The present disclosure deals with a process of producing a modified polyethylene. According to the disclosure it is possible to produce a modified polyethylene showing reduced melt flow rate and low gel content.

The process of the disclosure is particularly suitable for treating and modifying recycled polyethylene, for example a polyethylene which comprises recycled polyethylene. Recycled polyethylene is usually a non-homogeneous material which consists of a wide variety of different recycled polyethylene components with different properties, e.g. different melt flow rates. This also means that different recycled polyethylene components and their properties, e.g. melt flow rates, may differ from one day to another, depending on the origin of the recycled polyethylene material. Hereby the starting point any for modification of recycled polyethylene tend to be more difficult and the result tend to be more unpredictable compared to when using more homogeneous polyethylene, e.g. virgin polyethylene. According to the present disclosure, there is provided a process for treating and modifying a polyethylene comprising recycled polyethylene, and the melt flow rate thereof, with improved control.

In addition to providing a controlled reduction of the melt flow rate of a polyethylene, the present disclosure also provides polyethylene, in particular polyethylene comprising recycled polyethylene, with reduced variation of the polyethylene material, i.e. improved consistency of the polyethylene within a manufactured product. Hereby the risk of variations in product dimensions and appearance is lower. Accordingly, the disclosure enables processing polyethylene without additional negative effects on dimension accuracy and undesired surface effects, thus products with better material consistency regarding mechanical properties, long term performance, stretchability (both in molten form and in solid state) and weldability.

Accordingly, in a first aspect, the present disclosure refers to a process for obtaining a controlled reduction of the melt flow rate (5 kg, 190°C) (MFR) of a polyethylene comprising one or more recycled polyethylene components, wherein the polyethylene is a homopolymer or is a copolymer containing from 0.1 to 30 % by mole of comonomer(s), comprising the steps of:

(a) determining the starting melt flow rate (5 kg, 190°C) (MFR_0) of the polyethylene,

(b) feeding the polyethylene into an extrusion device comprising a feed zone, a melting zone, a mixing zone and a die zone,

(c) feeding peroxide in an amount of X ppm over the weight of the polyethylene into the extrusion device, wherein the amount of peroxide X is in a range of 300 ppm to 4000 ppm,

(d) mixing the polyethylene with the peroxide in the extrusion device at a temperature above the melting points of the components until substantially homogeneous,

(e) extruding and pelletizing the mixture obtained from step (d),

(f) determining the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene obtained from step (e),

characterized in that
the mixture comprising polyethylene and peroxide is heated to a temperature in the range of from 170 to 250°C;
the overall average residence time in the combined melting zone and the mixing zone of the extruder is from 15 to 60 seconds;

the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene fulfils the exponential decay (equation (I)) in respect of the starting melt flow rate (5 kg, 190°C) (MFR_0) and the concentration (X) of the peroxide based on the amount of polyethylene,

$$MFRf = MFR0 \times e^{-\mu X} \quad \text{(I)}$$

wherein the exponential decay constant μ is in the range between 0.0005 to 0.005; and
the final melt flow rate (MFRf) of the modified polyethylene is in the range of from 0.1 to 8.0 g/10min.

In another aspect, the present disclosure refers to a process for modifying a polyethylene comprising one or more recycled polyethylene components, comprising the steps of:

(a) determining a starting melt flow rate (5 kg, 190°C) (MFR_0) of the polyethylene,

(b) feeding the polyethylene into an extrusion device,

(c) feeding peroxide in an amount of X ppm over the weight of the polyethylene into the extrusion device, wherein the amount of peroxide X is in a range of 300 ppm to 4000 ppm,

(d) mixing the polyethylene with the peroxide in the extrusion device at a temperature above the melting point of the polyethylene until substantially homogeneous,

(e) extruding and optionally pelletizing the mixture obtained from step (d),

wherein the polyethylene preferably has a residence time in the extrusion device of at least 25 seconds,

(f) determining the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene obtained from step (e),

characterized in that

the mixture comprising polyethylene and peroxide is heated to a temperature in the range of from 170 to 250°C;
the overall average residence time in the combined melting zone and the mixing zone of the extruder is from 15 to 60 seconds;

the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene fullfils the exponential decay (equation (I)) in respect of the starting melt flow rate (5 kg, 190°C) (MFR_0) and the concentration (X) of the peroxide based on the amount of polyethylene,

$$MFRf = MFR0 \times e^{-\mu X} \quad \text{(I)}$$

wherein the exponential decay constant μ is in the range between 0.0005 to 0.005; and
the final melt flow rate (MFRf) of the modified polyethylene is in the range of from 0.1 to 8.0 g/10min.

Disclosed is a process for obtaining a controlled reduction of the melt flow rate (5 kg, 190°C) (MFR) of a polyethylene, comprising the steps of:

(a) determining the starting melt flow rate (5 kg, 190°C) (MFR_0) of a polyethylene,

(b) defining a target melt flow rate (5 kg, 190°C) (MFRt) for the modified polyethylene,

(c) determining the value of μ for the combination of polyethylene, peroxide and the extrusion conditions, determining the required amount of peroxide (X) from the equation (II) by using the starting melt flow rate, the target melt flow rate and the value of μ,

$$\mathrm{MFRt} = \mathrm{MFR0} \times \mathrm{e}^{-\mu \mathrm{X}} \quad \text{(II)}$$

(d) feeding the polyethylene into an extrusion device,

(e) feeding peroxide in an amount of X ppm over the weight of the polyethylene into the extrusion device, wherein the amount of peroxide X is in a range of 300 ppm to 4000 ppm,

(f) mixing the polyethylene with the peroxide in the extrusion device at a temperature above the melting points of the components until substantially

homogeneous,

(g) extruding and optionally pelletizing the mixture obtained from step (d),

(h) determining the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene obtained from step (e).

In another aspect, the present disclosure refers to a process for obtaining a controlled reduction of the melt flow rate (5 kg, 190°C) (MFR) of a polyethylene comprising one or more recycled polyethylene components, wherein the polyethylene is a homopolymer or is a copolymer containing from 0.1 to 30 % by mole of comonomer(s), comprising the steps of:

(a) determining the starting melt flow rate (5 kg, 190°C) (MFR_0) of the polyethylene,

(b) defining a target melt flow rate (5 kg, 190°C) (MFR_t) for the modified polyethylene,

(c) determining the value of μ for the combination of polyethylene, peroxide and the extrusion conditions, determining the required amount X of peroxide from the equation (II) by using the starting melt flow rate, the target melt flow rate and the value of μ,

$$\mathrm{MFRt} = \mathrm{MFR0} \times e^{-\mu X} \quad \text{(II)}$$

(d) feeding the polyethylene into an extrusion device comprising a feed zone, a melting zone, a mixing zone and a die zone,

(e) feeding the required amount of peroxide as determined in step (c) over the weight of the polyethylene into the extrusion device, wherein the amount X of peroxide is in a range of 300 ppm to 4000 ppm,

(f) mixing the polyethylene with the peroxide in the extrusion device at a temperature above the melting points of the components until substantially homogeneous,

(g) extruding and optionally pelletizing the mixture obtained from step (f),

(h) determining the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene obtained from step (g),

wherein the final melt flow rate (MFRf) of the modified polyethylene is in the range of from 0.1 to 8.0 g/10min;

the mixture comprising polyethylene and peroxide is heated to a temperature in the range of from 170 to 250°C; and

the overall average residence time in the combined melting zone and the mixing zone of the extruder is from 15 to 60 seconds.

Brief Description of the Drawing

Figure 1 shows an example plot of the final melt flow rate versus the amount of peroxide (X).

Claims

1. A process for obtaining a controlled reduction of the melt flow rate (5 kg, 190°C) (MFR) of a polyethylene comprising one or more recycled polyethylene components, wherein the polyethylene is a homopolymer or is a copolymer containing from 0.1 to 30 % by mole of comonomer(s), comprising the steps of:
   (a) determining the starting melt flow rate (5 kg, 190°C) (MFR_0) of the polyethylene,
   (b) feeding the polyethylene into an extrusion device comprising a feed zone, a melting zone, a mixing zone and a die zone,
   (c) feeding peroxide in an amount of X ppm over the weight of the polyethylene into the extrusion device, wherein the amount of peroxide X is in a range of 300 ppm to 4000 ppm,
   (d) mixing the polyethylene with the peroxide in the extrusion device at a temperature above the melting points of the components until substantially homogeneous,
   (e) extruding and optionally pelletizing the mixture obtained from step (d),
   (f) determining the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene obtained from step (e),

   characterized in that

   the mixture comprising polyethylene and peroxide is heated to a temperature in the range of from 170 to 250°C;

   the overall average residence time in the combined melting zone and the mixing zone of the extruder is from 15 to 60 seconds;

   the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene fullfils the exponential decay (equation (I)) in respect of the starting melt flow rate (5 kg, 190°C) (MFR_0) and the concentration (X) of the peroxide based on the amount of polyethylene,

   $$MFRf = MFR0 \times e^{-\mu X} \quad \text{(I)}$$

   wherein the exponential decay constant μ is in the range between 0.0005 to 0.005; and

   the final melt flow rate (MFR_f) of the modified polyethylene is in the range of from 0.1 to 8.0 g/10min.

2. A process for modifying a polyethylene comprising one or more recycled polyethylene components, comprising the steps of:
   (a) determining a starting melt flow rate (5 kg, 190°C) (MFR_0) of the polyethylene,
   (b) feeding the polyethylene into an extrusion device,
   (c) feeding peroxide in an amount of X ppm over the weight of the polyethylene into the extrusion device, wherein the amount of peroxide X is in a range of 300 ppm to 4000 ppm,
   (d) mixing the polyethylene with the peroxide in the extrusion device at a temperature above the melting point of the polyethylene until substantially homogeneous,
   (e) extruding and optionally pelletizing the mixture obtained from step (d), wherein the polyethylene preferably has a residence time in the extrusion device of at least 25 seconds,
   (f) determining the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene obtained from step (e),

   characterized in that

   the mixture comprising polyethylene and peroxide is heated to a temperature in the range of from 170 to 250°C;

   the overall average residence time in the combined melting zone and the mixing zone of the extruder is from 15 to 60 seconds;

   the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene fullfils the exponential decay (equation (I)) in respect of the starting melt flow rate (5 kg, 190°C) (MFR_0) and the concentration (X) of the peroxide based on the amount of polyethylene,

   $$MFRf = MFR0 \times e^{-\mu X} \quad \text{(I)}$$

   wherein the exponential decay constant μ is in the range between 0.0005 to 0.005; and

   the final melt flow rate (MFR_f) of the modified polyethylene is in the range of from 0.1 to 8.0 g/10min.

3. A process for obtaining a controlled reduction of the melt flow rate (5 kg, 190°C) (MFR) of a polyethylene comprising one or more recycled polyethylene

components, wherein the polyethylene is a homopolymer or is a copolymer containing from 0.1 to 30 % by mole of comonomer(s), comprising the steps of:

(a) determining the starting melt flow rate (5 kg, 190°C) (MFR_0) of the polyethylene,

(b) defining a target melt flow rate (5 kg, 190°C) (MFR_t) for the modified polyethylene,

(c) determining the value of μ for the combination of polyethylene, peroxide and the extrusion conditions, determining the required amount X of peroxide from the equation (II) by using the starting melt flow rate, the target melt flow rate and the value of μ,

$$\mathrm{MFRt} = \mathrm{MFR0} \times e^{-\mu X} \quad \text{(II)}$$

(d) feeding the polyethylene into an extrusion device comprising a feed zone, a melting zone, a mixing zone and a die zone,

(e) feeding the required amount of peroxide as determined in step (c) over the weight of the polyethylene into the extrusion device, wherein the amount X of peroxide is in a range of 300 ppm to 4000 ppm,

(f) mixing the polyethylene with the peroxide in the extrusion device at a temperature above the melting points of the components until substantially homogeneous,

(g) extruding and optionally pelletizing the mixture obtained from step (f),

(h) determining the final melt flow rate (5 kg, 190°C) (MFR_f) of the modified polyethylene obtained from step (g),

wherein the final melt flow rate (MFR_f) of the modified polyethylene is in the range of from 0.1 to 8.0 g/10min;

the mixture comprising polyethylene and peroxide is heated to a temperature in the range of from 170 to 250°C; and

the overall average residence time in the combined melting zone and the mixing zone of the extruder is from 15 to 60 seconds.

4. The process according to claim 1, 2 or 3, characterized in that the mixture

comprising polyethylene and peroxide is heated to a temperature in the range of from 180 to 240°C, preferably from 180 to 230°C.

5. The process according to any one of the preceding claims, characterized in that the extrusion is carried out at a specific energy input (SEI) is below 0.4 kWh/kg, suitably from 0.15 to 0.4 kWh/kg, preferably from 0.15 to 0.35 kWh/kg, and more preferably from 0.15 to 0.25 kWh/kg.

6. The process according to any one of the preceding claims, characterized in that the starting melt flow rate (5 kg, 190°C) (MFR_0) of the polyethylene is in the range of from 0.5 to 100.0 g/10min, preferably from 1.0 to 75 g/10 min, more preferably from 1.5 to 50 g/10min.

7. The process according to any one of the preceding claims, characterized in that the starting polydispersity index (PI_0) of the polyethylene is in the range of from 1 to 20, preferably in the range of from 2 to 18, more preferably in the range of from 2 to 15.

8. The process according to any one of the preceding claims, characterized in that the final melt flow rate (MFR_f) of the modified polyethylene is in the range of from 0.5 to 5.0, preferably from 0.2 to 3.0 g/10min.

9. The process according to any one of the preceding claims, characterized in that the modified polyethylene has a xylene insoluble content (XHU) of below 2.0 %, preferably of below 1.2 %, more preferably below 0.7 %.

10. The process according to any one of the preceding claims, characterized in that the modified polyethylene has a polydispersity index (PI_f) in the range of from 2 to 50, preferably in the range of from 4 to 40, most preferably in the range of from 5 to 15.

11. The process according to any one of the preceding claims, characterized in that the polyethylene used as raw material comprises recycled polyethylene.

12. The process according to any one of the preceding claims, characterized in that the polyethylene used as raw material is selected from homopolymers of

ethylene, copolymers of ethylene and one or more alpha-olefins having from 3 to 10 carbon atoms, and mixtures thereof.

13. The process according to any one of the preceding claims, characterized in that the polyethylene used as raw material comprises a copolymer of ethylene and comonomer(s) selected from one or more alpha-olefins having from 3 to 10 carbon atoms, wherein the copolymer contains from 0.1 to 15 % by mole of comonomer(s), preferably from 0.1 to 10 % by mole of comonomer(s), more preferably from 0.1 to 5 % by mole of comonomer(s).

14. The process according to any one of the preceding claims, characterized in that the extrusion device is a twin screw extruder or continuous intensive mixer, preferably a co-rotating twin screw extruder.

15. The process according to any one of the preceding claims, characterized in that the extrusion device has a length over diameter ratio, L/D, of from 4:1 to 65:1, preferably from 5:1 to 60:1, more preferably from 6:1 to 50:1.

16. The process according to any one of the preceding claims, characterized in that the extrusion device comprises a feed zone, melting zone and mixing zone, optionally one or more evacuation ports, wherein the peroxide is fed into the extrusion device in the feed zone or mixing zone, preferably in the feed zone, and preferably the peroxide is added as a premix or masterbatch.