

DESCRIPTION

POLYMERIZATION REACTION APPARATUS AND
METHOD OF PRODUCING METHACRYLATE POLYMER BY USING THE SAME

5

TECHNICAL FIELD

[0001]

The present invention relates to a polymerization reaction apparatus used for producing a methacrylate-based polymer and a method of producing the methacrylate-based polymer by using the apparatus.

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BACKGROUND OF THE INVENTION

[0002]

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The preparation of a methacrylate-based polymer uses a continuous bulk polymerization method or a continuous solution polymerization method wherein a monomer, a polymerization initiator and the like are continuously introduced into a polymerization reaction vessel. Among the above, in the continuous bulk polymerization method, the polymerization reaction is performed in a homogenous phase without using a solvent and a dispersant, so that an advantage of a methacrylate polymer containing little impurities is obtained. However, since a viscosity of a reaction system is very high, it is required to pay

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attention to removing heat from the reaction system,
controlling the polymerization temperature and the like.
On the other hand, the continuous solution polymerization
method has advantages that a methacrylate polymer
5 containing little impurities is obtained and that the
problem associated with the continuous bulk polymerization
method is reduced due to a low viscosity of the reaction
system, but has the problem that the productivity is
decreased due to use of solvents.

10 [0003]

JP 7-126308 A discloses a method for producing the
methacrylate-based polymer by using a continuous bulk
polymerization method, which comprises carrying out a
polymerization reaction by using a completely mixing type
15 reacting vessel under the condition that the reaction
vessel is fully filled with a liquid medium so that the
reaction vessel has substantially no gaseous phase.

[Prior Art Document]

20 [0004]

[Patent document 1] JP 7-126308 A

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

25 [0005]

In the polymerization reaction apparatus used for the production of such methacrylate polymer, a stirring blade fixed to a shaft is located inside of the polymerization reaction vessel, thereby a raw material mixture containing the monomer and the polymerization initiator is stirred and the polymerization reaction is performed. One end of the shaft is attached to a drive unit, thereby a rotational driving force is transmitted from the drive unit to the shaft so that the shaft and a stirring blade are rotated. The shaft is supported by a shaft seal bearing part arranged between the drive unit and the polymerization reaction vessel. In this shaft seal bearing part, there is provided a shaft seal portion around the shaft so that the reaction mixture in the polymerization reaction vessel does not reach the drive unit. Various types of a seal structure for forming the shaft seal portion are known. A mechanical seal is known as one of typical seal structures.

[0006]

The mechanical seal uses a mechanical seal liquid as a lubricating liquid for seal surfaces. There is the problem that, when a polymerization reaction apparatus comprising the mechanical seal is operated for a long period of time, a portion of the mechanical seal liquid leaks out from the shaft seal portion so that a reaction mixture and a produced methacrylate polymer have a possibility of being

contaminated. If the reaction mixture and the produced methacrylate polymer are contaminated, there are problems that transparency of the methacrylate polymer decreases and that the methacrylate polymer colors in a shaping process of the polymer.

[0007]

The present invention has been made in light of the aforementioned problems of the prior art. Objects of the present invention are to provide a polymerization reaction apparatus and also to provide a method of producing the methacrylate polymer by using the polymerization reaction apparatus, wherein the apparatus and the method can prevent contaminations of a reaction mixture and a produced methacrylate polymer.

MEANS FOR SOLVING THE PROBLEMS

[0008]

In order to achieve the objects stated above, the present invention provides a polymerization reaction apparatus for producing a methacrylate polymer, comprising: a polymerization reaction vessel for performing a polymerization reaction of a raw material mixture containing a monomer component which comprises a methacrylate monomer as a main component; a rotatable shaft;

a stirring blade fixed to the rotatable shaft, which stirs the raw material mixture within the polymerization reaction vessel; and

a shaft seal bearing part which supports the shaft,

5 wherein a shaft seal portion in the shaft seal bearing part comprises a mechanical seal which contains at least one mechanical seal liquid selected from the group consisting of adipate esters, phthalate esters, diisobutyrate esters and acetylated glycerides.

10 [0009]

Even if the mechanical seal liquid, which is at least one selected from the group consisting of adipate esters, phthalate esters, diisobutyrate esters and acetylated glycerides, is incorporated into the reaction mixture, the
15 mechanical seal liquid has the advantageous properties of scarcely giving the adverse effects causing the transparency decrease of the methacrylate polymer and the easy coloration in the shaping process of the methacrylate polymer. Thus, since the shaft seal portion comprises the
20 mechanical seal, and the mechanical seal liquid is selected from the group consisting of adipate esters, phthalate esters, diisobutyrate esters and acetylated glycerides, the present invention can prevent the contaminations of the reaction mixture and the produced methacrylate polymer,
25 even if the mechanical seal liquid leaks out into the

polymerization reaction vessel during continuous operation for a long period of time. The above-mentioned polymerization reaction apparatus can effectively produce the methacrylate polymer having the suppressed contamination, even if a production operation is continuously conducted for a long period of time.

[0010]

The present invention also provides a method of producing a methacrylate polymer by using the above-mentioned polymerization reaction apparatus, comprising a step of:

continuously feeding, into the polymerization reaction vessel, the raw material mixture containing the monomer component which comprises the methacrylate monomer as a main component, to carry out the polymerization reaction.

[0011]

The method of producing the methacrylate polymer according to the present invention can prevent contaminations of a reaction mixture and a produced methacrylate polymer, since the polymerization reaction apparatus of the present invention is used. The polymerization reaction apparatus of the present invention can effectively produce the methacrylate polymer with suppressing the contaminations, even if a production operation is continuously conducted for a long period of

time.

EFFECTS OF THE INVENTION

[0012]

5 According to the present invention, provided are the
polymerization reaction apparatus and the method of
producing the methacrylate polymer by using the
polymerization reaction apparatus, which prevent the
contaminations of the reaction mixture and the produced
10 methacrylate polymer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

15 Fig. 1 is a schematic structural diagram of a
preferable embodiment of a polymerization reaction
apparatus according to the present invention.

Fig. 2 is a partial cross-sectional view of a shaft
seal bearing part of the polymerization reaction apparatus
according to the present invention.

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EXPLANATION OF REFERENCE NUMERALS

10: Polymerization reaction vessel,
12: Raw material feeding port,
14: Polymer composition discharge port,
25 16: Jacket,

20: Shaft,
22: Stirring blade,
30: Shaft seal bearing part,
32: Shaft seal portion,
5 38: Lip seal,
100: Polymerization reaction apparatus,
101: Initiator preparation vessel,
102: Monomer preparation vessel.

10 EXPLANATION OF EMBODIMENTS

[0014]

Hereafter, preferred embodiments of the present invention will be described in detail with reference to the drawings. In each of the drawings, the same or the
15 corresponding element is denoted with the same number, for which redundant description may be omitted. Moreover, dimensional ratios are not limited to the dimensional ratios shown in the drawings.

[0015]

20 Fig. 1 is a schematic structural diagram of a preferable embodiment of a polymerization reaction apparatus according to the present invention. As shown in Fig. 1, the polymerization reaction apparatus 100 is equipped with a polymerization reaction vessel 10 in which
25 the polymerization reaction of the raw material mixture

containing the methacrylate monomer as a main component is performed, a rotatable shaft 20, a stirring blade 22 which is fixed to the rotatable shaft 20, which stirs the raw material mixture within the polymerization reaction vessel 10, and a shaft seal bearing part 30 which supports the shaft 20. Moreover, the polymerization reaction apparatus 100 is equipped with a raw material feeding port 12 for feeding the raw material to the polymerization reaction vessel 10 and a polymer composition discharge port 14 for discharging, out of the polymerization reaction vessel 10, a liquid (syrupe) polymer composition containing the methacrylate polymer produced by the polymerization reaction. Furthermore, the polymerization reaction apparatus 100 is equipped with a jacket 16 for adjusting a temperature of an external wall of the polymerization reaction vessel 10.

[0016]

Fig. 2 is a partial cross-sectional view of a shaft seal bearing part of the polymerization reaction apparatus according to the present invention. As shown in Fig. 2, the shaft seal bearing part 30 has a shaft seal portion 32, and the shaft seal portion 32 is formed by a mechanical seal. In this embodiment, a lip seal is provided between the shaft seal portion 32 and the polymerization reaction vessel 10. The lip seal prevents the reaction mixture in

the polymerization reaction vessel from reaching the shaft seal portion 32. The lip seal is preferably made from a PTFE (polytetrafluoroethylene). Use of the lip seal 38 made from PTFE contributes to increase chemical resistance to monomer and suitably maintains good sealing property even if a vibration of the shaft occurs. Thus, even when the apparatus is continuously operated for a long period of time, the sealing effect can be sustained. Moreover, there is provided a drive unit (not shown) for rotationally driving the shaft 20 above the shaft seal portion 32 (which is in the direction opposite to the polymerization reaction vessel 10).

[0017]

Since the type of the mechanical seal forming the shaft seal portion 32 is not particularly limited, any types of mechanical seals may be selected from those which are well known to the skilled person. For example, as shown in Fig. 2, the mechanical seal has a rotary ring 32a which is fixed on a side of the shaft 20 and a stationary ring 32b which is fixed on a side of a main body (a casing) of the shaft seal bearing part and is constructed so that the rotary ring 32a and the stationary ring 32b are pressed against each other at a constant pressure exerted by a spring (not shown). In addition, in order to reduce a friction between the contact surfaces of the rotary ring

32a and the stationary ring 32b, an inside of the mechanical seal is filled up with a mechanical seal liquid 32c. In Fig. 2, there is shown a construction of a pair of mechanical seals each having the combination of the rotary ring 32a and the stationary ring 32b, that is, a construction of a double mechanical seal. The mechanical seal liquid 32c is generally continuously fed through an inlet for the mechanical seal liquid (not shown) by a pump and the like, and continuously discharged through an outlet for the mechanical seal liquid (not shown). It is preferable that the mechanical seal liquid is circularly supplied. A filling pressure is suitably set depending on the size of the polymerization reaction apparatus 100 and the polymerization conditions and the like and is set higher than the pressure in the polymerization reaction vessel 10. The filling pressure is adjusted so that a good seal functionality and a good product quality of the finally resultant methacrylate polymer can be maintained, since too high filling pressure leaks a large amount of the mechanical seal liquid from the shaft seal portion so that a good seal functionality cannot be exhibited and the finally resultant polymer may have an inferior product quality due to incorporation of the excessively leaked mechanical seal liquid into a polymer composition.

The mechanical seal liquid 32c is at least one selected from the group consisting of adipate esters, phthalate esters, diisobutyrate esters and acetylated glycerides. The adipate esters include, for example, bis(2-ethylhexyl) adipate, diisononyl adipate and diisodecyl adipate. The phthalic esters include, for example, bis(2-ethylhexyl) phthalate, diisononyl phthalate and diisodecyl phthalate. The diisobutyrate esters include, for example, 2,2,4-trimethyl-1,3-pentanediol diisobutyrate.

The acetylated glycerides include, for example, glycerol diacetomonolaurate, glycerol diacetomonostearate, glycerol diacetomonooleate, glycerol diacetomonolinolate, glycerol diacetomono-12-hydroxy stearate, glycerol diacetomonomyristate, glycerol diacetomonopalmitate, glycerol diacetomonolaurate, glycerol monoacetomonostearate, glycerol monoacetomonomyristate, glycerol monoacetomonopalmitate, glycerol monoacetomonoricinolate, glycerol monoacetomono-12-hydroxystearate, glycerol monoacetomonobehenate, glycerol monoacetomonooleate, glycerol monoacetomonolaurate, glycerol monoacetodioleate, glycerol monoacetodiricinolate, glycerol monoacetodicaprylate, and glycerol monoacetodilaurate, glycerol monoacetodistearate. Among them, adipate esters and diisobutyrate esters are preferable and adipate eaters are particularly preferable. Adipate esters, phthalate

esters, diisobutyrate esters and acetylated glycerides have the advantages that they do not facilitate the polymerization reaction of the monomer component containing the methacrylate monomer as a main component and that they
5 scarcely cause adverse affects such as coloration of the resultant methacrylate polymer, even if they are mixed with the reaction mixture.

[0019]

The materials for the rotary ring 32a and the
10 stationary ring 32b are not particularly limited, and any well known material can be used. The material for the rotary ring 32a and the stationary ring 32b includes, for example, carbon, silicon carbide, cemented carbide, and chrome oxide coating.

15 [0020]

The polymerization reaction apparatus 100 of this embodiment is a continuous polymerizing apparatus, which is used for a continuous bulk polymerization method or a continuous solution polymerization method, wherein the
20 polymerization reaction vessel 10 can form substantially complete mixing state within the reaction vessel by the stirring blade 22. A shape of the stirring blade 22 may be Max blend wings (manufactured by Sumitomo Heavy Industries, Ltd.), paddle wings, double helical ribbon wings, MIG wings,
25 full zone wings (manufactured by Shinko Pantec Co., Ltd.)

and the like, but it is not particularly limited thereto. In addition, it is preferable to install one or more baffles in the polymerization reaction vessel 10 in order to improve the stirring effect.

5 [0021]

The higher stirring effect is preferable with regard to the polymerization reaction apparatus 100. However, the application of an excessive stirring power is not so preferable, since excess heat quantity is provided. Therefore, the stirring power is preferably in the range from 0.5 to 20 kW/m³, more preferably in the range from 1 to 15 kW/m³. It is preferable to increase the stirring power, as the viscosity of the content liquid, that is, the content ratio of the methacrylate polymer in the liquid increases.

15 [0022]

Preferably, the inside of the polymerization reaction vessel 10 is in the liquid-full condition that a gaseous phase is substantially absent. The liquid-full condition of the polymerization reaction vessel prevents the methacrylate polymer from forming at or from adhering to the inside wall of the vessel on the gaseous phase and the gas-liquid interface, so that the possible quantity degradation of the product caused by mixing of the polymer prepared at the inside wall may be avoided. In addition,

the whole volume of the polymerization reaction vessel 10 can be effectively used, so that the productivity can be improved.

[0023]

5 In order to put the polymerization reaction vessel 10 into the liquid-full condition, it is the simplest way to locate an outlet for the polymer composition after the polymerization reaction (a polymer composition discharge port 14) at the uppermost part of the reaction vessel 10 as shown in Fig. 1. In this case, it is preferable that a supply port 12 for the raw material (an initiator composition and a monomer composition) is located at the lower part of the polymerization reaction vessel 10 as shown in Fig. 1. In addition, it is desirable to prevent a gas of the monomer component from generating in the polymerization reaction vessel 10. To this end, it is preferable to make the pressure in the polymerization reaction vessel 10 to exceed a vapor pressure of the reaction mixture at the temperature of the reaction vessel 10. This pressure is generally in the range from about 1.0 to about 2.0 MPa in terms of a gage pressure.

[0024]

 Moreover, it is preferable to make the inside of the polymerization reaction vessel 10 to be an adiabatic state that heat cannot substantially enter from and exit into

outside of the vessel. That is, it is preferable to make the temperature in the reaction vessel and the temperature of the external wall surface of the reaction vessel to be almost the same temperature. Specifically, said same
5 temperature can be achieved by providing a jacket 16 at the external wall surface of the reaction vessel, thereby controlling the temperature of the external wall surface thereof so as to follow the internal temperature of the reaction vessel using a heat medium such as steam or other
10 heat medium, for example, as shown in Fig. 1.

[0025]

The jacket 16 covers substantially a whole external surface of the polymerization reaction vessel 10 and can properly heat or keep the temperature of the reaction
15 vessel 10 by introducing a heat medium such as steam, hot water and an organic heating medium into the jacket 16 through a heat medium supply path (not shown). The temperature of the jacket 16 can be suitably adjusted by the temperature or the pressure of the supplied heat medium.
20 The heat medium introduced into the jacket 16 is discharged through a heat medium discharge path (not shown).

[0026]

The provision of the adiabatic state of the reaction vessel 10 is to prevent the methacrylate polymer from
25 adhering to the inside wall in the reaction vessel and to

stabilize the polymerization reaction, thereby giving a self-controlled property for suppressing a possible runaway reaction. The setting of the internal temperature of the reaction vessel to a temperature which is too higher than
5 that of the content liquid is not preferable, since an excess heat is added to the inside of the reaction vessel. Preferably, a temperature difference between the reaction vessel and the external wall surface of the reaction vessel is as small as possible and the temperature difference may
10 be practically adjusted within the degree of instability of the range $\pm 5^{\circ}\text{C}$.

[0027]

In this embodiment, the heat generated within the polymerization reaction vessel 10, that is, the heat of
15 polymerization and the heat of stirring are preferably balanced with the quantity of heat taken away by the (syrupe) liquid polymer composition discharged from the polymerization reaction vessel 10. The quantity of heat taken away by the polymer composition is determined by the
20 amount of the polymer composition, the specific heats and the temperatures (polymerization temperature).

[0028]

The polymerization temperature is preferably in the range from about 120 to 180°C , more preferably in the range
25 from about 130°C to about 180°C depending on the type of

radical polymerization initiator used. When the polymerization temperature is too high, there is the tendency that the syndiotacticity of the obtained methacrylate polymer becomes low, the amount of generated oligomer increases, and the heat resistance of a resultant resin becomes low.

[0029]

The mean residence time of the raw material mixture within the polymerization reaction vessel 10 is preferably in the range from 15 minutes to 2 hours, more preferably in the range from 20 minutes to 1.5 hours. When the residence time is longer than required, there arises a tendency that the production of oligomer such as dimers and trimers increases so that a heat-resistance property of the product decreases. The mean residence time can be adjusted by changing a supply amount of the monomer per unit time.

[0030]

Supply of the raw material into the polymerization reaction vessel 10 may be performed by feeding the polymerization initiator composition containing the radical polymerization initiator from an initiator supply conduit 51 and the monomer composition containing the monomer component comprising the methacrylate monomer as a main component from a monomer supply conduit 52, separately from the feeding port 12;

by feeding the mixture of the initiator composition and the monomer composition from the feeding port 12 by merging the initiator supply conduit 51 between an initiator supply pump 53 and the feeding port 12 with the monomer supply conduit 52 between a monomer supply pump 54 and the feeding port 12; or

by feeding each of the initiator composition and the monomer composition from each corresponding feeding port by forming a feeding port different from the feeding port 12 (not shown). The initiator composition contains, for example, a mixture of a radical polymerization initiator, a monomer component containing the methacrylate monomer as a main component and a chain transfer agent, and the monomer composition contains, for example, a mixture of a monomer component containing the methacrylate monomer as a main component and a chain transfer agent.

[0031]

The initiator composition is prepared in the initiator preparation vessel 101. The prepared initiator composition is continuously supplied to the polymerization reaction vessel 10 by the initiator supply pump 53 through the initiator supply conduit 51 which connects the initiator preparation vessel 101 with the polymerization reaction vessel 10, as shown in Fig. 1. On the other hand, the monomer composition is prepared in the monomer preparation

vessel 102. The prepared monomer composition is continuously supplied to the polymerization reaction vessel 10 by the monomer supply pump 54 through the monomer supply conduit 52 which connects the monomer preparation vessel 102 with the polymerization reaction vessel 10 as shown in Fig. 1.

[0032]

As the initiator preparation vessel 101 and the monomer preparation vessel 102 which are used in this embodiment, a preparation vessel equipped with a stirring device which is similar to the polymerization reaction vessel 10 may be used. In the initiator preparation vessel 101, a radical polymerization initiator is thoroughly dissolved in the monomer component to give an initiator liquid. The temperature in the initiator preparation vessel 101 is maintained at a temperature at which the polymerization reaction does not proceed, preferably maintained at -20°C to 10°C . On the other hand, the temperature in the monomer preparation vessel 102 is maintained at a temperature at which the monomer component does not volatilize, preferably maintained at -20°C to 10°C .

[0033]

The initiator supply pump 53 and the monomer supply pump 54 are not particularly limited, and are preferably a pump which can set the supply flow rates of the initiator

composition and the monomer composition to the polymerization reaction vessel 10 at a constant rate. Specifically, it is preferable to use a multiple reciprocating pump, more preferably a nonpulsatile controlled-volume type pump such as a twin nonpulsatile controlled-volume type pump and a triple nonpulsatile controlled-volume type pump.

[0034]

Heating/cooling devices may be connected with the initiator supply conduit 51 and the monomer supply conduit 52, which connect the initiator preparation vessel 101 and the monomer preparation vessel 102 with the polymerization reaction vessel 10, thereby adjusting the temperature of the raw material which is fed to the polymerization reaction vessel 10.

[0035]

The supply rate of the initiator composition from the initiator preparation vessel 101 to the polymerization reaction vessel 10, which varies depending on the capacity of the polymerization reaction vessel 10, is preferably in the range from 0.1 to 10 kg/hr, more preferably in the range from 0.5 to 5 kg/hr, in the case that the capacity of the polymerization reaction vessel 10 is 10 L. The supply rate of the monomer composition from the monomer preparation vessel 102 to the polymerization reaction

vessel 10, which varies depending on the capacity of the polymerization reaction vessel 10, is preferably in the range from 4 to 40 kg/hr, more preferably in the range from 10 to 30 kg/hr in the case that the capacity of the polymerization reaction vessel 10 is 10 L.

[0036]

In order to avoid the influence due to dissolved oxygen during the preparation of the monomer, it is common to carry out bubbling of an inert gas into the monomer preparation vessel 102 or to deaerate under reduced pressure to remove dissolved oxygen. In this embodiment, it is not necessary to strictly remove the dissolved oxygen and the polymerization reaction can be performed in the presence of the dissolved oxygen in about 1.5 ppm to 3 ppm.

In the case that the obtained methacrylate polymer is used for the material of optical apparatus, it is particularly desirable to filtrate the monomer composition with a filter having pores corresponding to a desired size in order to remove impurities during feeding the prepared monomer composition to the polymerization reaction vessel 10.

[0037]

The methacrylate polymer produced by the polymerization reaction using the polymerization reaction apparatus 100 is removed through the polymer composition discharge port 14 of the polymerization reaction vessel 10

as a (syrupy) liquid polymer composition, transferred via a polymer composition lead-out passage 55 and recovered. Since the polymer composition contains unreacted monomer component, volatile substances mainly containing the unreacted monomer component are separated by evaporation by heating the polymer composition as necessary. As the transfer procedure of the above polymer composition, the procedure disclosed in JP 4-48802 B is suitable. As the procedure for the separation by evaporation of the volatile matters, the procedures using a vented extruder is known, for example, the procedures disclosed in JP 51-29914 B, JP 52-17555 B, JP 1-53682 B, JP 62-89710 A and JP 3-49925 A are suitable.

[0038]

The polymerization reaction vessel 10 used for the present invention is preferably a completely mixing type reacting vessel, a polymerization (conversion) rate of the monomer component to the methacrylate polymer within the reaction vessel generally corresponds to the content ratio of the polymer in the polymer composition. In the present invention, although the rate of polymerization is not particularly limited, it is usually set in the range from 40 to 70% by mass. As the rate of polymerization becomes higher, the productivity of the methacrylate polymer increases, but higher viscosity of the reaction system is

resulted to require a large extent of stirring power. As the rate of polymerization becomes lower, the productivity of the methacrylate polymer decreases so that the burden for recovering the unreacted monomer component is increased.

5 [0039]

The unreacted monomer component which is separated and collected from the polymer composition are stored in a monomer recovery tank and may be supplied to the polymerization reaction by feeding to the monomer preparation vessel 102 as necessary. It is preferable to store the monomer component under the condition that a the concentration of the polymerization inhibitor is from 2 ppm to 8 ppm and the concentration of oxygen in the gaseous phase is from 2% to 8% by volume so as not to proceed the polymerization reaction during storing in the monomer recovery tank. It is preferable to store in a cooled condition, specifically, at a temperature, for example, around from about 0°C to about 5°C.

15 [0040]

20 In the present invention, the monomer, the radical polymerization initiator and the chain transfer agent are selected depending on the polymer to be produced. Each of the components will be explained hereinafter in detail.

[0041]

25 The monomer component containing the methacrylate

monomer as a main component is a methacrylate monomer alone, or a mixture of a methacrylate monomer and another monomer copolymerizable with the methacrylate monomer. When the other monomer other than methacrylate monomer is used, the content of methacrylate monomer is preferably at least 50% by mass, more preferably at least 75% by mass based on a total of monomers.

[0042]

The methacrylate monomer is not particularly limited, and includes, for example, an alkyl methacrylate (wherein the alkyl group has 1 to 4 carbon atoms). The alkyl group in the alkyl methacrylate (wherein the alkyl group has 1 to 4 carbon atoms) includes, for example, methyl, ethyl, n-propyl, isopropyl, n-butyl and t-butyl. Methyl methacrylate is preferable among the alkyl methacrylate. The methacrylate monomer may be used alone or in combination of at least two. When at least two methacrylate monomers are used in combination, the monomer component containing the methacrylate monomer as a main component is a mixture of at least two methacrylate monomers, or a mixture of at least two methacrylate monomers and another monomer copolymerizable with the methacrylate monomers. When at least two methacrylate monomers are mixed with the other copolymerizable monomer, the total content of at least two methacrylate monomers is

preferably at least 50% by mass, more preferably at least 75% by mass based on a total of monomer components.

[0043]

The other monomer used together with the methacrylate monomer includes another vinyl monomer copolymerizable with the methacrylate monomer. The other vinyl monomer include, for example, an alkyl acrylate ester having an alkyl group containing 1 to 18 carbon atoms, such as methyl acrylate, ethyl acrylate, n-propyl acrylate, n-butyl acrylate, 2-ethylhexyl acrylate, dodecyl acrylate and stearyl acrylate; an unsaturated carboxylic acid or anhydride thereof such as acrylic acid, methacrylic acid, maleic acid, itaconic acid, maleic anhydride and itaconic acid anhydride; a monomer containing a hydroxyl group such as 2-hydroxyethyl acrylate, 2-hydroxypropyl acrylate, monoglycerol acrylate, 2-hydroxyethyl methacrylate, 2-hydroxypropyl methacrylate and monoglycerol methacrylate; a monomer containing nitrogen, such as acrylamide, methacrylamide, acrylonitrile, methacrylonitrile, diacetone acrylamide and dimethylaminoethyl methacrylate; a monomer containing an epoxy group such as allyl glycidyl ether, glycidyl acrylate and glycidyl methacrylate; and a styrene monomer such as styrene and alpha-methylstyrene.

[0044]

In the present invention, the polymerization initiator

supplied to the reaction vessel includes, for example, a radical polymerization initiator. The radical polymerization initiator includes, for example, azo compounds such as azobisisobutyronitrile, azobisdimethylvaleronitrile, azobiscyclohexanenitrile, 1,1'-azobis-(1-acetoxy-1-phenylethane), dimethyl 2,2'-azobisisobutyrate, 4,4'-azobis-4-cyanovaleric acid; organic peroxides such as benzoyl peroxide, lauroyl peroxide, acetyl peroxide, caprylyl peroxide, 2,4-dichloro benzoyl peroxide, isobutyl peroxide, acetyl cyclohexyl sulfonyl peroxide, t-butyl peroxy-pivalate, t-butyl peroxy neodecanoate, t-butyl peroxy neoheptanoate, t-butylperoxy-2-ethyl hexanoate, 1,1-di(t-butylperoxy)cyclohexane, 1,1-di(t-butylperoxy)-3,3,5-trimethylcyclohexane, 1,1-di(t-hexylperoxy)-3,3,5-trimethylcyclohexane, isopropyl peroxydicarbonate, isobutyl peroxydicarbonate, s-butyl peroxydicarbonate, n-butyl peroxydicarbonate, 2-ethylhexyl peroxydicarbonate, bis(4-t-butylcyclohexyl)peroxy dicarbonate, t-amyl peroxy-2-ethyl hexanoate, 1,1,3,3-tetramethylbutyl peroxyethylhexanoate, 1,1,2-trimethylpropyl peroxy-2-ethylhexanoate, t-butylperoxy isopropyl monocarbonate, t-amyl peroxyisopropyl monocarbonate, t-butylperoxy-2-ethylhexyl carbonate, t-butyl peroxyallyl carbonate, t-butyl peroxy isopropyl carbonate, 1,1,3,3-tetramethylbutyl peroxy isopropyl

monocarbonate, 1,1,2-trimethylpropyl peroxyisopropyl
monocarbonate, 1,1,3,3-tetramethylbutyl peroxyisononanoate,
1,1,2-trimethylpropylperoxy isononanoate and t-butyl
peroxybenzoate. The above radical polymerization initiator
5 can be used solely or as a mixture of two or more thereof.
[0045]

The amount of the radical polymerization initiator is
not particularly limited, and is typically in the range
from 0.001 to 1 part by mass based on 100 parts by mass of
10 the raw material monomer component. When two or more
radical polymerization initiators are used in a mixture,
the total amount thereof may be within the above range.
The polymerization initiator supplied to the reaction
vessel, which is not particularly limited in the present
15 invention, is selected depending on the types of the
methacrylate polymer to be produced and the raw material
monomer component to be used. For example, the radical
polymerization initiator preferably has a half-life of at
most 1 minute at the polymerization temperature. When the
20 half-life at the polymerization temperature is at most 1
minute, the reaction rate is suitable, thus the initiator
is suitable for the polymerization reaction in the
continuous polymerization apparatus. The relationship
between the temperature and the half-life of the radical
25 polymerization initiators are described in various articles

and the technical documents of manufacturing companies for every type of the radical polymerization initiator. In the present invention, the values described in the well-known product brochures available from Wako Pure Chem, Inc., or
5 Kayaku Akzo Corporation are used.

[0046]

In the present invention, a chain transfer agent can be added to the reaction vessel so as to adjust a molecular weight of the produced methacrylate polymer. The chain
10 transfer agent used may be any of a monofunctional chain transfer agent and a multifunctional chain transfer agent. Specifically, the chain transfer agent includes, for example, alkyl mercaptans such as propyl mercaptan, butyl mercaptan, hexyl mercaptan, octyl mercaptan, 2-ethylhexyl
15 mercaptan and dodecyl mercaptan; aromatic mercaptans such as phenyl mercaptan and thiocresol; mercaptans having at most 18 carbon atoms such as ethylene thioglycol; polyhydric alcohols such as ethylene glycol, neopentyl glycol, trimethylolpropane, pentaerythritol,
20 dipentaerythritol, tripentaerythritol and sorbitol; and an ester produced by esterifying a hydroxyl group with thioglycolic acid or 3-mercaptopropionic acid, 1,4-dihydronaphthalene, 1,4,5,8-tetrahydronaphthalene, beta-terpinene, terpinolene, 1,4-cyclohexadiene and hydrogen
25 sulfide. The above may be used alone or in combination of

two or more.

[0047]

5 The amount of the chain transfer agent is not particularly limited, since it varies depending on the types of the chain transfer agent to be used. For example, it is typically in the range from 0.01 to 3 parts by mass, preferably in the range from 0.05 to 1 part by mass based on 100 parts by mass of the monomer component, when mercaptans are used. The amount of the above range is
10 preferable, since the mechanical property of the methacrylate polymer is not spoiled. When two or more chain transfer agents are used in combination, the total usage amount may be within the above range.

[0048]

15 In the present invention, any of a bulk polymerization method without using a solvent or a solution polymerization method with using a solvent may be used as the polymerization method for the methacrylate polymer. The bulk polymerization is particularly preferable.

20 [0049]

 When the polymerization is performed by a continuous solution polymerization method, the polymerization proceeds in the same manner as the continuous bulk polymerization method except that a solvent is used. The solvent to be
25 used for the polymerization reaction, which is suitably

selected depending on the monomer component for the continuous solution polymerization method, and which is not particularly limited, includes, for example, toluene, xylene, ethylbenzene, methyl isobutyl ketone, methyl alcohol, ethyl alcohol, octane, decane, cyclohexane, decalin, butyl acetate and pentyl acetate. Among them, toluene, methanol, ethylbenzene and butyl acetate are preferable. The solvent can be added to one or both of the initiator composition and the monomer composition, or can be directly introduced to the polymerization reaction vessel 10. Although the ratio of the solvent is not particularly limited, it is preferably in the range from 5 to 30% by mass, more preferably in the range from 1 to 20% by mass based on the total raw material mixture.

[0050]

The above-mentioned polymerization reaction apparatus and the above-mentioned method of producing the methacrylate polymer by using the polymerization reaction apparatus can effectively produce the methacrylate polymer having the suppressed contamination, even if a production operation is continuously conducted for a long period of time.

[0051]

The above-mentioned polymerization reaction apparatus and the above-mentioned method of producing the

methacrylate polymer by using the polymerization reaction apparatus can be suitably used for producing the methacrylate polymer obtained by polymerizing the monomer mixture containing methyl methacrylate as a main component, among methacrylate polymers.

[0052]

Since the methacrylate polymer obtained by the above polymerization method has excellent transparency and weather resistance, they can be conveniently used in various fields including illumination, signboards and vehicles. The methacrylate polymer can be suitably used for, especially, materials for an optical disc substrate; optical device materials such as an Fresnel lens, a lenticular lens, a light guide plate used for a back light system of a liquid crystal display, a diffuser plate and a protecting front face plate of a liquid crystal display; and vehicles components such as a tail-lamp covering, a head-lamp covering, a visor and a meter panel.

CLAIMS

1. A polymerization reaction apparatus for producing a methacrylate polymer, comprising:

- 5 a polymerization reaction vessel for performing a polymerization reaction of a raw material mixture containing a monomer component which comprises a methacrylate monomer as a main component;
- a rotatable shaft;
- 10 a stirring blade fixed to the rotatable shaft, which stirs the raw material mixture within the polymerization reaction vessel; and
- a shaft seal bearing part which supports the shaft,
- wherein a shaft seal portion in the shaft seal bearing part
- 15 comprises a mechanical seal which contains at least one mechanical seal liquid selected from the group consisting of adipate esters, phthalate esters, diisobutyrate esters and acetylated glycerides.

- 20 2. A method of producing a methacrylate polymer by using the polymerization reaction apparatus according to claim 1, comprising a step of:
- continuously feeding, into the polymerization reaction vessel, the raw material mixture containing the monomer
- 25 component which comprises the methacrylate monomer as a

main component, to carry out the polymerization reaction.