

POLYMER PROCESSING AIDS COMPRISING SILICONE POLYETHERS
CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 63/626,250 filed January 29, 2024, the contents of which are incorporated in their entirety herein.

TECHNICAL FIELD

[0002] The present disclosure generally relates to polymer processing aids.

BACKGROUND

[0003] Plastics are used for a wide range of industrial applications, including packaging, construction, and wire and cable. However, many plastics suffer from melt fracture during extrusion, which is a phenomenon wherein the surface of the plastic becomes distorted with undulations or irregularities. Some types of melt fracture, such as sharkskin melt fracture, impact the surface of the plastic by causing irregular and sometimes scaly surface texture which may reduce the glossiness of the surface.

[0004] Conventional processes for preventing melt fracture in polyethylene include using fluoropolymer-based processing aids. However, concerns that fluorinated chemical compounds may be persistent in the environment have spurred restrictions on these materials, including fluoropolymer-based processing aids. Accordingly, a need exists for improved formulations and methods that may reduce melt fracture, while also alleviating concerns about environmental persistence.

SUMMARY

[0005] Embodiments of the present disclosure address these and other needs by providing a method of reducing or eliminating melt fracture during extrusion, the method including blending an ethylene-based polymer having a melt index (I_2) of less than 2.0 dg/min with a polymer processing aid (PPA) to remove the melt fracture during extrusion, wherein the PPA comprises silicone polyether.

[0006] According to one or more embodiments of the present disclosure, an article may be produced by the above method.

[0007] Additional features and advantages will be set forth in the detailed description that follows and, in part, will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments described herein, including the detailed description which follows in addition to the claims.

[0008] It is to be understood that both the foregoing general description and the following detailed description describe various embodiments and are intended to provide an overview or framework for understanding the nature and character of the claimed subject matter.

DETAILED DESCRIPTION

[0009] Reference will now be made in detail to embodiments of methods of reducing or eliminating melt fracture during extrusion including blending an ethylene-based polymer having a melt index (I_2) of less than 2.0 dg/min with a polymer processing aid (PPA) to remove the melt fracture during extrusion, wherein the PPA comprises silicone polyether.

[0010] As used in this disclosure, the term “polymer” may refer to a polymeric compound prepared by polymerizing monomers, whether of the same or a different type. The generic term polymer thus embraces the term “homopolymer,” usually employed to refer to polymers prepared from only one type of monomer as well as “copolymer,” which refers to polymers prepared from two or more different monomers. The term “interpolymer,” as used herein, refers to a polymer prepared by the polymerization of at least two different types of monomers. The generic term interpolymer thus includes copolymers, and polymers prepared from more than two different types of monomers, such as terpolymers.

[0011] “Blend”, “polymer blend” and like terms mean a composition of two or more polymers. Such a blend may or may not be miscible. Such a blend may or may not be phase separated. Such a blend may or may not contain one or more domain configurations, as determined from transmission electron spectroscopy, light scattering, x-ray scattering, and any other method known in the art. Blends are not laminates, but one or more layers of a laminate may contain a blend.

Such blends can be prepared as dry blends, formed *in situ* (e.g., in a reactor), melt blends, or using other techniques known to those of skill in the art.

[0012] As used in this disclosure, the term “polyethylene” or “ethylene-based polymer” may refer to polymers comprising greater than 50% by mole of units which have been derived from ethylene monomer. This includes polyethylene homopolymers or copolymers (meaning units derived from two or more comonomers). Common forms of ethylene-based polymer known in the art include Low Density Polyethylene (LDPE); Linear Low Density Polyethylene (LLDPE); Ultra Low Density Polyethylene (ULDPE); Very Low Density Polyethylene (VLDPE); single-site catalyzed Linear Low Density Polyethylene, including both linear and substantially linear low density resins (m-LLDPE); Medium Density Polyethylene (MDPE); and High Density Polyethylene (HDPE).

[0013] The term “LLDPE”, includes both resin made using the traditional Ziegler-Natta catalyst systems and chromium-based catalyst systems as well as single-site catalysts, including, but not limited to, bis -metallocene catalysts (sometimes referred to as “m- LLDPE”), constrained geometry catalysts (CGC), and molecular catalysts. Resins include linear, substantially linear, or heterogeneous polyethylene copolymers or homopolymers. LLDPEs contain less long chain branching than LDPEs and includes the substantially linear ethylene polymers which are further defined in U.S. Patent 5,272,236, U.S. Patent 5,278,272, U.S. Patent 5,582,923 and US Patent 5,733,155; the homogeneously branched linear ethylene polymer compositions such as those in U.S. Patent No. 3,645,992; the heterogeneously branched ethylene polymers such as those prepared according to the process disclosed in U.S. Patent No. 4,076,698; and/or blends thereof (such as those disclosed in US 3,914,342 or US 5,854,045). The LLDPEs can be made via gas-phase, solution-phase or slurry polymerization or any combination thereof, using any type of reactor or reactor configuration known in the art.

[0014] As used herein, “fluoropolymer” refers to polymeric compounds comprising fluorine, and is intended to be interpreted broadly so as to include what might be referred to as oligomeric species. As a non-limiting example, the fluoropolymer may comprise molecules containing at least three, at least four, at least five, or at least six fluorine containing units.

[0015] As used herein, “essentially free of” means comprising less than 50 ppmw.

[0016] As used herein, “melt fracture” refers to the formation of defects on a polymeric extrudate under various processing conditions. The defects may be any deviation from a smooth, glossy, regular extrudate.

[0017] As used herein, “parts per million” or “ppm” refers to parts per million by weight.

[0018] As used herein, “polymer melt” refers to polymers or polymer blends that are at temperatures above their glass transition temperature, i.e. the temperature below which the physical properties of the polymers change to those of a glassy or crystalline state, and usually above their melting temperature. The polymer melts may present as highly viscous liquids, and may possess non-Newtonian or viscoelastic natures.

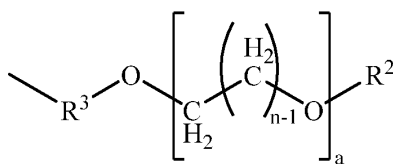
[0019] As used herein, “polyether” denotes a polyoxyalkylene copolymer represented by the formula $\text{---}(\text{C}_n\text{H}_{2n}\text{O})\text{---}$ wherein n is from 2 to 4 inclusive. The polyoxyalkylene copolymer unit typically may comprise oxyethylene units $\text{---}(\text{C}_2\text{H}_4\text{O})\text{---}$, oxypropylene units $\text{---}(\text{C}_3\text{H}_6\text{O})\text{---}$, oxybutylene units $\text{---}(\text{C}_4\text{H}_8\text{O})\text{---}$, or mixtures thereof. The oxyalkylene units can be arranged in any fashion to form either a homopolymer, block copolymer, or randomized copolymer structure, but typically form a homopolymer or randomized copolymer group. In some embodiments, the polyoxyalkylene comprises both oxyethylene units ($\text{C}_2\text{H}_4\text{O}$) and oxypropylene units ($\text{C}_3\text{H}_6\text{O}$) in a randomized copolymer. In some embodiments, the polyoxyalkylene is a homopolymer that comprises only oxyethylene units ($\text{C}_2\text{H}_4\text{O}$). In specific embodiments, the polyether may be selected from those having the average formula: $\text{R}^1\text{O}(\text{C}_n\text{H}_{2n}\text{O})_m\text{R}^2$ (Formula I); where n is from 2 to 4 inclusive, m is greater than 2, R^1 is a monovalent terminally unsaturated aliphatic hydrocarbon group containing 2 to 12 carbon atoms, R^2 is R^1 , hydrogen, an acetyl group, or a monovalent hydrocarbon group containing 1 to 8 carbons. In Formula I, the polyether may be terminated at one end with an unsaturated aliphatic hydrocarbon group containing 2 to 12 carbon atoms, such as an alkenyl or alkynyl group. The polyether may also contain an unsaturated aliphatic hydrocarbon group at each terminal end, when $\text{R}^2=\text{R}^1$, which will result in the formation of an $(\text{AB})_n$ type of silicone polyether if the organohydrogensiloxane contains at least two SiH units, and in particular terminal SiH units. More details and examples of polyethers are provided in U.S. Pat. Nos. 6,987,157 and 8,008,407, which are incorporated by reference herein in their entireties. The polyether may comprise polyethylene glycol (PEG).

[0020] As used herein, the “silicone” is an organohydrogensiloxane, which is any organopolysiloxane containing at least one silicon-bonded hydrogen atom (SiH) per molecule. Organopolysiloxanes are well known in the art and are often designated as comprising any number or combination of $(R_3SiO_{0.5})$, (R_2SiO) , $(RSiO_{1.5})$, (SiO_2) siloxy units, where R is independently an organic group or hydrocarbon group. When R is methyl in $(R_3SiO_{0.5})$, (R_2SiO) , $(RSiO_{1.5})$, siloxy units of an organopolysiloxane, the siloxy units are often designated as M, D, and T units respectively while the (SiO_2) siloxy unit is designated as a Q unit. Organohydrogensiloxanes have similar structures, but have at least one SiH present on a siloxy unit. Thus, methyl based siloxy units in an organohydrogensiloxane can be represented as comprising “M^H” siloxy units $(R_2HSiO_{0.5})$, “D^H” siloxy units $(RHSiO)$, “T^H” siloxy units $(HSiO_{1.5})$. The organohydrogensiloxanes useful in the present invention may comprise any number of M, M^H, D, D^H, T, T^H, or Q siloxy units, providing at least one siloxy unit contains SiH. More details and examples of silicones are provided in U.S. Pat. No. 8,008,407, which is incorporated by reference herein in its entirety. The silicone may comprise polydimethylsiloxane (PDMS).

[0021] The “silicone polyether” is the reaction product of the silicone and polyether as defined above, specifically, the reaction product of a polyoxyalkylene copolymer represented by the formula $R^1-(C_nH_{2n}O)-R^2$ wherein n is from 2 to 4 inclusive and R^1 is a monovalent terminally unsaturated aliphatic hydrocarbon group containing 2 to 12 carbon atoms and R^2 is hydrogen, an acetyl group, a monovalent terminally unsaturated aliphatic hydrocarbon group containing 2 to 12 carbon atoms, or a monovalent hydrocarbon group containing 1 to 8 carbons; and organopolysiloxane containing at least one silicon-bonded hydrogen atom (SiH) per molecule.

[0022] Alternatively, the silicone polyether may comprise a linear siloxane backbone with pendant polyether groups. Said silicone polyether may have unit formula: $(R_3SiO_{1/2})_2(R_2SiO_{2/2})_x(RR'SiO_{2/2})_y$. In this unit formula, subscript x is an integer with a value of 1 to 500, alternatively 1 to 200, alternatively 1 to 100, alternatively 1 to 50, alternatively 1 to 10, alternatively 3 to 8, and alternatively 5. Subscript y is an integer with a value of 1 to 100, alternatively 1 to 50, alternatively 1 to 10, alternatively 1 to 5, alternatively 2 to 5, alternatively 3.5. Each R is an independently selected monovalent hydrocarbon group containing 1 to 30 carbon atoms. Alternatively each R may be an alkyl group, and alternatively methyl. Each R' is a

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polyether group of formula: $\text{R}^3\text{-O-}\left[\text{C}\begin{smallmatrix} \text{H}_2 \\ \text{H}_2 \end{smallmatrix}\text{-C}\begin{smallmatrix} \text{H}_2 \\ \text{H}_2 \end{smallmatrix}\text{-O}\right]_a\text{-R}^2$, wherein R^3 is a divalent hydrocarbyl group of 2 to 12 carbon atoms, alternatively 2 to 5 carbon atoms; each subscript n is independently 2, 3, or 4, alternatively 2 or 3; and R^2 is hydrogen, an acetyl group, a monovalent terminally unsaturated aliphatic hydrocarbon group containing 2 to 12 carbon atoms, or a monovalent hydrocarbon group containing 1 to 8 carbon atoms. Alternatively, R^2 may be hydrogen. R^3 is formed by hydrosilylation reaction of a silicon bonded hydrogen atom on the organohydrogensiloxane described above and R^1 , the terminally unsaturated aliphatic hydrocarbon group of the polyether of Formula I.

[0023] In various embodiments, a method of removing melt fracture during extrusion includes blending ethylene-based polymer with a polymer processing aid (PPA) to remove melt fracture during extrusion. In one or more embodiments, the PPA is dry blended with the ethylene-based polymer. In one or more embodiments, the PPA or a masterbatch thereof is melt blended with the ethylene-based polymer.

[0024] Various compositions are considered suitable for the ethylene-based polymer. In one or more embodiments, the ethylene-based polymer may comprise linear low density polyethylene (LLDPE). In embodiments, the ethylene-based polymer may comprise a melt index (I_2) of less than 2.0 dg/min as measured according to ASTM D-1238 (190° C / 2.16 Kg). In embodiments, the ethylene-based polymer may comprise a melt index of from 0.05 to 2.0 dg/10 mins, from 0.05 to 1.8 dg/10 mins, from 0.05 to 1.6 dg/10 mins, from 0.05 to 1.5 dg/10 mins, from 0.1 to 2.0 dg/10 mins, from 0.1 to 1.8 dg/10 mins, from 0.1 to 1.6 dg/10 mins, from 0.1 to 1.5 dg/10 mins, from 0.1 to 1.4 dg/10 mins, from 0.5 to 2.0 dg/10 mins, from 0.5 to 1.8 dg/10 mins, from 0.5 to 1.6 dg/10 mins, from 0.5 to 1.5 dg/10 mins, from 0.5 to 1.4 dg/10 mins, from 1.0 to 2.0 dg/10 mins, from 1.0 to 1.8 dg/10 mins, from 1.0 to 1.6 dg/10 mins, from 1.0 to 1.5 dg/10 mins, or from 1.0 to 1.4 dg/10 mins. In further embodiments, the ethylene-based polymer may comprise a density from 0.850 to 0.950 g/cc, from 0.875 to 0.925 g/cc, from 0.890 to 0.915 g/cc, or from 0.895 to 0.910 g/cc.

[0025] As stated above, the PPA comprises silicone polyether. In one or more embodiments, the silicone polyether may comprise a kinematic viscosity from 100 to 100,000 centistokes (cSt). In embodiments, the silicone polyether may comprise a kinematic viscosity from 100 to 100,000 cSt, from 150 to 100,000 cSt, from 200 to 100,000 cSt, from 250 to 100,000 cSt, from 275 to 100,000 cSt, from 280 to 100,000 cSt, from 285 to 100,000 cSt, from 100 to 75,000 cSt, from 150 to 75,000 cSt, from 200 to 75,000 cSt, from 250 to 75,000 cSt, from 275 to 75,000 cSt, from 280 to 75,000 cSt, from 100 to 50,000 cSt, from 150 to 50,000 cSt, from 200 to 50,000 cSt, from 250 to 50,000 cSt, from 100 to 25,000 cSt, from 150 to 25,000 cSt, from 200 to 25,000 cSt, from 100 to 10,000 cSt, from 150 to 10,000 cSt, from 100 to 7,500 cSt, from 100 to 5,000 cSt, from 100 to 3500 cSt, from 100 to 1,000 cSt, or from 100 to 500 cSt.

[0026] In some embodiments, the PPA also includes free silicone, free polyether, or combinations thereof. In some embodiments, the free polyether may be free PEG. “Free PEG” or “free polyether” does not react with the silicone. In some embodiments, the free silicone may be PDMS. “Free PDMS” or “free silicone” does not react with polyether. In one or more embodiments, the PPA includes from 0 ppm to 2000 ppm, from 0 ppm to 1500 ppm, from 0 ppm to 1000 ppm, from 100 ppm to 2000 ppm, from 100 ppm to 1500 ppm, or from 100 ppm to 1000 ppm free polyether. In one or more embodiments, the PPA may include free polyether having an average molecular weight (MW) of 1,000 to 100,000 grams per mol (g/mol). In embodiments, the free polyether may have an average MW of from 100 to 40,000 g/mol, from 250 to 40,000 g/mol, from 500 to 40,000 g/mol, from 750 to 40,000 g/mol, from 1,000 to 40,000 g/mol, from 2,500 to 40,000 g/mol, from 5,000 to 40,000 g/mol, from 7,500 to 40,000 g/mol, from 10,000 to 40,000 g/mol, or from 25,000 to 40,000 g/mol.

[0027] In some embodiments, the PPA includes a mixture of silicone polyether, free silicone, and free polyether, wherein the majority of the mixture, by weight, is silicone polyether. In some embodiments, the PPA includes a mixture of silicone polyether, free silicone, and free polyether, wherein the silicone polyether makes up from greater than 50 to 100 wt.%, from 55 to 100 wt.%, from 60 to 100 wt.%, from 65 to 100 wt.%, from greater than 50 to 95 wt.%, from 55 to 95 wt.%, from 60 to 95 wt.%, from 65 to 95 wt.%, from greater than 50 to 90 wt.%, from 55 to 90 wt.%, from 60 to 90 wt.%, from 65 to 90 wt.%, from greater than 50 to 85 wt.%, from 55 to 85 wt.%, from 60 to 85 wt.%, from 65 to 85 wt.%, from greater than 50 to 80 wt.%, from 55 to 80 wt.%,

from 60 to 80 wt.%, from 65 to 80 wt.%, from greater than 50 to 75 wt.%, from 55 to 75 wt.%, from 60 to 75 wt.%, or from 65 to 75 wt.% of the mixture.

[0028] In one or more embodiments, the PPA may be essentially free of fluoropolymer. In embodiments, the PPA may comprise less than 50 ppmw, less than 40 ppmw, less than 30 ppmw, less than 20 ppmw, less than 10 ppmw, less than 5 ppmw, less than 2 ppmw, or less than 1 ppmw fluoropolymer.

[0029] Further optional additives are contemplated for the PPA. In some embodiments, the PPA may include one or more other additives. Non limiting examples of suitable other additives include antioxidants, antistatic agents, stabilizing agents, nucleating agents, colorants, pigments, ultra violet (UV) absorbers or stabilizers, flame retardants, compatibilizers, plasticizers, fillers, processing aids, antifog additive, crosslinking agents (e.g., peroxides), and combinations thereof. All individual values and subranges from 0 to 3 wt.% are included and disclosed herein; for example, the total amount of additives in the polymer blend can be from a lower limit of 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, or 4.5 wt.% to an upper limit of 1, 2, 3, 4, or 5 wt.%.

[0030] Various process procedures are considered suitable for producing the PPA. For example, it is contemplated to add the PPA components in various orders. In some embodiments, the PPA may be melt blended directly into the ethylene-based polymer. In one or more embodiments, the PPA may be added to the ethylene-based polymer via a masterbatch. In embodiments, generating a masterbatch may comprise compounding a polyethylene resin with the PPA. The masterbatch may be combined with a base resin to reduce melt fracture in the base resin in an extruder to fabricate a finished article, for example, a tape extrudate, a blown film, cable, wire, tube, or pipe. The masterbatch may be melt-blended or dry-blended with the base resin before or during extrusion to fabricate an article, for example, a tape extrudate, a blown film, cable, wire, tube, or pipe, with reduced melt fracture. The base resin may include ethylene-based polymer, for example, LLDPE.

[0031] In various embodiments, the PPA may be provided in a polymer masterbatch. In one or more embodiments, the polymer masterbatch may include from 1 to less than 15 weight percent (wt.%) PPA. In some embodiments, the polymer masterbatch may include from 1 to less than 15 wt.%, from 2 to less than 15 wt.%, from 3 to less than 15 wt.%, from 5 to less than 15 wt.%, from

10 to less than 15 wt.%, from 1 to 14 wt.%, from 2 to 14 wt.%, from 3 to 14 wt.%, from 5 to 14 wt.%, from 10 to 14 wt.%, from 1 to 12 wt.%, from 2 to 12 wt.%, from 3 to 12 wt.%, from 5 to 12 wt.%, from 10 to 12 wt.%, from 1 to 10 wt.%, from 2 to 10 wt.%, from 3 to 10 wt.%, or from 5 to 10 wt.% PPA.

[0032] In one or more embodiments, the PPA may remove melt fracture in less than or equal to 120 minutes (min). In embodiments, the PPA may remove melt fracture in less than or equal to 120 min, less than or equal to 110 min, less than or equal to 100 min, or less than or equal to 90 min.

[0033] ARTICLES

[0034] In one or more embodiments, an article may be produced from the base resin and the PPA described herein. The articles may include films, for example, blown films. The films may be monolayer or multilayer films. Articles, which incorporate film, may include non-rigid packages, such as flexible packages, pouches, stand-up pouches, and the like. The articles may also include rigid packages. Articles may also include tubes, conduits, wires, cables, tapes, or pipes.

[0035] In various embodiments, an article, for example, a blown-film, produced according to the method disclosed and described herein may include from 200 to 800 ppm silicone polyether. In some embodiments, an article, for example, a blown-film, produced according to the method disclosed and described herein may include from 200 to 800 ppm, 400 to 800 ppm, 600 to 800 ppm, 200 to 600 ppm, 400 to 600 ppm, or 200 to 400 ppm silicone polyether.

[0036] TEST METHODS

[0037] Melt Index (190 °C, 2.16 kg, "I₂") Test Method: ASTM D 1238-13, *Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer*, using conditions of 190 °C/2.16 kilograms (kg). Results were reported in units of grams eluted per 10 minutes (dg/10 min.)

[0038] Kinematic viscosity was measured using an MCR 301 rheometer commercially available from Anton-Paar. The rheometer was fitted with a 25 millimeter (mm) stainless steel

cone-in-plate fixture at an operative temperature of 25 °C. Steady shear measurements at shear rates ranging from 0.1 to 500 s⁻¹ were performed. Prior to each measurement, the material was allowed to equilibrate for at least 5 min. The kinematic viscosity is the average viscosity over the shear rate from 0.1-10 s⁻¹.

EXAMPLES

[0039] The following examples are offered by way of illustration and are presented in a manner such that one skilled in the art should recognize are not meant to be limiting to the present disclosure as a whole or to the appended claims.

[0040] The following compositions were used in the Examples below.

[0041] LLDPE-1 has a melt index (I₂) of 0.5 g/10 mins and a density of 0.905 g/cc.

[0042] Polyether-1 is CARBOWAX™ 600 PEG, which is commercially available from Dow Inc, has a molecular weight of from 570 to 630 g/mol.

[0043] PDMS-1, which is a non-functionalized PDMS, has a kinematic viscosity of 350 cSt.

[0044] PDMS-2, which is a silicone polyether, has a kinematic viscosity of 278 cSt.

[0045] DOWLEX™ 2047G, which is a polyethylene resin, has a density of 0.917 g/cm³ and an I₂ of 2.3 g/10 mins.

[0046] EXAMPLE 1 – Production of LLDPE-1 resin

[0047] LLDPE-1 was prepared according to Inventive Example 1 described in US. Patent Number 8,372,931, the entirety of which is hereby incorporated by reference.

[0048] EXAMPLE 2 – Production of PDMS-2

[0049] PDMS-2 was prepared according to Process 1, as described in US. Patent Number 8,008,407, the entirety of which is hereby incorporated by reference, polyoxyethylene and

trimethylsiloxy-endblocked dimethyl methyl(polyether) siloxane (M-D_x-D^R_y-M), where polyether (R) is a hydroxy-endcapped polyethylene oxide group, i.e. -(CH₂)₃O(EO)_mH. PDMS-2 included 33.5 wt.% silicone and 66.5 wt.% polyether. The molecular weight (MW) of PDMS-2 was 3,703 g/mol. A mixture was then prepared that included 78 wt.% PDMS-2, 20 wt.% polyether, and 2 wt.% silicones.

[0050] EXAMPLE 3 – Production of PPA masterbatch

[0051] Additive masterbatches containing PDMS-1, or the PDMS-2 mixture were made in a 26 mm diameter twin screw extruder (TSE) with 48 L/D from Coperion. DOWLEX™ 2047G, which was used as a base resin, was fed into the main extruder feed hopper using a Ktron pellet feeder, the Polyether-1 powder, if applicable, was also fed in the main feed hopper using a Ktron powder feeder, and the liquid PDMS-1 or liquid PDMS-2 mixture, as applicable was injected using a ISCO pump 5.25 mL/min). The flow rate for the ISCO pump was 1.68 mL/min. The polymer melt was extruded using a 3.2 mm, 2 hole die and was pelletized using a Conair pelletizer. The process conditions are presented in Table 1.

Table 1: Masterbatch Production Process Conditions

Process Variable	Unit	Value for Masterbatch with PDMS-1	Value for Masterbatch with PDMS-2
Total throughput	Lb/h	15	15
DOWLEX™ 2047G	Lb/h	14.4	14.25
PDMS	Lb/h	0.6	0.75
Screw Speed	RPM	300	300
Extruder Temperature Profile			
Barrel 1	°C	150	150
Barrel 2	°C	170	170
Barrel 3 – Barrel 11	°C	190	190
Die Temperature	°C	190	190
Water Temperature	°C	23	23

[0052] EXAMPLE 4 – Production of Tape Extrudates

[0053] Monolayer PE tape extrudates were prepared using a twin screw extruder (TSE). The TSE is a ZSK 18 MEGAlab TSE from Coperion. The TSE is a 18 mm co-rotating TSE with a 40 to 1 L/D ratio and 1.55 Do/Di. The apparent shear rate used in the die was 151/s and the die that

was used is an unpolished slit die, with the slit width, die gap, and the land length being 10 mm, 2 mm, and 10 mm, respectively.

[0054] The base resin, which was LLDPE-1, without any processing aid, was added to the feed hopper of the TSE until the flow was stabilized, which led to melt fracture in the film. Then, a PPA masterbatch prepared according to Example 3 and Polyether-1 (if used) was dry blended with the base resin and fed in the same hopper of the TSE to create tape extrudates with polymer processing aid (PPA). The processing conditions used in the extruder is listed in Table 2.

Table 2: Processing Conditions

Zone 1 temperature (°C)	140
Zone 2 temperature (°C)	180
Remaining Zone Temperatures (°C)	190
Screw speed (RPM)	300

[0055] A timer was started when each formulation was introduced in the extruder after the process was stabilized. If melt fracture was not cleared after 120 minutes, the timer was stopped. The time to clear melt fracture, concentration of the PDMS, and the Polyether in the resulting extruded tape is shown in Table 5. After every formulation, the extruder was purged with the base resin until the melt fracture was fully re-established; confirmed visually as well by the stabilization of the processing conditions (extruder torque, pressure).

Table 3: Concentration of PDMS, Polyether, and Time to Clear Melt Fracture

Sample ID	PDMS-1 (ppm)	PDMS-2 Mixture (ppm)	Polyether-1 (ppm)	Total PDMS and Polyether (ppm)	Polyether Form(s)	Total Polyether (ppm)	Free Polyether (ppm)	Time to Clear Melt Fracture (min)
CE1	1680			1680				> 120
CE2	804		1596	2400	Free	1596	1596	> 120
IE1		2400		2400	Free and Bound	1596	413	80

[0056] As shown in Table 3, sample IE1 cleared the melt fracture in 80 minutes. Conversely, samples CE1 and CE2, which did not contain silicone polyether, both failed to clear melt fracture

in 120 minutes or less. This is particularly notable, as samples CE2 and IE1 both contained the same concentration of total combined PDMS and Polyether. Thus, sample IE1 demonstrates the utility of using silicone polyether as a polymer processing aid.

[0057] The subject matter of the present disclosure has been described in detail and by reference to specific embodiments. It should be understood that any detailed description of a component or feature of an embodiment does not necessarily imply that the component or feature is essential to the particular embodiment or to any other embodiment. Further, it should be apparent to those skilled in the art that various modifications and variations can be made to the described embodiments without departing from the spirit and scope of the claimed subject matter.

[0058] It is noted that one or more of the following claims utilize the term “wherein” as a transitional phrase. For the purposes of defining the present technology, it is noted that this term is introduced in the claims as an open-ended transitional phrase that is used to introduce a recitation of a series of characteristics of the structure and should be interpreted in like manner as the more commonly used open-ended preamble term “comprising.”

[0059] It should be understood that where a first component is described as “comprising” a second component, it is contemplated that, in embodiments, the first component “consists” or “consists essentially of” that second component. It should further be understood that where a first component is described as “comprising” a second component, it is contemplated that, in embodiments, the first component comprises at least 10%, at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 95%, or even at least 99% that second component (where % can be weight % or molar %).

[0060] It is also noted that recitations herein of “at least one” component, element, etc., should not be used to create an inference that the alternative use of the articles “a” or “an” should be limited to a single component, element, etc.

CLAIMS

1. A method of reducing or eliminating melt fracture during extrusion comprising:
blending an ethylene-based polymer having a melt index (I_2) of less than 2.0 dg/min with a polymer processing aid (PPA) to remove the melt fracture during extrusion, wherein the PPA comprises silicone polyether, the silicone polyether being the reaction product of:
a polyoxyalkylene copolymer represented by the formula $R^1-(C_nH_{2n}O)-R^2$,
wherein:
n is from 2 to 4 inclusive;
 R^1 is a monovalent terminally unsaturated aliphatic hydrocarbon group containing 2 to 12 carbon atoms; and
 R^2 is hydrogen, an acetyl group, a monovalent terminally unsaturated aliphatic hydrocarbon group containing 2 to 12 carbon atoms, or a monovalent hydrocarbon group containing 1 to 8 carbons; and
organopolysiloxane containing at least one silicon-bonded hydrogen atom (SiH) per molecule.
2. The method of claim 1, wherein the silicone polyether has a kinematic viscosity of from 100 to 100,000 cSt.
3. The method of claim 1 or claim 2, wherein the ethylene-based polymer has a melt index (I_2) from 0.05 to 1.5 dg/min.
4. The method of any one of claims 1 to 3, wherein the PPA is provided in a polymer masterbatch.
5. The method of claim 4, wherein the polymer masterbatch comprises from 1 to less than 15 wt. % PPA.
6. The method of any one of claims 1 to 5, wherein the method further comprises obtaining an extrusion product, wherein the extrusion product comprises 200-8000 ppm silicone polyether.
7. The method of any one of claims 1 to 6, wherein the PPA or a masterbatch thereof is dry blended with the ethylene-based polymer.

8. The method of any one of claims 1 to 6 wherein the PPA or a masterbatch thereof is melt blended with the ethylene-based polymer.
9. The method of any one of claims 1 to 8, wherein the ethylene-based polymer comprises LLDPE.
10. An article produced from the method of any one of claims 1 to 9.
11. The article of claim 10, wherein the article is a blown film, a cable, a wire, a pipe, or a tube.
12. The use of a polymer processing aid (PPA) to remove melt fracture during extrusion, the use comprising blending ethylene-based polymer having a melt index (I_2) of less than 2.0 dg/min with the PPA, wherein the PPA comprises silicone polyether.
13. The use of a PPA of claim 12, wherein the silicone polyether has a kinematic viscosity of from 100 to 100,000 cSt.
14. The use of a PPA of claim 12 or claim 13, wherein the ethylene-based polymer comprises LLDPE.
15. The use of a PPA of any one of claims 12-14 wherein the PPA is provided in a polymer masterbatch, wherein the polymer masterbatch comprises from 1 to less than 15 wt. % PPA.