lowered to a point below its dew point in condensed mode operation, an increase in polymer production may be possible.

[0005] Cooling of the recycle stream to a temperature below the gas dew point temperature produces a two-phase gas/liquid mixture that may have entrained solids contained in both phases. The liquid phase of this two-phase gas/liquid mixture in condensed mode operation is generally entrained in the gas phase of the mixture. Vaporization of the liquid occurs only when heat is added or pressure is reduced. Generally, the vaporization occurs when the two-phase mixture enters the fluidized bed, with the resin providing the required heat of vaporization. The vaporization thus provides an additional means of extracting heat of reaction from the fluidized bed.

[0006] The cooling capacity of the recycle gas may be increased further while at a given reaction temperature and a given temperature of the cooling heat transfer medium. This can be performed by adding non-polymerizing, non-reactive materials to the reactor, which are condensable at the temperatures encountered in the process heat exchanger. Such materials are collectively known as induced condensing agents (ICA). Increasing concentrations of an ICA in the reactor causes corresponding increases in the dew point temperature of the reactor gas, which promotes higher levels of condensing for higher (heat transfer limited) production rates from the reactor. However, attempts to operate polymerization reactors with excessive ICA concentrations have led to the polymer particles suspended in the fluid bed to become cohesive or "sticky" and, in some cases, to solidification of the fluid bed in the form of a large chunk. Therefore, the reactor temperature is reduced below the stickiness temperature, which reduces polyolefin production rate.

SUMMARY

[0006a] In one aspect, there is provided a method comprising:

contacting in a fluidized bed gas phase reactor an olefin monomer with a catalyst system in the presence of an induced condensing agent (ICA) and optionally hydrogen to produce a polyolefin having a sticking temperature, wherein the ICA comprises a first ICA component and a second ICA component;

operating the fluidized bed gas phase reactor at an operating temperature lower than the sticking temperature of the polyolefin;

withdrawing a gas phase composition comprising at least some of the olefin, at least some of the ICA, and optionally at least some hydrogen;

condensing a portion of the ICA from the gas phase composition yielding a condensed ICA;

recycling at least a portion of the condensed ICA and at least a portion of the gas phase composition to the fluidized bed gas phase reactor; and

changing a mole percent of total reactor gas for each of the first and the second ICA components according to a first ICA to second ICA equivalency factor whereby one mole of the second ICA component is substituted with a predetermined number of moles of the first ICA component to cause a dew point approach temperature of the ICA to increase, which allows for an increase in a production rate of the polyolefin while maintaining the sticking temperature, wherein the dew point approach temperature is an operating temperature of the reactor minus a dew point of the condensed recycle stream.

[0006b] In another aspect, there is provided a method comprising:

contacting in a fluidized bed gas phase reactor an olefin monomer with a catalyst system in the presence of an induced condensing agent (ICA) and optionally hydrogen to produce a polyolefin having a sticking temperature, wherein the ICA comprises a first ICA component and a second ICA component;

operating the fluidized bed gas phase reactor at an operating temperature lower than the sticking temperature of the polyolefin;

withdrawing a gas phase composition comprising at least some of the olefin, at least some of the ICA, and optionally at least some hydrogen;

condensing a portion of the ICA from the gas phase composition yielding a condensed ICA;

recycling at least a portion of the condensed ICA and at least a portion of the gas phase composition to the fluidized bed gas phase reactor; and

changing a mole percent of total reactor gas for each of the first and the second ICA components according to a first ICA component to second ICA component equivalency factor whereby one mole of the second ICA component is substituted with a predetermined number of moles of the first ICA component to increase the dew point approach temperature and the production rate of the polyolefin while maintaining the sticking temperature of the polyolefin.

[0006c] In another aspect, there is provided a method comprising:

contacting in a fluidized bed gas phase reactor an olefin monomer with a catalyst system in the presence of an induced condensing agent (ICA) and optionally hydrogen to produce a polyolefin having a sticking temperature, wherein the ICA comprises a first ICA component and a second ICA component;

operating the fluidized bed gas phase reactor at an operating temperature lower than the sticking temperature of the polyolefin;

withdrawing a gas phase composition comprising at least some of the olefin, at least some of the ICA, and optionally at least some hydrogen;

condensing a portion of the ICA from the gas phase composition yielding a condensed ICA;

recycling at least a portion of the condensed ICA and at least a portion of the gas phase composition to the fluidized bed gas phase reactor; and

increasing a polyolefin production rate by changing a mole percent of total reactor gas for each of the first and the second ICA components according to a first ICA component to second ICA component equivalency factor whereby one mole of the second ICA component is substituted with a predetermined number of moles of the first ICA component while maintaining the sticking temperature of the polyolefin, thereby increasing a dew point approach temperature of the ICA, wherein the dew point approach temperature is an operating temperature of the reactor minus a dew point of the condensed recycle stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The following figures are included to illustrate certain aspects of the embodiments, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, as will occur to those skilled in the art and having the benefit of this disclosure.

[0008] Fig. 1A is a schematic diagram of a polymerization system that can be monitored and controlled in accordance with some of the embodiments described herein.

[0009] Fig. 1B is a block diagram of a control system that can be used to control the polymerization system in accordance with some of the embodiments described herein.

[0010] Fig. 2 is a plot of the sticking temperature of the polyethylene as a function of the ICA partial pressure when the ICA is either n-butane or isopentane.

CLAIMS

The invention claimed is:

1. A method comprising:

contacting in a fluidized bed gas phase reactor an olefin monomer with a catalyst system in the presence of an induced condensing agent (ICA) and optionally hydrogen to produce a polyolefin having a sticking temperature, wherein the ICA comprises a first ICA component and a second ICA component;

operating the fluidized bed gas phase reactor at an operating temperature lower than the sticking temperature of the polyolefin;

withdrawing a gas phase composition comprising at least some of the olefin, at least some of the ICA, and optionally at least some hydrogen;

condensing a portion of the ICA from the gas phase composition yielding a condensed ICA;

recycling at least a portion of the condensed ICA and at least a portion of the gas phase composition to the fluidized bed gas phase reactor; and

changing a mole percent of total reactor gas for each of the first and the second ICA components according to a first ICA to second ICA equivalency factor whereby one mole of the second ICA component is substituted with a predetermined number of moles of the first ICA component to cause a dew point approach temperature of the ICA to increase, which allows for an increase in a production rate of the polyolefin while maintaining the sticking temperature, wherein the dew point approach temperature is an operating temperature of the reactor minus a dew point of the condensed recycle stream.

2. The method of claim 1 further comprising:

contacting in the fluidized bed gas phase reactor the olefin monomer and at least one comonomer with the catalyst system in the presence of the ICA and optionally hydrogen to produce the polyolefin.

3. The method of claim 2, wherein the olefin monomer is ethylene and the at least one comonomer is selected from the group consisting of propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 4-methylpent-1-ene, 1-decene, 1-dodecene, 1-hexadecene, 1,3-hexadiene, 1,4-hexadiene, cyclopentadiene, dicyclopentadiene, 4-vinylcyclohex-1-ene, methyloctadiene, 1-methyl-1,6-octadiene, 7-methyl-1,6-octadiene, 1,5-cyclooctadiene,

norbornadiene, ethylidene norbornene, 5-vinylidene-2-norbornene, 5-vinyl-2-norbornene, isoprene, styrene, butadiene, isobutylene, chloroprene, acrylonitrile, and a cyclic olefin.

4. The method of claim 1, wherein the first ICA is n-butane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 1.5 to 3.5; or

wherein the first ICA is n-pentane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 0.8 to 1.2; or

wherein the first ICA is hexane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 0.2 to 0.4.

5. A method comprising:

contacting in a fluidized bed gas phase reactor an olefin monomer with a catalyst system in the presence of an induced condensing agent (ICA) and optionally hydrogen to produce a polyolefin having a sticking temperature, wherein the ICA comprises a first ICA component and a second ICA component;

operating the fluidized bed gas phase reactor at an operating temperature lower than the sticking temperature of the polyolefin;

withdrawing a gas phase composition comprising at least some of the olefin, at least some of the ICA, and optionally at least some hydrogen;

condensing a portion of the ICA from the gas phase composition yielding a condensed ICA;

recycling at least a portion of the condensed ICA and at least a portion of the gas phase composition to the fluidized bed gas phase reactor; and

changing a mole percent of total reactor gas for each of the first and the second ICA components according to a first ICA component to second ICA component equivalency factor whereby one mole of the second ICA component is substituted with a predetermined number of moles of the first ICA component to increase the dew point approach temperature and the production rate of the polyolefin while maintaining the sticking temperature of the polyolefin.

6. The method of claim 5 further comprising:

contacting in the fluidized bed gas phase reactor the olefin monomer and at least one comonomer with the catalyst system in the presence of the ICA and optionally hydrogen to produce the polyolefin.

7. The method of claim 5, wherein the first ICA is n-butane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 1.5 to 3.5; or

wherein the first ICA is n-pentane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 0.8 to 1.2; or

wherein the first ICA is hexane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 0.2 to 0.4.

8. A method comprising:

contacting in a fluidized bed gas phase reactor an olefin monomer with a catalyst system in the presence of an induced condensing agent (ICA) and optionally hydrogen to produce a polyolefin having a sticking temperature, wherein the ICA comprises a first ICA component and a second ICA component;

operating the fluidized bed gas phase reactor at an operating temperature lower than the sticking temperature of the polyolefin;

withdrawing a gas phase composition comprising at least some of the olefin, at least some of the ICA, and optionally at least some hydrogen;

condensing a portion of the ICA from the gas phase composition yielding a condensed ICA;

recycling at least a portion of the condensed ICA and at least a portion of the gas phase composition to the fluidized bed gas phase reactor; and

increasing a polyolefin production rate by changing a mole percent of total reactor gas for each of the first and the second ICA components according to a first ICA component to second ICA component equivalency factor whereby one mole of the second ICA component is substituted with a predetermined number of moles of the first ICA component while maintaining the sticking temperature of the polyolefin, thereby increasing a dew point approach temperature of the ICA, wherein the dew point approach temperature is an operating temperature of the reactor minus a dew point of the condensed recycle stream.

9. The method of claim 8 further comprising:

contacting in the fluidized bed gas phase reactor the olefin monomer and at least one comonomer with the catalyst system in the presence of the ICA and optionally hydrogen to produce the polyolefin.

10. The method of claim 8, wherein the first ICA is n-butane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 1.5 to 3.5; or

wherein the first ICA is n-pentane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 0.8 to 1.2; or

wherein the first ICA is hexane, the second ICA is isopentane, and the first ICA to second ICA equivalency factor is 0.2 to 0.4.