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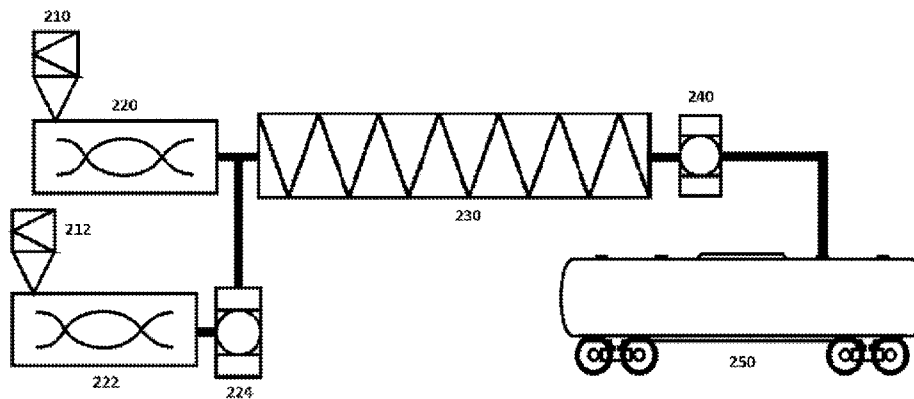


FIG. 2

(57) Abstract: Provided are processes for blending virgin polymers and polymer recyclates. In one embodiment, virgin polymer is melted in a first melt mixing apparatus, polymer recyclate is melted in a second melt mixing apparatus followed by filtering, the virgin polymer melt and the filtered polymer recyclate melt are co-fed to a melt pump, and the recyclate blend is filtered. In another embodiment, polymer recyclate is melted in a first melt mixing apparatus followed by filtering, the filtered polymer recyclate melt is co-fed with a virgin polymer to a second melt mixing apparatus, the recyclate melt is optionally fed to a melt pump and is then filtered. In another embodiment, virgin polymer and polymer recyclate are blended and then melted in an melt mixing apparatus followed by filtering. Also provided are methods for retrofitting existing polymer production facilities with such processes.

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METHOD FOR PROCESSING RECYCLED POLYMERS

FIELD OF THE INVENTION

[0001] The present disclosure relates to processes for blending virgin polymers with polymer recyclates and methods for retrofitting existing polymer production facilities to implement such processes.

BACKGROUND OF THE INVENTION

[0002] Polyolefins, in particular polyethylene and polypropylene, are increasingly consumed in large amounts for many applications, including packaging for food and other goods, electronics, automotive components, and a great variety of manufactured articles. Large amounts of waste plastic materials are presently coming from differential recovery of municipal plastic wastes, mainly constituted of flexible packaging (cast film, blown film and BOPP film), rigid packaging, blow molded bottles and injection molded containers. Usually, through a step of separation from other polymers, such as PVC, PET or PS, two main polyolefinic fractions are obtained, namely polyethylenes (in particular, HDPE, LDPE, LLDPE) and polypropylenes (homopolymers, random copolymers, heterophasic copolymers). After such separation of polymer recyclate, different types of polymers are separated into various post-consumer recycle (PCR) resins.

[0003] There has been much research and development to improve the processability of PCR resins either alone or as a blend component with virgin polymers. Likewise, there has also been much effort by industry to develop end-use applications that incorporate PCR resins and have quality and/or performance similar or equal to corresponding end-use applications fabricated from virgin polymers. of articles fabricated from such PCR resins. Existing and new environmental regulations provide continued motivation to develop suitable commercial uses of PCR resins while reducing the amount of waste plastics landfill. Successful development of these commercial pathways will create demand for higher production rates of products incorporating blends of PCR resins with virgin polymers.

[0004] There is a need to provide processes for recycling of polymers at higher rates, in particular, blends of PCR resins with virgin polymers. Ideally, such processes could be implemented by retrofitting existing polymer production facilities with commonly used equipment and familiar techniques to produce useful blends of PCR resins with virgin polymers at commercial rates.

SUMMARY OF THE INVENTION

[0005] The present disclosure relates to processes for blending a virgin polymers with polymer recyclates.

[0006] In some embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus to produce a virgin polymer melt. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt. The process further comprises adding the polymer recyclate melt to a first melt filtration apparatus to produce a filtered polymer recyclate melt. The virgin polymer melt and the filtered polymer recyclate melt are co-fed to a melt pump to produce a recyclate blend melt, which is processed through a recyclate blend melt to a second melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus.

[0007] In some embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is added to an inlet to the first melt mixing apparatus. A recyclate blend melt is withdrawn from the first melt mixing apparatus and fed to a melt pump and then processed through a second melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus.

[0008] In some embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is fed to the first melt mixing apparatus. A recyclate blend melt is withdrawn from the first melt mixing apparatus and processed through a second melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus.

[0009] In some embodiments, a process comprises adding a virgin polymer and a polymer recyclate to a first melt mixing apparatus to produce a recyclate blend melt and processing the recyclate blend melt through a melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus.

[0010] The present disclosure further relates to methods for retrofitting existing polymer production facilities to implement the processes for blending a virgin polymers with polymer recyclates, as disclosed herein. The methods for retrofitting a polymer production facility to add a processing capacity for polymer recyclate. The polymer production facility comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a first melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration

apparatus having an outlet adapted for withdrawal of a polymer product. The polymer production facility has a first throughput rate.

[0011] In some embodiments, a method for retrofitting a polymer production facility comprises adding a polymer recycle feed system. The polymer recycle system comprises a polymer recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus, the second melt filtration apparatus having an outlet. The polymer recycle system has a second throughput rate.

[0012] The method for retrofitting a polymer production facility further comprises replacing the first melt pump and the first melt filtration apparatus with a recycle blend system. The recycle blend system comprises a second melt pump having an inlet fluidly connected to the outlet from the first melt pump and the outlet from the second melt filtration apparatus and an outlet fluidly connected to an inlet to a third melt filtration apparatus. The third melt filtration apparatus has an outlet adapted for withdrawal of a recycle blend product. The recycle blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0013] In some embodiments, a method for retrofitting a polymer production facility comprises adding a polymer recycle feed system. The polymer recycle feed system comprises a polymer recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recycle feed system has a second throughput rate.

[0014] The method for retrofitting a polymer production facility further comprises fluidly connecting the outlet of the second melt filtration apparatus to a second inlet to the first melt mixing apparatus.

[0015] The method for retrofitting a polymer production facility further comprises adding a control system, wherein the control system provides for maintaining the sum of a virgin polymer feed rate and a polymer recycle feed rate being less than or equal to the first throughput rate.

[0016] In some embodiments, a method for retrofitting a polymer production facility comprises adding a polymer recycle feed system. The polymer recycle feed system comprises a polymer recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recycle feed system has a second throughput rate.

[0017] The method for retrofitting a polymer production facility further comprises replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recycle blend system. The recycle blend system comprises a second melt mixing apparatus. The second melt mixing apparatus has one or more inlets fluidly connected to the virgin polymer feed apparatus and the outlet from the second melt filtration apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet adapted for withdrawal of a recycle blend product. The recycle blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0018] In some embodiments, a method for retrofitting a polymer production facility comprises converting the virgin polymer feed apparatus to a recycle blend feed apparatus by adapting the virgin polymer feed apparatus to accept the virgin polymer feed and a polymer recycle feed and increasing the throughput rate of the virgin polymer feed apparatus to accept a second throughput rate of the polymer recycle in addition to the first throughput rate of the virgin polymer.

[0019] The method for retrofitting a polymer production facility further comprises replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recycle blend system. The recycle blend system comprises a second melt mixing apparatus. The second melt mixing apparatus has an inlet fluidly connected to the recycle blend feed apparatus and an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet adapted for withdrawal of a recycle blend product. The recycle blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0020] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter, which form the subject matter of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiments disclosed may be readily utilized as a basis for modifying or designing other film structures and/or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. The novel features which are believed to be characteristic of the invention, both as to its structure and method of manufacture, together with further objects and advantages will be better understood from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The claimed subject matter may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

[0022] **FIG. 1** shows a simplified flow diagram of a conventional polyolefins production facility;

[0023] **FIG. 2** shows a simplified flow diagram of a polyolefins production facility according to embodiments of the invention, wherein a conventional polyolefins production facility is modified by addition of a polyolefin recyclate extruder and replacement of the melt pump and melt filtration apparatus with a larger melt pump and melt filtration apparatus;

[0024] **FIG. 3** shows a simplified flow diagram of a polyolefins production facility according to embodiments of the invention, wherein a conventional polyolefins production facility is modified by addition of a polyolefin recyclate extruder feeding into the original extruder;

[0025] **FIG. 4** shows a simplified flow diagram of a polyolefins production facility according to embodiments of the invention, wherein a conventional polyolefins production facility is modified by addition of a polyolefin recyclate extruder and replacement of the extruder, melt pump and melt filtration apparatus with a larger extruder and melt filtration apparatus; and

[0026] **FIG. 5** shows a simplified flow diagram of a polyolefins production facility according to embodiments of the invention, wherein a conventional polyolefins production facility is modified by replacement of the extruder, melt pump and melt filtration apparatus with a larger extruder and melt filtration apparatus.

[0027] While the disclosed process and composition are susceptible to various modifications and alternative forms, the drawings illustrate specific embodiments herein described in detail by way of example. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

[0028] Illustrative embodiments of the subject matter claimed below will now be disclosed. In the interest of clarity, some features of some actual implementations may not be described in this specification. It will be appreciated that in the development of any such actual embodiments, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development

effort, even if complex and time-consuming, would be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0029] The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special definition of a term or phrase, i.e., a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be implied by consistent usage of the term or phrase herein. To the extent that a term or phrase is intended to have a special meaning, i.e., a meaning other than the broadest meaning understood by skilled artisans, such a special or clarifying definition will be expressly set forth in the specification in a definitional manner that provides the special or clarifying definition for the term or phrase. It must also be noted that, as used in the specification and the appended claims, the singular forms "a," "an," and "the" include plural references unless otherwise specified.

[0030] For example, the following discussion contains a non-exhaustive list of definitions of several specific terms used in this disclosure (other terms may be defined or clarified in a definitional manner elsewhere herein). These definitions are intended to clarify the meanings of the terms used herein. It is believed that the terms are used in a manner consistent with their ordinary meaning, but the definitions are nonetheless specified here for clarity.

Definitions

[0031] As used herein, "advanced filtration technology" in polymer processing is a set of techniques and equipment used to improve the quality of recycled polymers by removing contaminants and impurities from the polymer melt. Recycled polymers can contain various contaminants such as residual monomers, oligomers, pigments, additives, and particulate matter, which can affect the physical, chemical, and mechanical properties of the final product. Advanced filtering technology aims to remove these contaminants and produce high-quality recycled polymers that can be used in various applications. In some embodiments, advanced filtering technologies includes melt filtration, which involves passing the polymer melt through a filter to remove contaminants. Melt filtration can be performed using different types of filters, such as screen changers, candle filters, and disc filters. In some embodiments, advanced filtering technology includes membrane filtration, which uses a semi-permeable membrane to separate and remove contaminants from the polymer melt. Membrane filtration can be performed using different types of membranes, such as ultrafiltration, nanofiltration, and reverse osmosis. These membranes have different pore sizes and can selectively remove contaminants based on their size and molecular weight. The characteristics of recycled polymers that can be improved with advanced filtering technology include:

- **Contaminant Removal:** Advanced filtering technology can remove various contaminants from the polymer melt, such as residual monomers, oligomers, pigments, additives, and particulate matter. The removal of these contaminants can improve the color, clarity, and purity of the recycled polymer.
- **Molecular Weight Distribution:** The molecular weight distribution (MWD) of the polymer can be improved with advanced filtering technology. The removal of high molecular weight species from the polymer melt can result in a narrower MWD, which can improve the processability, mechanical properties, and stability of the recycled polymer.
- **Rheological Properties:** Advanced filtering technology can also improve the rheological properties of the recycled polymer, such as melt flow rate, viscosity, and elasticity. The removal of contaminants and high molecular weight species can result in a more consistent and predictable rheological behavior of the recycled polymer.

The numerical levels of improvement in these characteristics depend on the specific application and the quality of the recycled polymer before filtration. In general, advanced filtering technology can achieve significant improvements in the quality of recycled polymers, such as reducing the level of contaminants by more than 90%, improving the MWD by up to 50%, and increasing the melt flow rate by up to 30%. One skilled in the art would be familiar with the required and the possible numerical levels of improvement depending on the specific equipment and polymers in specific application.

[0032] As used herein, “compounding conditions” means temperature, pressure, and shear force conditions implemented in an melt mixing apparatus to provide intimate mixing of two or more polymers and optionally additives to produce a substantially homogeneous polymer product. The compounding conditions will be such that the specific energy from the compounder from shear and/or added heat are sufficient to melt the polymer components and homogenize them.

[0033] As used herein, “extruder” means a single screw mixing extruder.

[0034] As used herein, “HDPE” means ethylene homopolymers and ethylene copolymers produced in a suspension, solution, slurry, or gas phase polymerization process and having a density in the range of 0.940 g/cm³ to 0.970 g/cm³.

[0035] As used herein, “LDPE” means ethylene homopolymers and/or ethylene copolymers produced in a high pressure free radical polymerization and having a density in the range of 0.910 g/cm³ to 0.940 g/cm³.

[0036] As used herein, “LLDPE” means ethylene copolymers produced in a suspension, solution, slurry, or gas phase polymerization process and having a density in the range of 0.910 g/cm³ to 0.940 g/cm³.

[0037] As used herein, “MDPE” means ethylene copolymers produced in a suspension, solution, slurry, or gas phase polymerization process and having a density in the range of 0.925 g/cm³ to 0.940 g/cm³.

[0038] As used herein, “melt mixing apparatus” means an extruder, a continuous mixer, or any other device suitable for producing temperature, pressure, and shear force conditions to melt and homogenize a polymer or mixture of polymers and optionally any optional additives.

[0039] As used herein, “miscibility” means the degree to which two polymers will mix to form a homogeneous polymer blends. Miscibility is the capability of a mixture to form a single phase over certain ranges of temperature, pressure, and composition. Whether or not a single phase exists depends on the chemical structure, molar mass distribution, and molecular architecture of the components present. A single phase in a mixture may be confirmed by light scattering, x-ray scattering, and/or neutron scattering. For a two-component mixture, a necessary and sufficient condition for stable or metastable equilibrium of a homogeneous, single-phase is:

$$\left(\frac{\partial^2 \Delta_{\text{mix}} G}{\partial \Phi^2} \right)_{T,p} > 0$$

wherein $\Delta_{\text{mix}} G$ is the Gibbs energy of mixing per unit volume, and Φ the composition, where Φ is usually taken as the volume fraction of one of the component substances. The system is unstable if the above second derivative is negative. The borderline (spinodal) between (meta)stable and unstable states is defined by the above second derivative equaling zero. Further discussion of miscibility can be found in J.M.G. Cowie, ‘Miscibility’, *Encyclopedia of Polymer Science and Engineering*, 2nd Ed., J.I. Kroschwitz, ed., Wiley Interscience, New York, 1985, Supplement, p. 455-480, and Work, W. J., Horie, K., Hess, M., & UK, R. S. (2004), Definitions of Terms Related to Polymer Blends, Composites and Multiphase Polymeric Materials, *Pure and Applied Chemistry* 76/11, the substance of which is fully incorporated herein by reference.

[0040] As used herein, “melt pump” refers to a machine that is used to control the flow of molten polymer from an extruder. A melt pump is typically used in applications where precise control over the flow rate and pressure is required. Melt pumps are especially useful in extrusion processes where the flow rate and pressure of the polymer melt need to be maintained to produce consistent products. They are also used to increase the output rate of the extruder.

[0041] As used herein, “polymer recyclate” means post-consumer recycled (“PCR”) polymers and/or post-industrial recycled (“PIR”) polymers. Polymer recyclate is derived from an end product that has completed its life cycle as a consumer item and would otherwise be disposed of as waste (e.g., a polyethylene water bottle) or from plastic scrap that is generated as waste from an

industrial process. Post-consumer polymers include polymers that have been collected in commercial and residential recycling programs.

[0042] As used herein, “polyolefin” in some embodiments is a type of polymer with the general formula $(CH_2CHR)_n$ where R is an alkyl group, including, but not limited to LDPE, LLDPE, MDPE, HDPE, and PP. Polyolefins are nonpolar polymers.

[0043] As used herein, “processability,” refers to how well a polymer composition can be formed into a cast of blown film of commercial quality or molded by injection or compression molding into a molded article of commercial quality at commercially acceptable rates using the equipment and conditions.

[0044] As used herein, “recyclate blend” means a blend of a polymer recyclate and or a filtered polymer recyclate a virgin polymer.

[0045] As used herein, “twin screw extruder” means an extruder that uses two screws to mix, melt, and extrude polymers. They are commonly used in compounding, blending, and reactive processing applications. Twin screw extruders offer many advantages over other machines, including the ability to handle a wide range of materials, high mixing efficiency, and precise control over the processing conditions. They are also useful for processing materials with high viscosity, high filler loading, and high levels of shear-sensitive additives. In some cases, a twin screw extruder can eliminate the need for a melt pump in polymer processing.

[0046] As used herein, “virgin polymer” means pre-consumer polymers. Pre-consumer polymers are obtained directly or indirectly from petrochemical feedstocks fed to a polymerization apparatus. Pre-consumer polyolefins can be subjected to post polymerization processes such as, but not limited to, extrusion, pelletization, visbreaking, and/or other processing completed before the product reaches the end-use consumer.

[0047] As used herein, “wt%” means weight percent.

[0048] It is noted that in this disclosure and particularly in the claims and/or paragraphs, terms such as “comprises”, “comprised”, “comprising” and the like can have the meaning attributed to it in U.S. patent law; e.g., they can mean “includes”, “included”, “including”, and the like; and that terms such as “consisting essentially of” and “consists essentially of” have the meaning ascribed to them in U.S. patent law, e.g., they allow for elements not explicitly recited, but exclude elements that are found in the prior art or that affect a basic or novel characteristic of the disclosure.

Process

[0049] In a first group of process embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus to produce a virgin polymer melt. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a

filtered polymer recyclate melt. The virgin polymer melt and the filtered polymer recyclate melt are co-fed to a melt pump to produce a recyclate blend melt. The recyclate blend melt is processed through a second melt filtration apparatus to produce a filtered recyclate blend product.

[0050] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0051] In a second group of process embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is fed to the first melt mixing apparatus. A recyclate blend melt is withdrawn from the first melt mixing apparatus and fed to a melt pump and then processed through a second melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus.

[0052] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0053] In a third group of process embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is fed to the first melt mixing apparatus. A recyclate blend melt is withdrawn from the first melt mixing apparatus and then processed through a second melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus.

[0054] In some embodiments, the first melt mixing apparatus comprises a twin screw extruder.

[0055] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0056] In a fourth group of process embodiments, a process comprises adding a virgin polymer and a polymer recyclate to a first melt mixing apparatus to produce a recyclate blend melt. The recyclate blend melt is processed through a melt filtration apparatus, and a filtered recyclate blend product is withdrawn from the melt filtration apparatus.

[0057] In some embodiments, the first melt mixing apparatus comprises a twin screw extruder.

[0058] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0059] In any of the foregoing embodiments of the process, the ratio of the virgin polymer to the polymer recycle added to the process is in the range of from 20:1 to 1:2.5, from 10:1 to 1:1.5, from 6:1 to 1:1, or from 4:1 to 1.5:1.

[0060] In any of the foregoing embodiments of the process, the virgin polymer and/or the polymer recycle comprise:

- a) an ethylene homopolymer;
- b) a copolymer of units derived from ethylene and units derived from one or more of C₃-C₂₀ alpha-olefins or mixtures thereof;
- c) a copolymer of units derived from ethylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof.
- d) a propylene homopolymer;
- e) a copolymer of units derived from propylene and units derived one or more of ethylene and C₄-C₂₀ alpha-olefins or mixtures thereof;
- f) a copolymer of units derived from propylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof; or
- g) a combination thereof.

[0061] In any of the foregoing embodiments of the process, the virgin polymer is miscible with the polymer recycle.

Retrofitting

[0062] Methods are disclosed for retrofitting existing polymer production facilities to implement the processes for blending a virgin polymers with polymer recycles, as disclosed herein. The methods for retrofitting a polymer production facility to add a processing capacity for polymer recycle. The polymer production facility comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a first melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration apparatus having an outlet adapted for withdrawal of a polymer product. The polymer production facility has a first throughput rate.

[0063] In a first group of method embodiments, a method for retrofitting existing polymer production facilities comprises adding a polymer recycle feed system. The polymer recycle feed system comprises a recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recycle feed system has a second throughput rate. In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0064] The method for retrofitting existing polymer production facilities further comprises replacing the first melt pump and the first melt filtration apparatus with a recycle blend system. The recycle blend system comprises a second melt pump having an inlet fluidly connected to the outlet from the first melt pump and the outlet from the second melt filtration apparatus and an outlet fluidly connected to an inlet to a third melt filtration apparatus. The third melt filtration apparatus has an outlet adapted for withdrawal of a recycle blend product. The recycle blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0065] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0066] In a second group of method embodiments, a method for retrofitting existing polymer production facilities comprises adding a polymer recycle feed system. The polymer recycle feed system comprises a recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recycle feed system has a second throughput rate.

[0067] The method for retrofitting existing polymer production facilities further comprises fluidly connecting the outlet of the second melt filtration apparatus to a second inlet to the first melt mixing apparatus.

[0068] The method for retrofitting existing polymer production facilities further comprises adding a control system, wherein the control system provides for maintaining the sum of a virgin polymer feed rate and a polymer recycle feed rate being less than or equal to the first throughput rate.

[0069] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0070] In a third group of method embodiments, a method for retrofitting existing polymer production facilities comprises adding a polymer recycle feed system. The polymer recycle feed system comprises a recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recycle feed system has a second throughput rate.

[0071] The method for retrofitting existing polymer production facilities further comprises replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recycle blend system. The recycle blend system comprises a second melt mixing apparatus. The second melt mixing apparatus has one or more inlets fluidly connected to the virgin

polymer feed apparatus and the outlet from the second melt filtration apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet adapted for withdrawal of a recyclate blend product. The recyclate blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0072] In some embodiments, the first melt mixing apparatus comprises a twin screw extruder.

[0073] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0074] In a fourth group of method embodiments, a method for retrofitting existing polymer production facilities comprises converting the virgin polymer feed apparatus to a recyclate blend feed apparatus by (1) adapting the virgin polymer feed apparatus to accept the virgin polymer feed and a polymer recyclate feed and (2) increasing the throughput rate of the virgin polymer feed apparatus to accept a second throughput rate of the polymer recyclate in addition to the first throughput rate of the virgin polymer.

[0075] The method for retrofitting existing polymer production facilities further comprises replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recyclate blend system. The recyclate blend system comprises a second melt mixing apparatus and a second melt filtration system. The second melt mixing apparatus has an inlet fluidly connected to the recyclate blend feed apparatus and an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet adapted for withdrawal of a recyclate blend product. The recyclate blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0076] In some embodiments, the first melt mixing apparatus comprises a twin screw extruder.

[0077] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0078] In any of the first, second, third, or fourth groups of embodiments of the method for retrofitting existing polymer production facilities, in addition to the above limitations in any of the foregoing embodiments of the method for retrofitting existing polymer production facilities, the method is further characterized by one or more of the following:

- a) the ratio of the virgin polymer to the polymer recyclate added to the process is in the range of from 20:1 to 1:2.5, from 10:1 to 1:1.5, from 6:1 to 1:1, or from 4:1 to 1.5:1;
- b) the virgin polymer comprises:
 - (i) an ethylene homopolymer;
 - (ii) a copolymer of units derived from ethylene and units derived from one or more of C₃-C₂₀ alpha-olefins or mixtures thereof;

- (iii) a copolymer of units derived from ethylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof.
- (iv) a propylene homopolymer;
- (v) a copolymer of units derived from propylene and units derived one or more of ethylene and C₄-C₂₀ alpha-olefins or mixtures thereof;
- (vi) a copolymer of units derived from propylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof; or
- (vii) a combination thereof;
- c) the polymer recyclate comprises:
 - (i) an ethylene homopolymer;
 - (ii) a copolymer of units derived from ethylene and units derived from one or more of C₃-C₂₀ alpha-olefins or mixtures thereof;
 - (iii) a copolymer of units derived from ethylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof.
 - (iv) a propylene homopolymer;
 - (v) a copolymer of units derived from propylene and units derived one or more of ethylene and C₄-C₂₀ alpha-olefins or mixtures thereof;
 - (vi) a copolymer of units derived from propylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof; or
 - (vii) a combination thereof;
- d) the virgin polymer is miscible with the polymer recyclate.

Certain Embodiments

[0079] In a first group of process embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus to produce a virgin polymer melt. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a filtered polymer recyclate melt. The virgin polymer melt and the filtered polymer recyclate melt are co-fed to a melt pump to produce a recyclate blend melt. The recyclate blend melt is processed through a second melt filtration apparatus to produce a filtered recyclate blend product. In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0080] In a second group of process embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is fed to the first melt mixing apparatus. A

recyclate blend melt is withdrawn from the first melt mixing apparatus and fed to a melt pump and then processed through a second melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus. In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0081] In a third group of process embodiments, a process comprises adding a virgin polymer to a first melt mixing apparatus. The process further comprises adding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt and processing the polymer recyclate melt through a first melt filtration apparatus to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is fed to the first melt mixing apparatus. A recyclate blend melt is withdrawn from the first melt mixing apparatus and then processed through a second melt filtration apparatus. A filtered recyclate blend product is withdrawn from the second melt filtration apparatus. In some embodiments, the first melt mixing apparatus comprises a twin screw extruder. In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0082] In a fourth group of process embodiments, a process comprises adding a virgin polymer and a polymer recyclate to a melt mixing apparatus to produce a recyclate blend melt. The recyclate blend melt is processed through a melt filtration apparatus, and a filtered recyclate blend product is withdrawn from the melt filtration apparatus. In some embodiments, the melt mixing apparatus comprises a twin screw extruder. In some embodiments, the melt filtration apparatus comprises advanced filtration technology.

[0083] In any of the first, second, third, or fourth groups of embodiments of the process, in addition to the above limitations in any of the foregoing embodiments of the process, the method is further characterized by one or more of the following:

- a) the ratio of the virgin polymer to the polymer recyclate added to the process is in the range of from 20:1 to 1:2.5, from 10:1 to 1:1.5, from 6:1 to 1:1, or from 4:1 to 1.5:1;
- b) the virgin polymer and/or the polymer recyclate comprise:
 - (i) an ethylene homopolymer;
 - (ii) a copolymer of units derived from ethylene and units derived from one or more of C₃-C₂₀ alpha-olefins or mixtures thereof;
 - (iii) a copolymer of units derived from ethylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof.
 - (iv) a propylene homopolymer;
 - (v) a copolymer of units derived from propylene and units derived one or more of ethylene and C₄-C₂₀ alpha-olefins or mixtures thereof;
 - (vi) a copolymer of units derived from propylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof; or

(vii) a combination thereof;

c) the virgin polymer is miscible with the polymer recyclate.

[0084] Methods are disclosed for retrofitting existing polymer production facilities to implement the processes for blending a virgin polymers with polymer recyclates, as disclosed herein. The methods for retrofitting a polymer production facility to add a processing capacity for polymer recyclate. The polymer production facility comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a first melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration apparatus having an outlet adapted for withdrawal of a polymer product. The polymer production facility has a first throughput rate.

[0085] In a first group of method embodiments, a method for retrofitting existing polymer production facilities comprises adding a polymer recyclate feed system. The polymer recyclate feed system comprises a recyclate feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recyclate feed system has a second throughput rate.

[0086] The method for retrofitting existing polymer production facilities further comprises replacing the first melt pump and the first melt filtration apparatus with a recyclate blend system. The recyclate blend system comprises a second melt pump having an inlet fluidly connected to the outlet from the first melt pump and the outlet from the second melt filtration apparatus and an outlet fluidly connected to an inlet to a third melt filtration apparatus. The third melt filtration apparatus has an outlet adapted for withdrawal of a recyclate blend product. The recyclate blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0087] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0088] In a second group of method embodiments, a method for retrofitting existing polymer production facilities comprises adding a polymer recyclate feed system. The polymer recyclate feed system comprises a recyclate feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recyclate feed system has a second throughput rate.

[0089] The method for retrofitting existing polymer production facilities further comprises fluidly connecting the outlet of the second melt filtration apparatus to a second inlet to the first melt mixing apparatus.

[0090] The method for retrofitting existing polymer production facilities further comprises adding a control system, wherein the control system provides for maintaining the sum of a virgin polymer feed rate and a polymer recyclate feed rate being less than or equal to the first throughput rate.

[0091] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0092] In a third group of method embodiments, a method for retrofitting existing polymer production facilities comprises adding a polymer recyclate feed system. The polymer recyclate feed system comprises a recyclate feed apparatus fluidly connected to an inlet to a second melt mixing apparatus. The second melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet. The polymer recyclate feed system has a second throughput rate.

[0093] The method for retrofitting existing polymer production facilities further comprises replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recyclate blend system. The recyclate blend system comprises a third melt mixing apparatus. The third melt mixing apparatus has one or more inlets fluidly connected to the virgin polymer feed apparatus and the outlet from the second melt filtration apparatus. The third melt mixing apparatus has an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet adapted for withdrawal of a recyclate blend product. The recyclate blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0094] In some embodiments, the third melt mixing apparatus comprises a twin screw extruder.

[0095] In some embodiments, the first melt filtration apparatus comprises advanced filtration technology.

[0096] In a fourth group of method embodiments, a method for retrofitting existing polymer production facilities comprises converting the virgin polymer feed apparatus to a recyclate blend feed apparatus by (1) adapting the virgin polymer feed apparatus to accept the virgin polymer feed and a polymer recyclate feed and (2) increasing the throughput rate of the virgin polymer feed apparatus to accept a second throughput rate of the polymer recyclate in addition to the first throughput rate of the virgin polymer.

[0097] The method for retrofitting existing polymer production facilities further comprises replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recycle blend system. The recycle blend system comprises a second melt mixing apparatus and a second melt filtration system. The second melt mixing apparatus has an inlet fluidly connected to the recycle blend feed apparatus and an outlet fluidly connected to a second melt filtration apparatus. The second melt filtration apparatus has an outlet adapted for withdrawal of a recycle blend product. The recycle blend system has a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

[0098] In some embodiments, the second melt mixing apparatus comprises a twin screw extruder.

[0099] In some embodiments, the second melt filtration apparatus comprises advanced filtration technology.

[0100] In any of the first, second, third, or fourth groups of embodiments of the method for retrofitting existing polymer production facilities, in addition to the above limitations in any of the foregoing embodiments of the method for retrofitting existing polymer production facilities, the method is further characterized by one or more of the following:

- a) the ratio of the virgin polymer to the polymer recycle added to the process is in the range of from 20:1 to 1:2.5, from 10:1 to 1:1.5, from 6:1 to 1:1, or from 4:1 to 1.5:1;
- b) the virgin polymer and/or the polymer recycle comprise:
 - (i) an ethylene homopolymer;
 - (ii) a copolymer of units derived from ethylene and units derived from one or more of C₃-C₂₀ alpha-olefins or mixtures thereof;
 - (iii) a copolymer of units derived from ethylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof.
 - (iv) a propylene homopolymer;
 - (v) a copolymer of units derived from propylene and units derived one or more of ethylene and C₄-C₂₀ alpha-olefins or mixtures thereof;
 - (vi) a copolymer of units derived from propylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof; or
 - (vii) a combination thereof;
- c) the virgin polymer is miscible with the polymer recycle.

EXAMPLES

[0101] The following examples are included to demonstrate preferred embodiments of the invention. It should be appreciated by those of skill in the art that the techniques disclosed in the examples which follow represent techniques discovered by the inventor to function well in the

practice of the invention, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or similar result without departing from the spirit and scope of the invention.

Example 1

[0102] An embodiment of a conventional polymer processing system **100** is shown in **FIG. 1**. Virgin polymer is fed to extruder **120** from feed hopper **110**. The virgin polymer is heated to above its melting temperature and optionally mixed with additives in extruder **120**. Melt pump **130** receives virgin polymer melt from extruder **120**. The discharge from melt pump **130** is processed through melt filtration apparatus **140** from which a filtered virgin polymer melt is withdrawn and sent to railcar **150** for shipping.

Example 2

[0103] An embodiment of polymer processing system **200** as disclosed herein is shown in **FIG. 2**. Virgin polymer is fed to extruder **220** from feed hopper **210**. The virgin polymer is heated to above its melting temperature and optionally mixed with additives in extruder **220**. Polymer recyclate is fed to extruder **222** from feed hopper **212**. The polymer recyclate is heated to above its melting temperature and optionally mixed with additives in extruder **222**. A polymer recyclate melt is withdrawn from extruder **222** and processed through a melt filtration apparatus **224** comprising advanced filtration technology to produce a filtered polymer recyclate melt. The virgin polymer melt and the filtered polymer recyclate melt are co-fed to melt pump **230**, which is sized to accommodate the combined output of virgin polymer extruder **220** and polymer recyclate extruder **222**. A recyclate blend, comprising the combination of the virgin polymer melt and the filtered polymer recyclate melt is withdrawn from melt pump **230** and then processed through melt filtration apparatus **240**, from which a filtered virgin polymer melt is withdrawn and sent to railcar **250** for shipping.

[0104] An existing polymer production facility having polymer processing system **100** as shown in **FIG. 1** could be retrofitted to form polymer processing system **200** as shown in **FIG. 2** to both add a capacity for processing polymer recyclate and expand the overall production capacity of the existing polymer production facility. A polymer recyclate feed system is added to system **100**. The polymer recyclate feed system comprises feed hopper **212**, extruder **222**, and melt filtration apparatus **224** comprising advanced filtration technology. Melt pump **130** and melt filtration apparatus **140** are replaced with larger melt pump **230** and larger melt filtration apparatus **240**, respectively. The capacity of melt pump **230** and melt filtration apparatus **240** are sufficient to handle the combined outputs from extruder **220** and extruder **222**, respectively. The virgin

polymer feed system remains unchanged such that feed hopper **110** is the same as feed hopper **210**, and extruder **110** is the same as extruder **210**.

Example 3

[0105] An embodiment of polymer processing system **300** as disclosed herein is shown in **FIG. 3**. Virgin polymer is fed to extruder **320** from feed hopper **310**. Polymer recyclate is fed to extruder **322** from feed hopper **312**. The polymer recyclate is heated to above its melting temperature and optionally mixed with additives in extruder **322**. A polymer recyclate melt is withdrawn from extruder **322** and processed through a melt filtration apparatus **324** comprising advanced filtration technology to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is fed to extruder **320** along with the virgin polymer. The filtered polymer recyclate melt and the virgin polymer are heated to above their melting temperatures and intimately mixed, optionally with additives, and a recyclate blend melt is withdrawn from extruder **320**. The recyclate blend melt is fed to melt pump **330**, which is sized to accommodate the output of extruder **320**. The discharge of melt pump **330** is processed through melt filtration apparatus **340**, from which a filtered virgin polymer melt is withdrawn and sent to railcar **350** for shipping.

[0106] An existing polymer production facility having polymer processing system **100** as shown in **FIG. 1** could be retrofitted to form polymer processing system **300** as shown in **FIG. 3** to add a capacity for processing polymer recyclate to the existing polymer production facility. A polymer recyclate feed system is added to system **100**. The polymer recyclate feed system comprises feed hopper **312**, extruder **322**, and melt filtration apparatus **324** comprising advanced filtration technology. Melt pump **130** and melt filtration apparatus **140** are unchanged such that they are the same as melt pump **330** and melt filtration apparatus **340**, respectively. A control system (not shown) is added to maintain the total of virgin polymer feed from feed hopper **310** and the flow of filtered polymer recyclate from melt filtration apparatus **324** are less than or equal to the capacity of extruder **320**.

Example 4

[0107] An embodiment of polymer processing system **400** as disclosed herein is shown in **FIG. 4**. Virgin polymer is fed to extruder **420** from feed hopper **410**. Polymer recyclate is fed to extruder **422** from feed hopper **412**. A polymer recyclate melt is withdrawn from extruder **422** and processed through a melt filtration apparatus **424** comprising advanced filtration technology to produce a filtered polymer recyclate melt. The filtered polymer recyclate melt is fed to twin screw extruder **420** along with the virgin polymer. The filtered polymer recyclate melt and the virgin polymer are heated to above their melting temperatures and intimately mixed, optionally with additives, and a recyclate blend melt is withdrawn from extruder **420**. The recyclate blend

melt is processed through melt filtration apparatus **440**, from which a filtered virgin polymer melt is withdrawn and sent to railcar **450** for shipping.

[0108] An existing polymer production facility having polymer processing system **100** as shown in **FIG. 1** could be retrofitted to form polymer processing system **400** as shown in **FIG. 4** to both add a capacity for processing polymer recyclate and expand the overall production capacity of the existing polymer production facility. A polymer recyclate feed system is added to system **100**. The polymer recyclate feed system comprises feed hopper **412**, extruder **422**, and melt filtration apparatus **424** comprising advanced filtration technology. Extruder **120** and melt pump **130** are replaced with larger capacity twin screw extruder **420**. The capacity of twin screw extruder **420** is sized to be greater than or equal to the desired flow of virgin polymer feed from feed hopper **410** and the flow of filtered polymer recyclate from melt filtration apparatus **424** are less than or equal to the capacity of extruder **420**. The virgin polymer feed hopper **110** remains unchanged as is the same as feed hopper **410**. Melt filtration apparatus **424** is designed to match the capacity of twin screw extruder **420**.

Example 5

[0109] An embodiment of polymer processing system **500** as disclosed herein is shown in **FIG. 5**. Virgin polymer and polymer recyclate are fed to extruder **520** from feed hopper **510**. The polymer recyclate and the virgin polymer are heated to above their melting temperatures and intimately mixed, optionally with additives, and a recyclate blend melt is withdrawn from extruder **520**. The recyclate blend melt is processed through melt filtration apparatus **540**, from which a filtered virgin polymer melt is withdrawn and sent to railcar **550** for shipping.

[0110] An existing polymer production facility having polymer processing system **100** as shown in **FIG. 1** could be retrofitted to form polymer processing system **500** as shown in **FIG. 5** to both add a capacity for processing polymer recyclate and expand the overall production capacity of the existing polymer production facility. Feed hopper **510** is sized to accommodate a desired combined feed rate of the original virgin polymer feed rate plus a desired polymer recyclate feed rate. Extruder **120** and melt pump **130** are replaced with twin screw extruder **520**, having a capacity to match the feed rate from feed hopper **510**. Melt filtration apparatus **140** is replaced with melt filtration apparatus **540**, comprising advanced filtration technology and having a capacity to match twin screw extruder **520**.

[0111] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, in addition to recited ranges, any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited.

Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[0112] All documents and references cited herein, including testing procedures, publications, patents, journal articles, etc., are herein fully incorporated by reference for all jurisdictions in which such incorporation is permitted and to the extent such disclosure is consistent with the description of the present invention.

[0113] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the processes, machines, means, methods, and/or steps described in the specification. As one of the ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, means, methods, and/or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein, may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, means, methods, and/or steps.

CLAIMS

What is claimed is:

1. A process comprising:
 - a) feeding a virgin polymer to a first melt mixing apparatus to produce a virgin polymer melt;
 - b) feeding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt;
 - c) processing the polymer recyclate melt through a first melt filtration apparatus, comprising advanced filtration technology, to produce a filtered polymer recyclate melt;
 - d) feeding the virgin polymer melt and the filtered polymer recyclate melt to a melt pump to produce a recyclate blend melt; and
 - e) processing the recyclate blend melt through a second melt filtration apparatus; and
 - f) withdrawing a filtered recyclate blend product from the second melt filtration apparatus.
2. The process of claim 1, wherein the ratio of the virgin polymer to the polymer recyclate added to the process is in the range of from 20:1 to 1:2.5.
3. The process of claim 1, wherein the ratio of the virgin polymer to the polymer recyclate added to the process is in the range of from 10:1 to 1:1.5.
4. The process of claim 1, wherein the ratio of the virgin polymer to the polymer recyclate added to the process is in the range of from 6:1 to 1:1.
5. The process of claim 1, wherein the ratio of the virgin polymer to the polymer recyclate added to the process is in the range of from 4:1 to 1.5:1.
6. The process of claim 1, wherein the virgin polymer and/or the polymer recyclate comprises:
 - a) an ethylene homopolymer;
 - b) a copolymer of units derived from ethylene and units derived from one or more of C₃-C₂₀ alpha-olefins or mixtures thereof;
 - c) a copolymer of units derived from ethylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof.
 - d) an ethylene homopolymer;
 - e) a copolymer of units derived from propylene and units derived one or more of ethylene and C₄-C₂₀ alpha-olefins or mixtures thereof;

- f) a copolymer of units derived from propylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof; or
 - g) a combination thereof.
7. The process of claim 1, wherein the virgin polymer is miscible with the polymer recyclate.
8. A process comprising:
- a) feeding a virgin polymer to a first melt mixing apparatus;
 - b) feeding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt;
 - c) processing the polymer recyclate melt through to a first melt filtration apparatus, comprising advanced filtration technology, to produce a filtered polymer recyclate melt;
 - d) feeding the filtered polymer recyclate melt to the first melt mixing apparatus;
 - e) withdrawing a recyclate blend melt from the first melt mixing apparatus;
 - f) processing the recyclate blend melt through a melt pump;
 - f) processing an effluent from the melt pump through a second melt filtration apparatus; and
 - g) withdrawing a filtered recyclate blend product from the second melt filtration apparatus.
9. A process comprising:
- a) feeding a virgin polymer to a first melt mixing apparatus;
 - b) feeding a polymer recyclate to a second melt mixing apparatus to produce a polymer recyclate melt;
 - c) processing the polymer recyclate melt through a first melt filtration apparatus, comprising advanced filtration technology, to produce a filtered polymer recyclate melt;
 - d) feeding the filtered polymer recyclate melt to the first melt mixing apparatus;
 - e) withdrawing a recyclate blend melt from the first melt mixing apparatus;
 - f) processing the recyclate blend melt through a second melt filtration apparatus; and
 - g) withdrawing a filtered recyclate blend product from the second melt filtration apparatus.
10. A process comprising:
- a) adding a virgin polymer and a polymer recyclate to a first melt mixing apparatus to produce a recyclate blend melt;
 - b) processing the recyclate blend melt through a melt filtration apparatus, comprising advanced filtration technology; and

- c) withdrawing a filtered recycle blend product from the melt filtration apparatus.
11. A method for retrofitting a polymer production facility to add a processing capacity for polymer recycle, wherein the polymer production facility (1) comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a first melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration apparatus having an outlet adapted for withdrawal of a polymer product and (2) has a first throughput rate, the method comprising:
- a) adding a polymer recycle feed system:
 - (1) comprising a polymer recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus, the second melt mixing apparatus having an outlet fluidly connected to a second melt filtration apparatus, wherein the second melt filtration apparatus comprises advanced filtration technology; and
 - (2) having a second throughput rate; and
 - b) replacing the first melt pump and the first melt filtration apparatus with a recycle blend system (1) comprising a second melt pump having an inlet fluidly connected to the outlet from the first melt pump and an outlet from the second melt filtration apparatus and an outlet fluidly connected to an inlet to a third melt filtration apparatus, the third melt filtration apparatus having an outlet adapted for withdrawal of a recycle blend product and (2) having a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.
12. The method of claim 11, wherein the ratio of the virgin polymer to the polymer recycle added to the process is in the range of from 20:1 to 1:2.5.
13. The method of claim 11, wherein the ratio of the virgin polymer to the polymer recycle added to the process is in the range of from 10:1 to 1:1.5.
14. The method of claim 11, wherein the ratio of the virgin polymer to the polymer recycle added to the process is in the range of from 6:1 to 1:1.
15. The method of claim 11, wherein the ratio of the virgin polymer to the polymer recycle added to the process is in the range of from 4:1 to 1.5:1.
16. The method of claim 11, wherein the virgin polymer and/or the polymer recycle comprise:
- a) an ethylene homopolymer;
 - b) a copolymer of units derived from ethylene and units derived from one or more of C₃-C₂₀ alpha-olefins or mixtures thereof;

- c) a copolymer of units derived from ethylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof.
 - d) an ethylene homopolymer;
 - e) a copolymer of units derived from propylene and units derived one or more of ethylene and C₄-C₂₀ alpha-olefins or mixtures thereof;
 - f) a copolymer of units derived from propylene and units derived from one or more of alpha mono-olefins comprising polar groups; or combinations thereof; or
 - g) a combination thereof.
17. The method of claim 11, wherein the virgin polymer is miscible with the polymer recyclate.
18. A method for retrofitting a polymer production facility to add a processing capacity for polymer recyclate, wherein the polymer production facility (1) comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration apparatus having an outlet adapted for withdrawal of a polymer product and (2) has a first throughput rate, the method comprising:
- a) adding a polymer recyclate feed system:
 - (1) comprising a polymer recyclate feed apparatus fluidly connected to an inlet to a second melt mixing apparatus, the second melt mixing apparatus having an outlet fluidly connected to a second melt filtration apparatus, the second melt filtration apparatus comprising advanced filtration technology; and
 - (2) having a second throughput rate;
 - b) fluidly connecting an outlet from the second melt filtration apparatus to a second inlet to the first melt mixing apparatus; and
 - c) adding a control system, wherein the control system provides for maintaining the sum of a virgin polymer feed rate and a polymer recyclate feed rate being less than or equal to the first throughput rate.
19. A method for retrofitting a polymer production facility to add a processing capacity for polymer recyclate, wherein the polymer production facility (1) comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration apparatus having an outlet adapted for withdrawal of a polymer product and (2) has a first throughput rate, the method comprising:

- a) adding a polymer recyclate feed system:
 - (1) comprising a polymer recyclate feed apparatus fluidly connected to an inlet to a second melt mixing apparatus, the second melt mixing apparatus having an outlet fluidly connected to a second melt filtration apparatus, the second melt filtration apparatus comprising advanced filtration technology; and
 - (2) having a second throughput rate; and
 - b) replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recyclate blend system (1) comprising a second melt mixing apparatus having (i) one or more inlets fluidly connected to the virgin polymer feed apparatus and an outlet from the second melt filtration apparatus and (ii) an outlet fluidly connected to a second melt filtration apparatus, the second melt filtration apparatus having an outlet adapted for withdrawal of a recyclate blend product and (2) having a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.
20. A method for retrofitting a polymer production facility to add a processing capacity for polymer recyclate, wherein the polymer production facility (1) comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration apparatus having an outlet adapted for withdrawal of a polymer product and (2) has a first throughput rate, the method comprising:
- a) converting the virgin polymer feed apparatus to a recyclate blend feed apparatus by
 - (1) adapting the virgin polymer feed apparatus to accept the virgin polymer feed and a polymer recyclate feed and (2) increasing the throughput rate of the virgin polymer feed apparatus to accept a second throughput rate of the polymer recyclate in addition to the first throughput rate of the virgin polymer; and
 - b) replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recyclate blend system (1) comprising a second melt mixing apparatus having (i) an inlet fluidly connected to the recyclate blend feed apparatus and (ii) an outlet fluidly connected to a second melt filtration apparatus comprising advanced filtration technology, the second melt filtration apparatus having an outlet adapted for withdrawal of a recyclate blend product and (2) having a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate.

100

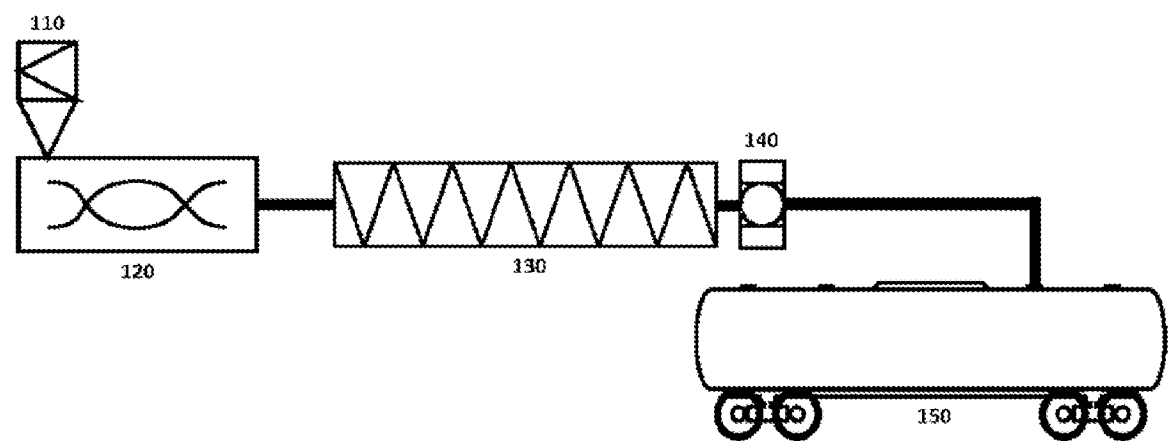


FIG. 1

200

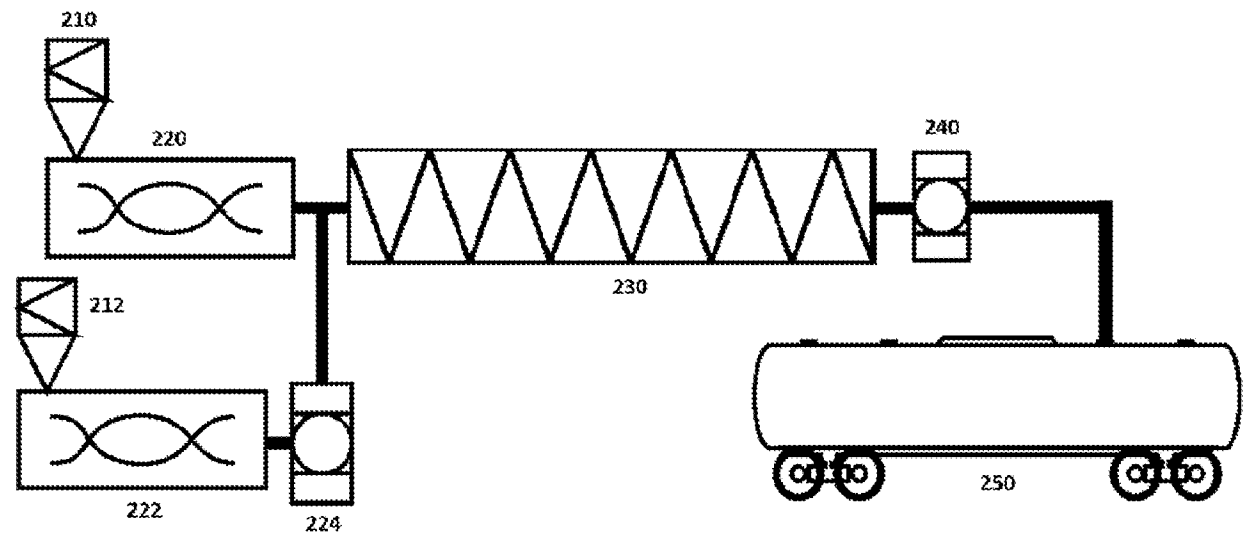


FIG. 2

300

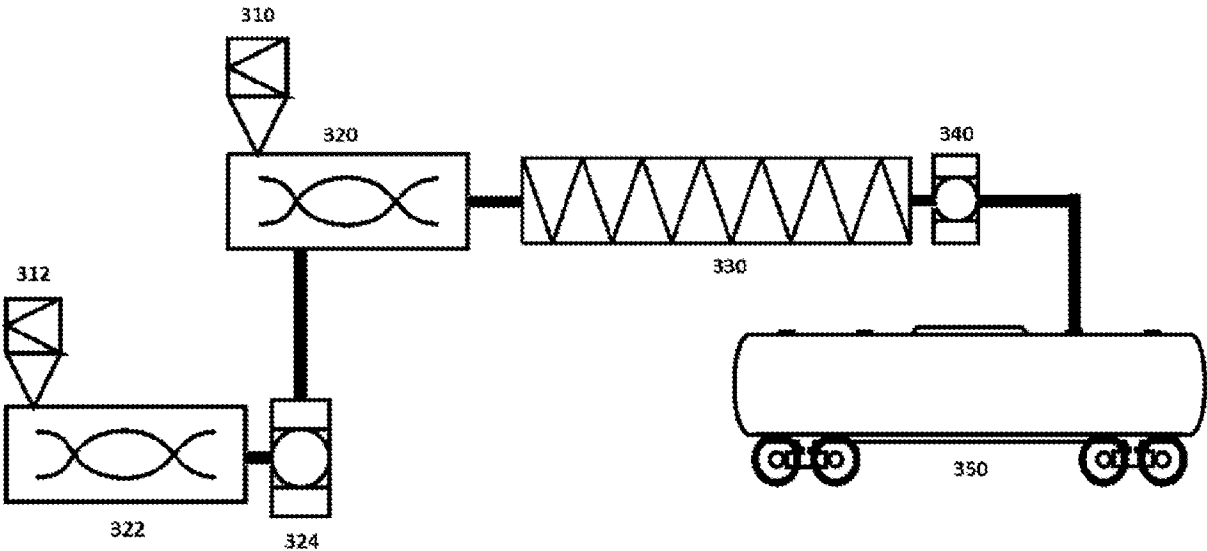


FIG. 3

400

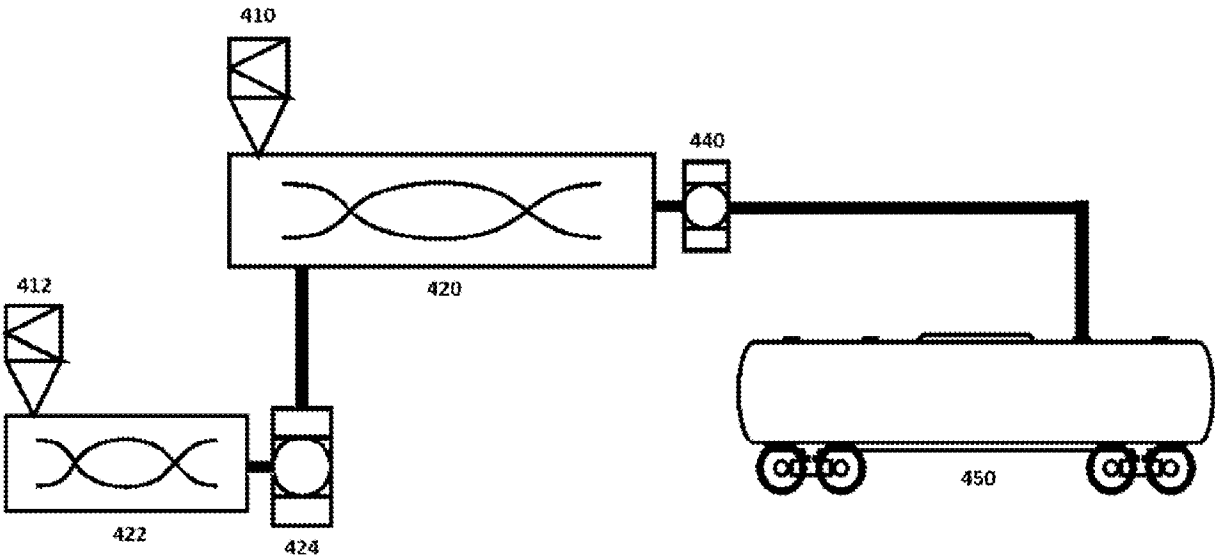


FIG. 4

500

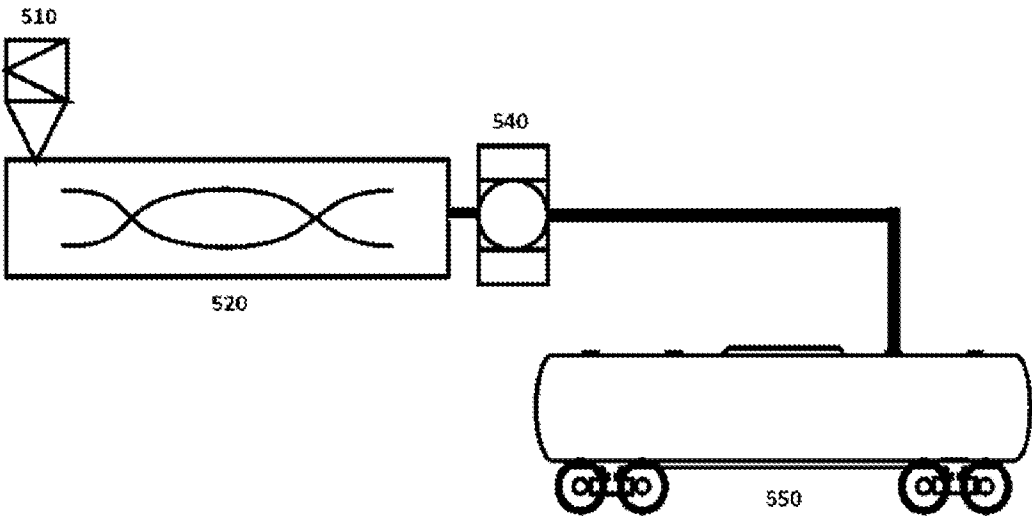


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US23/24831

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. D01F 13/04; B29B 17/00; B29B 17/02; C08J 11/04; D01F 8/14 (2023.01)

ADD.

CPC - INV. D01F 13/04; B29B 17/02; C08J 11/04; D01D 1/106; D01F 8/14

ADD. B29B 2017/0224; C08J 2367/02; Y02P 70/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2023/083802 A1 (POLYMETRIX AG) 19 May 2023; abstract, paragraphs [0019]-[0021], [0032], [0043], [0047], [0079]-[0080], [0118], [0121], [0202]-[0205], [0237]; figure 1, see English translation	1-10
A	US 2021/0388535 A1 (PFNONWOVENS LLC) 16 December 2021; figure 1; paragraph [0025], claim 17	1

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

03 October 2023 (03.10.2023)

Date of mailing of the international search report

OCT 24 2023

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Shane Thomas

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US23/24831

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-Please See Supplemental Page-

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
Group I: Claims 1-10

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

-***-Continued From Box No. III: Observations where unity of invention is lacking-***-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-10 are directed toward a process comprising a virgin polymer and a polymer recycle.

Group II: Claims 11-20 are directed toward a method for retrofitting a polymer production facility.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical features of Group I include feeding a process comprising feeding virgin polymer to a first melt mixing apparatus to produce a virgin polymer melt; feeding a polymer recycle to a melt mixing apparatus to produce a polymer recycle melt; processing the polymer recycle melt through a first melt filtration apparatus, to produce a filtered polymer recycle melt; feeding the virgin polymer melt and the filtered polymer recycle melt to a melt pump to produce a recycle blend melt; processing the recycle blend melt through a melt pump and a second melt filtration apparatus; and feeding the filtered polymer recycle melt to the first melt mixing apparatus, withdrawing a polymer melt from the first melt mixing apparatus; withdrawing a filtered recycle blend product from the second melt filtration apparatus, not present in Group II; the special technical features of Group II include a method for retrofitting a polymer production facility to add a processing capacity for polymer recycle, wherein the polymer production facility comprises a virgin polymer feed apparatus fluidly connected to an inlet to first melt mixing apparatus, the first melt mixing apparatus having an outlet fluidly connected to an inlet to a first melt pump, the melt pump having an outlet fluidly connected to an inlet to a melt filtration apparatus, the melt filtration apparatus having an outlet adapted for withdrawal of a polymer product and has a first throughput rate, the method comprising: adding a polymer recycle feed system: comprising a polymer recycle feed apparatus fluidly connected to an inlet to a second melt mixing apparatus, the second melt mixing apparatus having an outlet fluidly connected to a second melt filtration apparatus, wherein the second melt filtration apparatus comprises advanced filtration technology; and having a second throughput rate; and replacing the first melt pump and the first melt filtration apparatus with a recycle blend system comprising a second melt pump having an inlet fluidly connected to the outlet from the first melt pump and an outlet from the second melt filtration apparatus and an outlet fluidly connected to an inlet to a third melt filtration apparatus, the third melt filtration apparatus having an outlet adapted for withdrawal of a recycle blend product and having a third throughput rate, wherein the third throughput rate is the sum of the first throughput rate and the second throughput rate, fluidly connecting an outlet from the second melt filtration apparatus to a second inlet to the first melt mixing apparatus; and adding a control system, wherein the control system provides for maintaining the sum of a virgin polymer feed rate and a polymer recycle feed rate being less than or equal to the first throughput rate, replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recycle blend system (1) comprising a second melt mixing apparatus having (i) one or more inlets fluidly connected to the virgin polymer feed apparatus and an outlet from the second melt filtration apparatus and an outlet fluidly connected to a second melt filtration apparatus, the second melt filtration apparatus having an outlet adapted for withdrawal of a recycle blend product, converting the virgin polymer feed apparatus to a recycle blend feed apparatus by (1) adapting the virgin polymer feed apparatus to accept the virgin polymer feed and a polymer recycle feed and increasing the throughput rate of the virgin polymer feed apparatus to accept a second throughput rate of the polymer recycle in addition to the first throughput rate of the virgin polymer; and replacing the first melt mixing apparatus, the first melt pump, and the first melt filtration apparatus with a recycle blend system (1) comprising a second melt mixing apparatus having (i) an inlet fluidly connected to the recycle blend feed apparatus and (ii) an outlet fluidly connected to a second melt filtration apparatus comprising advanced filtration technology, the second melt filtration apparatus having an outlet adapted for withdrawal of a recycle blend product, not present in Group II.

Groups I and II share the technical features including: a virgin polymer, a polymer recycle, a first melt filtration apparatus, a second melt filtration apparatus, comprising advanced filtration technology, and a filtered recycle blend product.

However, these shared technical features are previously disclosed by US 2022/0356323 A1 to BRASKEM S.A. (hereinafter 'BRASKEM') in view of WO 2022/112906 A1 to LOHIA CORP LIMITED (hereinafter 'LOHIA'). BRASKEM discloses a virgin polymer (a virgin resin material; claim 1), a polymer recycle (a sorted polymer flake material; claim 1), a first melt filtration apparatus (a cleaning melt filter; claim 5), and a filtered recycle blend product (extruding the polymer flake material with a virgin to form an extruded polymer blend, filtering the extruded polymer blend; abstract). BRASKEM does not disclose a second melt filtration apparatus, comprising advanced filtration technology. LOHIA discloses a first melt filtration apparatus, a second melt filtration apparatus (multiple melt filtration system, molten material from the extrusion barrel 10 is filtered by first filtration unit 5 and delivered to melt pump 7 which then delivers the molten material into second filtration unit 8; abstract) comprising advanced filtration technology (by using this filter media, it is possible to remove foreign particles like solid particles as well as soft components so called gels from the melt; this ensures a high-quality extrusion result; pore size of first and second filters is in the range between 0.5 micrometer to 200 micrometer; page 3 lines 13-15, claim 15). It would have been obvious to one of ordinary skill in the art, at the time the invention was made, to modify the method of BRASKEM to include a second melt filtration apparatus, comprising advanced filtration technology, as taught by LOHIA, because this will provide greater filtration capacity, better purity, and ensures a high-quality extrusion result (LOHIA; page 3 lines 14-15).

Since none of the special technical features of the Groups I and II inventions is found in more than one of the inventions, and since all of the shared technical features are previously disclosed by a combination of the BRASKEM and LOHIA references, unity of invention is lacking.