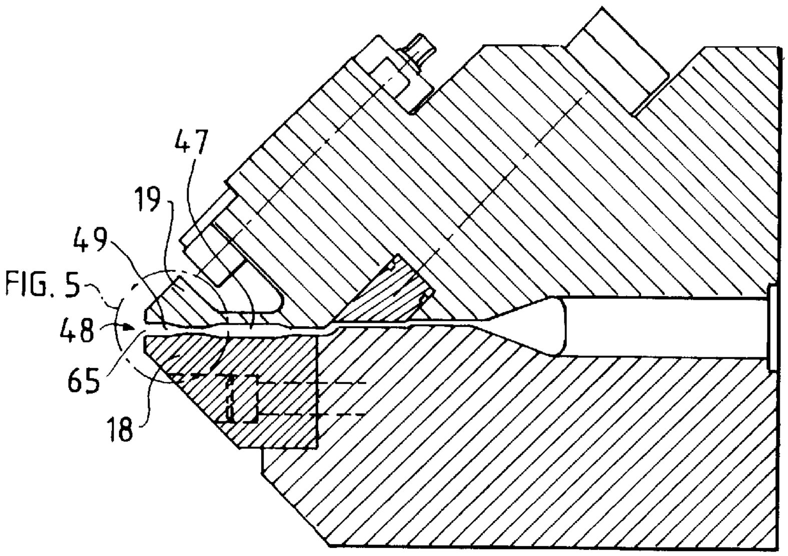
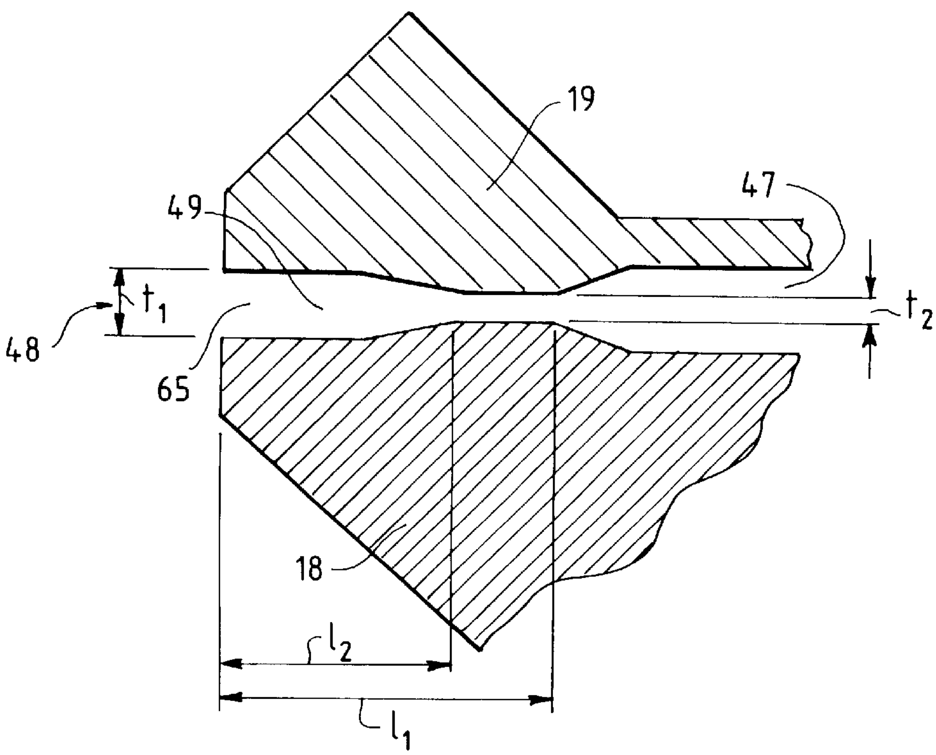


FIG. 5



METHOD FOR EXTRUDING FOAMED POLYPROPYLENE SHEET HAVING IMPROVED SURFACE APPEARANCE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/098,958, filed Sep. 3, 1998, U.S. Provisional Application No. 60/122,129, filed Mar. 1, 1999, and U.S. Provisional Application No. 60/128,173, filed Apr. 6, 1999.

BACKGROUND OF THE INVENTION

This invention relates to polyolefins, and more particularly to improved expanded or foamed compositions comprising propylene polymers. Still more particularly, the invention relates to an apparatus including an improved extrusion die and to a method for the extrusion of rigid or semi-rigid polypropylene foam sheet having improved surface appearance. Polypropylene foam sheet according to the invention is readily thermoformable into shaped articles that are particularly useful in rigid and semi-rigid packaging and in fabricating trays, plates, containers and other articles used in food service applications.

Polystyrene has found wide acceptance for use in food service applications because of its good rigidity and shape retention and, as foam sheet, it is readily molded and thermoformed. However, polystyrene articles suffer from low service temperature, and generally are fragile and lack chemical resistance. The food service and packaging arts have long sought alternative materials that do not have these undesirable characteristics.

Polyolefin resins are widely known for their ease of fabrication and are found in a great variety of applications. Propylene polymers, or polypropylene resins, are particularly noted for their good heat resistance and mechanical properties, and resin formulations based on polypropylene are supplied to meet the demands imposed by a variety of structural and decorative uses in the production of molded parts for appliances, household goods and autos. Impact-modified polypropylene and elastomeric ethylene-propylene copolymers have found application in automotive applications including interior trim as well as in exterior parts such as bumper facia, grill components, rocker panels and the like. Polypropylene resins have the thermal and chemical resistance to withstand exposure to the wide variety of environments encountered in automotive uses, and are easily molded at a cost far below that of metal stamping to provide parts that resist rust and corrosion and are impact resistant, even at low temperature. Considerable effort has been expended in recent years to develop rigid expanded or foamed polyolefin sheet as a replacement for polystyrene foams, particularly for use in food service applications. A number of processes for producing polypropylene foam have been disclosed and are well described in the art, including for example the methods disclosed in U.S. Pat. No. 5,180,571 to J. J. Park, et al and those set forth in the references cited and summarized therein.

At the surface of extruded foam sheet there generally may be found a layer consisting substantially of crystalline polypropylene (PP). This surface layer or skin is important to part appearance and surface hardness. The thickness and crystallinity of the PP surface layer that forms depends in part upon extrusion conditions including die temperatures and cooling rates, and upon annealing. The Park et al patent is directed to the extrusion of polypropylene to provide foam sheet with a smooth surface skin and a uniform cell structure. According to Park et al, high melt strength, high melt elasticity polypropylene with a particularized combination of molecular and rheological characteristics including bimodal molecular weight distribution and a minor component that is highly branched is necessary to provide acceptable foam sheet. Patentees provide comparisons showing that low density foam sheet extruded using conventional or generic polypropylene resins, further characterized as polypropylene resins with monomodal molecular weight distributions and an absence of significant branching, generally have roughened sheet surfaces and non-uniform microcellular structure and are unacceptable for commercial use.

The surfaces of extruded polyolefin foam sheet generally lack the smooth, shiny, uniform and substantially unblemished surfaces observed with extruded styrenic foam sheet, particularly including higher density ABS foam sheet. For example, surface roughness is commonly encountered when extruding polyethylene foam sheet, and lack of uniformity in cell structure and distribution at the surface is visually more readily apparent because of the transparent nature of unfilled polyethylene. Sensible surface roughness, that is, roughness that can be sensed tactilely, may be reduced by contacting the lower melt temperature polyethylene sheet with a polishing roll during the extrusion process to give a smooth, more even surface. The surface imperfections that remain are mainly visible density variations and are generally uniformly distributed, providing a textured or marbleized surface appearance that is pleasing and generally acceptable.

Rigid polypropylene foam sheet obtainable from conventional resins by the processes currently known and practiced in the art continues to be somewhat lacking in surface appearance characteristics. Characteristically, polypropylene foam sheet extruded with conventional processes and using conventional or generic polypropylene resins will have regularly-spaced markings in the form of alternating bands or corrugation-like markings extending the length of the sheet in the machine direction. In light, low-density foams obtained from conventional polypropylene resins, particularly soft, flexible foams having densities of 20 lb/ft^3 (0.3 g/cm^3) and lower, these bands may have the form of a regularly spaced, wave-like or sinusoidal distortion, forming a corrugated sheet. The bands or corrugations become less pronounced for rigid foam sheet and, particularly at higher foam densities, are seen as surface flaws or appearance defects that take the form of linear, valley-like surface depressions along the machine direction.

The surface roughness of sheet extruded using these higher melting resins is more difficult to smooth adequately using a polishing roll. Moreover, the imperfections and visible density variations found in the surfaces of extruded polypropylene foam sheet are often not uniformly distributed over the surface, and are generally quite visible, even for sheet that otherwise is tactilely smooth. In rigid, higher density foams, such as are sought for the production of food service articles, the defects more often appear as a pattern of alternating linear bands of high and low foam density, characterized by readily visible variations in translucence and surface gloss, possibly including surface voids, bubbles, streaks and uneven color. Such flaws may be without significant effect on the mechanical properties of the foam, and generally do not affect the performance of finished goods fabricated from such foam. However, in consumer goods, food packaging, and the like, these visible surface defects and related cosmetic flaws are highly undesirable, thus limiting acceptance of polypropylene foam sheet by the industry.

Coextrusion of multilayer sheets having solid outer skins and a foamed core has been disclosed in the art and is widely used to overcome surface appearance problems encountered in the production of a variety of prior art foam sheet materials including those made from polystyrene and ABS. Foam core sheet, provided with a shiny or glossy unfoamed surface layer formed of the same or another resin, may be improved in resistance to surface abrasion and cuts and have a superior appearance. The more rigid skin serves to stiffen the foam structure, allowing a lighter and thinner structure while attaining maximum bending stiffness. Foam sheet coextrusion processes are well described in the art for use with a variety of resins such as polystyrene and ABS, and methods have been recently disclosed for use in the coextrusion of multilayered foam sheet comprising polyolefins including polypropylene. Coextrusion processes suffer the disadvantage of generally requiring more costly feedblocks, dies and related machinery having a more complicated design, thereby increasing the complexity of the operation and raising cost of producing such foam sheet.

Thus, there continues to be a need for a reliable method for the manufacture of rigid, high density foamed polypropylene sheet comprising conventional generic polypropylene resins with reduced visible surface defects and related cosmetic flaws and having the attractive, defect-free surface appearance necessary for acceptance in the food service and packaging industries.

SUMMARY OF THE INVENTION

The invention pertains to apparatus and method for the production of foamed polypropylene sheet with improved appearance characteristics. More particularly, the invention relates to an improved extrusion die for use in extruding foamed polypropylene sheet having excellent surface appearance and to a method for extruding improved foamed polypropylene sheet.

Rigid, foamed polypropylene sheet according to the invention has a low average surface roughness uniformly distributed over the surface of the foam sheet, and a substantial absence of corrugation and surface banding. When molded or otherwise thermoformed, the invented foam sheet will afford rigid or semi-rigid articles having improved surface appearance while retaining a good balance of mechanical properties including stiffness and toughness. The invention thus may also be characterized as a method for providing molded articles having improved appearance comprising expanded or foamed polypropylene.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a diagrammatic, perspective view, partially in phantom, of a typical coathanger-type sheet extrusion die.

FIG. **2** is a sectional view of a prior art polyolefin sheet extrusion die, taken along line 2—2 of FIG. **1**.

FIG. **3** is a sectional view, taken along line 2—2 of FIG. **1**, showing an improved sheet extrusion die according to the invention.

FIG. **4** is a sectional view, taken along line 2—2 of FIG. **1**, showing an alternative embodiment of the improved sheet extrusion die according to the invention.

FIG. **5** is a fragmentary, enlarged sectional view showing the detail of the die land portion of the embodiment of FIG. **4**.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Thermoformable polyolefin foam sheet having improved surface appearance together with high modulus, service temperature and thermal insulation properties will be obtained by extruding a foamable polyolefin composition employing an improved, coathanger-type foam sheet extrusion die according to the invention.

Processes for extruding foam sheet generally employ an extrusion apparatus having single or multiple extruders, which may be single or twin screw extruders, to conduct the mixture of polypropylene resin and additives through the plasticating and mixing steps, and provide a molten, foaming or foamable resin mass to the inlet of a sheet extrusion die. Preferably the extrusion die will be a coathanger type sheet extrusion die wherein the inlet extends to a coathanger-shaped plenum in the form of a relatively wide and vertically narrow cavity, elongated in the horizontal or transverse direction (Y axis) and relatively narrow in the vertical direction (Z axis). The resin flow direction or machine direction may also be referred to as the extrusion axis (X axis). The plenum is in liquid communication with an exit port or mouth extending along the width or Y axis of the die, forming a slit defined by die lips. Molten, foaming resin enters the die through the inlet, is spread across the width of the die by way of the plenum, passes between die lips and exits through the exit port or die exit in a molten or semi-molten state as a continuous sheet. The extruded sheet will then be cooled to become solidified, for example by being passed through a roll stack to cool the foam and finish the sheet. Differential roll speeds and take-up speeds may be employed to draw the foam sheet, orienting the crystalline polypropylene and achieving a final form and thickness for the sheet.

Turning now to the drawings, it may be seen in FIG. **1** that a typical coathanger die, generally designated by the reference numeral **10**, for extruding thermoplastic sheet will comprise a first or lower half **1** and a second or upper half **2**, indicated in phantom. Assembled in opposed relationship, the halves form cavity **3**. Molten foaming resin enters the die through inlet **4** and flows into coathanger-shaped plenum **5**. Plenum **5** spreads the molten resin uniformly across the width of the die as it flows through the preland passage **6** to melt well **7**. Adjustable choke means (not shown) may be included to provide control of resin flow, and any differences in pressure still remaining may be evened out by melt well **7**. The molten resin continues through planar extrusion passageway or die land **9** defined by the opposing, spaced apart faces of lower die lip **11** and upper die lip **12**, exiting the die through exit opening **8** forming a sheet.

It will be understood that the die body may include passages for heating and cooling, and further that clamping and fastening means and means for assembling the die to the extruder, also required, have been omitted from the drawings for clarity.

In FIG. **2** it will be seen that Prior Art sheet extrusion die **20** includes assembled upper and lower halves **21** and **22**, together defining cavity **23**, and upper and lower die lips **14** and **15**. As described above, molten foaming resin will be supplied under pressure by extruder means (not shown) to die cavity **23** through inlet **24**, in fluid communication with exit opening **28**. Flowing into the coat hanger plenum **25**, and dammed by the narrowing of the cavity at preland passage **26**, the melt stream is spread across the width of the die by plenum **25** and fills melt well **27**. The molten resin, further regulated by adjustable choke means **61**, flows from melt well **27** and passes through extrusion passageway or die land **29**, exiting the die through exit opening **28** as continuous foam sheet.

Either or both of die lips **14** and **15** may be made fixed or removable as desired. As shown in FIG. **2**, lower die lip **14**

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