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Process for continuous production of polycarbonates by the melt transesterification process

5 The present invention relates to a process for continuous production of polycarbonates from oligocarbonates by the melt transesterification process using a special reactor.

Oligocarbonates are produced by transesterification of diaryl carbonates with diphenols in the presence of catalysts. Processes for the production of polycarbonates are described in the applications DE-A-1 031 512, US-3 022 272, 10 US-5 340 905, US-5 399 659, DE-A 4 312 390, US 5 912 318, US 5 932 683, US 5 912 289, WO 00/26 276 and EP-A 620 240 in which the production of the intermediate stages, the oligocarbonates, is illustrated. A process for producing oligocarbonates is described first hand in the German application No. 1 01 14 808.9. 15 Further details of the melt transesterification process in general are found in the literature (see for example Hermann Schnell, Chemistry and Physics of Polycarbonates, Polymer Reviews, Vol. 9, 1964, pages 44 to 51).

Various devices for the polycondensation of oligocarbonates are described. 20

A helical spiral for a horizontal cylinder or a horizontal reaction pipe which spreads and conveys the melt on the reactor wall is proposed in DE-A 1 495 730 (Farbenfabriken Bayer AG). A disadvantage is that, owing to gravitation, the upper housing walls are only partially wetted and products are therefore damaged. A stable 25 design of the spirals for large scale plant is very doubtful.

EP-A 0 711 597 (Hoechst Celanese Corporation and Hoechst AG) proposes a horizontal cylinder with a stirrer rotating therein without a centre line as a reactor device for polyester. The supporting connection elements are located on the external 30 periphery of the stirrer. A disadvantage here is the external supporting structure, as it may lead to film bridges which may form closed chambers with the films on the stirrer blades and then impair optimal removal of the cleaved monomer and other

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products. The effective treatment of higher viscosity melts is also affected as the ratio of film surface to melt volume is considerably reduced and impaired owing to the increasingly thick melt coatings.

5 EP-A 0 778 078 (Teijin Limited) describes a twin shaft reactor for polycondensation. Here the reaction chambers are narrow and production is difficult owing to the restricted play. Therefore, the overall dimensions are limited and are not suitable for high throughputs. Furthermore, energy is introduced via the drive and this leads to undesirable rises in temperature.

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US 5,932,683 (Asahi Kasei Kogyo Kabushiki Kaisha) describes a reactor device in which the oligocarbonate melt is distributed via a perforated disk onto a plurality of vertically attached wires and runs down them into the sump. In example 1, 50 wires 8 m in length are required for just 5 kg prepolymer per hour. It is clear that these are
15 very complex structures which are difficult to produce on a large scale. Nitrogen is used in addition to the vacuum to aid the progress of the reaction and subsequently has to be liberated from the phenol in complex operations.

US 5,767,224 (Bayer AG) proposes a reactor with kinematic self-cleaning for
20 polycondensation of oligocarbonates. This reactor is described in EP A 460 466, EP A 528 210 and EP A 638 354. For high throughputs in large-scale plant this construction is very expensive and, owing to the restricted play, limited in its overall size. Furthermore, energy is introduced by the drive and this leads to undesirable rises in temperature. As inappropriate average residence times are possible, basic
25 alkali, alkaline-earth and transition metal hydroxides, alkoxides, carbonates, acetates, boranates, phosphates and hydrides are used as catalysts in order to reduce the reaction times. However, these have an adverse effect on the quality of the polycarbonate formed.

30 WO-A 99/28 370 (Hitachi, Ltd.) describes a reactor or reactor device consisting of horizontal cylindrical containers which are equipped with single or twin shaft stirrers. They have good cascade characteristics and reduce the production costs

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compared with stirred tank cascades. A disadvantage is the external supporting structure in the single shaft stirrer, as it may lead to film bridges which may form closed chambers with the films on the stirrer blades and then impair optimal removal of the cleaved phenol and other products. The use of twin shaft stirrers is proposed
5 for higher viscosities. The single shaft stirrer forms excessively thick films at higher viscosities. As a result, the film surface or material exchange area is drastically reduced and the reactor does not operate effectively. In the reactor with twin shaft stirrers this deficiency is remedied by the mixing energy which is converted into kneading work. However, the drawback of a high ratio of surface area to volumetric
10 content still exists. Another disadvantage is the energy which is introduced by the kneading work and leads to undesirable rises in temperature.

The object of all reactor devices is to provide the residence time and surface or surface renewal required for progress of the reaction. Kneading work is necessary
15 for surface renewal, particularly at higher viscosities. The residence time required is substantially influenced by the use of catalysts and by the surface area or intensity of surface renewal over which evaporation of phenol and diaryl carbonate takes place.

In reactors with shorter residence times, an attempt is made to accelerate the reaction
20 by using basic alkali, alkaline-earth and transition metal hydroxides, alkoxides, carbonates, acetates, boronates, phosphates and hydrides as catalysts and optionally by elevated temperatures, and to bring about sufficient surface renewal, for example by intensive kneading work. However, the use of these catalysts does not have a favourable effect on the quality of the polycarbonate formed as they remain in the
25 product. Elevated temperatures in the presence of the above-mentioned transesterification catalysts are particularly disadvantageous to the colour of the product. The kneading work required may only be brought about by reinforced reactor constructions with high power input. Reactor devices of this type cannot be built in any size and this adversely affects economical throughput rates.

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The object was therefore to find a reactor design which, on the one hand, permits particularly good evaporation of phenol and optionally diaryl carbonate by creating

large melt surfaces, but, on the other hand, may also still be operated economically on a large scale.

The object has surprisingly been achieved by reactor devices which continuously
5 form free films under the influence of gravity and have a high film-forming rate. This is achieved with rotating perforated disks in the form of rings having a ratio of the total area of the ring to the area taken up by the webs between the holes of 2.2 to 6.5, preferably of 2.5 to 5. It has proved advantageous to allow the falling length of the films to increase with the viscosity. It is particularly advantageous to select the
10 equivalent hole diameter according to the formula $A = x(\eta^2/(\text{kg}^2\text{m}^{-5} \text{ s}^{-2}))^\square$. The equivalent hole diameter A is defined here as the diameter of a circle of identical area. The dimensionless numerical factor x may vary between 0.002 and 0.030, preferably between 0.004 and 0.016. The various values for x may be assumed simultaneously at various points in a reaction device with varying viscosity. η is the
15 kinematic melt viscosity in Pas.

The holes may be designed with various geometric shapes. Holes in the form of equilateral rotationally symmetrical n -angled polygons, which permit constant web widths of the circumscribing metal faces, and rectangles are preferred.

20 Different shapes may be used at the inner and outer rim of the annular disks in order to be able to form a circular rim. At high viscosities the equivalent hole diameter is so large that the inner and outer rim have to be divided by spokes, optionally subdivided even by a central ring. These holes are then delimited by the spokes or
25 spoke segments and ring segments.

All of the metal faces or webs surrounding the holes are advantageously square or rectangular in cross-section. By selecting suitable web widths, the ratio of the area carrying the melt when the annular disk emerges from the melt to the surrounding
30 hole may best be adapted to the melt viscosity and other properties of the melt. It has proven advantageous with an annular disk to select all the metal faces or webs surrounding the holes so as to have constant identical dimensions in cross-section.

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During production of different polycarbonates, various viscosity profiles should be expected in the reactor device. The perforated disks are to be provided in the above-mentioned relationship in the reactor and adapted to the viscosity trend in the reactor.

In principle, polycondensation of the oligocarbonate may be carried out in one reactor. However, it may be expedient to arrange two or more reactors in succession as the final molecular weight to be attained is determined by the reaction equilibrium which depends on the temperature, pressure and the terminal group contents of the polycarbonate. At insufficient pressures the monomers to be drawn off may scarcely be condensed or may not be condensed at all and this leads to expensive, over-size vacuum systems. However, the advantage of low pressures is that the reaction temperature which, in conjunction with the residence time, determines quality, may be reduced. The gas exposure of vacuum systems and the heat exposure of the product may be optimised by distribution between two reactors.

The pipelines between the apparatuses should be as short as possible and the curvatures of the pipes kept as low as possible. The external constraints of the plant construction should be taken into account in the process.

It has been found that a particularly preferred reactor device for polycondensation of oligocarbonates is a horizontal cylindrical container with a stirrer, as described in DE 44 47 422 C2 (Karl Fischer Industrieanlagen GmbH), column 1, line 63 to column 7, line 39. This reactor does not have the drawbacks of the above-described reactor devices and may be built for very high throughputs.

Of particular advantage is the extremely rigid construction and design of the cylinder supporting the perforated disks and forming the reactor shaft. The cylinder is also provided with apertures or holes, so the resulting vapours may escape unimpeded. The nature of the rotor mounting allows the reactor to be operated at various temperature zones and thus a temperature profile adapted to the progress of

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the reaction to be adjusted. The construction also limits entrainment of higher viscosity melts upon rotation of the rotor owing to the installation of stators which project between the disks. The ratio of melt surface to melt volume on the disk is optimised, particularly in the higher viscosity range, as a result of this measure.

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For optimal and therefore preferred use of the reactor device illustrated in DE 44 47 422 C2 for the production of polycarbonates, however, further modifications are required over the constructions illustrated in the above-mentioned application.

10 It may therefore happen that there is insufficient wetting of the rotating circular disk at the inlet to the reactor device at low viscosities. It has proven advantageous optionally to equip up to half the reactor length with scoop elements on the outer periphery in such a way that upon ascent of the scoop elements the circular disk is deliberately continuously washed with the low-viscosity melt.

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In the high viscosity range, toward the end of the reactor, excessive entrainment of product by the rotating circular disk may lead to undesirable conditions, such as interruptions in film-formation. A method of preventing this, which is improved over DE 44 47 422 C2, is to attach horizontal stripping beams to the stators at the
20 level of the sump. Convergence of the melt downstream of this beam in the direction of rotation of the rotor is therefore avoided. These beams may be attached directly to the housing or may be supported by optional additional beams which are also fastened to the wall of the reactor. A stripping beam and/or support beam design which promotes conveying may be selected for this purpose, as described in DE 44
25 47 422 C2. It is particularly significant and advantageous in aiding conveyance of the melt toward the reactor outlet.

For the progress of the reaction and the quality of product obtained it is advantageous to divide the reactor into a plurality of disk-shaped zones which may
30 be heated separately from one another, so a temperature profile adapted to the molecular weight trend may be followed. The heat exposure of the polycarbonate

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may therefore be minimised and this generally has a positive effect on properties such as the colour of the polycarbonate.

A further possibility is to heat the vapour or gas region differently from the melt or sump region located therebelow. Thus it is advantageous to heat the upper gas region less than the melt region located therebelow. Possible polycarbonate films on the walls in the gas region reside for a long time and are therefore damaged less by lower temperatures. To this end, heating of the sections of the reactor may advantageously be horizontally separated accordingly. This measure leads to higher reactor running times, less pinholing owing to cracked products and improved end product colours.

The processing temperatures for polycondensation are generally between 250 to 330°C, preferably 260 to 310°C, the pressures between 0.01 to 15 mbar, preferably 0.05 to 10 mbar and the mean residence times 30 to 240 minutes, preferably 60 to 180 minutes.

If the temperatures of the oligocarbonate melts introduced into the reactor are significantly lower than the desired operating temperature of the reactor it may be expedient to heat the melt prior to entry into the reactor using heat exchangers suitable for polymer melts. As a result the temperature differences between heating means and product in the reactor may be reduced in order to avoid product damage on the walls of the reactor.

According to the invention the product is introduced into the reaction device via a valve with automatic pressure control in a manner such that direct decompression occurs in the product chamber at the inlet side of the reactor. Cooling effects which may have drawbacks in view of particle contents of a crystalline nature are avoided owing to the high heating potential of the immediate surroundings. To this end the product inlet valves are attached, for example, to the end face of the reactor.

It is advantageous to displace the vapour outlets on the reactor so as to be 15° to 60° off the vertical in the direction of rotation of the rotor in order to reduce the reflux of melts.

- 5 Any conventional materials which do not lead to direct product damage may be used to produce and manufacture the reactors and the heat exchangers. However, it has been found that the use of materials with less than 2 % iron, a nickel content between 56 and 60 % and a chromium content between 22 and 24 % is advantageous for product quality. The material DIN 2.4605 is preferably used.

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- It has surprisingly been found that the use of the reactor device illustrated is particularly well suited to producing industrially serviceable polycarbonates of very high quality from oligocarbonates of the type produced, for example, by the procedure illustrated in German application No. 1 01 14 808.9 by transesterification of diaryl carbonates with diphenols in the presence of catalysts. The very good colour qualities of the polycarbonates obtained are particularly surprising.

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- The melt transesterification process proceeds in a known manner from dihydroxy compounds, carbonic acid diesters and optionally branching agents and/or monophenols.

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Dihydroxy compounds suitable for production of oligomers are those of formula (I)



25

in which Ar is an aromatic radical with 6 to 30 C atoms, which may contain one or more aromatic nuclei, may be substituted and may contain aliphatic or cycloaliphatic radicals or alkyl aryls or heteroatoms as bridging elements.

- 30 Examples of dihydroxy compounds of formula (I) are
hydroquinone,
resorcinol,

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- dihydroxydiphenyls,
bis-(hydroxyphenyl)-alkanes,
bis-(hydroxyphenyl)-cycloalkanes,
bis-(hydroxyphenyl)-sulphides,
5 bis-(hydroxyphenyl)-ethers,
bis-(hydroxyphenyl)-ketones,
bis-(hydroxyphenyl)-sulphones,
bis-(hydroxyphenyl)-sulphoxides,
 α,α' -bis-(hydroxyphenyl)-diisopropylbenzenes,
10
and compounds thereof which are alkylated in the nucleus and halogenated in the nucleus.

These and other suitable diphenols are described in US-PS 3 028 365, 3 148 172, 3
15 275 601, 2 991 273, 3 271 367, 3 062 781, 2 970 131 and 2 999 846, in DE-A 1 570
703, 2 063 050, 2 063 052, 2 211 0956, the French patent specification 1 561 518
and in the monograph "H. Schnell, Chemistry and Physics of Polycarbonates,
Interscience Publishers, New York 1964".

20 Preferred diphenols are, for example:

- 4,4'-dihydroxydiphenyl,
2,2-bis-(4-hydroxyphenyl)propane,
2,4-bis-(4-hydroxyphenyl)-2-methylbutane,
25 1,1-bis-(4-hydroxyphenyl)cyclohexane,
1,1-bis-(4-hydroxyphenyl)-4-methylcyclohexane,
 α,α' -bis-(4-hydroxyphenyl)-p-diisopropylbenzene,
 α,α' -bis-(4-hydroxyphenyl)-m-diisopropylbenzene,
bis-(4-hydroxyphenyl)sulphone,
30 bis-(4-hydroxyphenyl)methane,
1,1-bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane,
bis-(2,6-bis-(4-hydroxyphenyl)hexafluoropropane,

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- (4-hydroxyphenyl)-1-phenylethane,
(4-hydroxyphenyl)diphenylmethane,
dihydroxydiphenylether,
4,4'-thiobisphenol,
5 bis-(4-hydroxyphenyl)-1-(1-naphthyl)ethane,
bis-(4-hydroxyphenyl)-1-(2-naphthyl)ethane,
dihydroxy-3-(4-hydroxyphenyl)-1,1,3-trimethyl-1*H*-inden-5-ol,
dihydroxy-1-(4-hydroxyphenyl)-1,3,3-trimethyl-1*H*-inden-5-ol,
2,2',3,3'-tetrahydro-3,3,3'-tetramethyl-1,1'-spirobi[1*H*-inden]-5,5'-diol.

10

Particularly preferred are

- resorcinol,
bis-(4-hydroxyphenyl)-1-(1-naphthyl)ethane,
15 bis-(4-hydroxyphenyl)-1-(2-naphthyl)ethane,
2,2-bis-(4-hydroxyphenyl)propane,
 α,α' -bis-(4-hydroxyphenyl)-*p*-diisopropylbenzene,
 α,α' -bis-(4-hydroxyphenyl)-*m*-diisopropylbenzene,
1,1-bis-(4-hydroxyphenyl)cyclohexane,
20 bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane,
bis-(4-hydroxyphenyl)diphenylmethane.

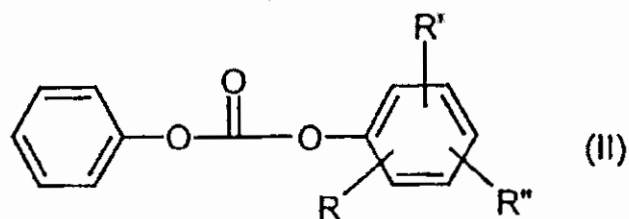
More particularly preferred are

- 25 bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane,
4,4'-dihydroxydiphenyl,
2,2-bis-(4-hydroxyphenyl)propane.

- A diphenol of formula (I) with formation of homooligocarbonates as well as a
30 plurality of diphenols of formula (I) with formation of cooligocarbonates may be
used.

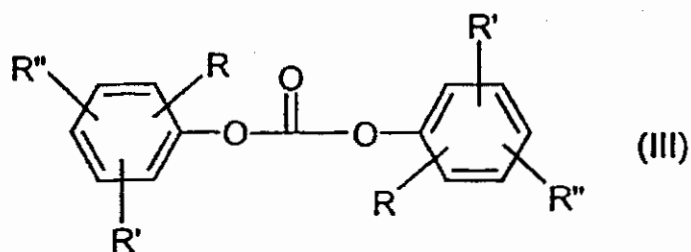
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Carbonic acid diesters are those diaryl esters of formula (II)



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and formula (III),



- 10 wherein R, R' and R'', independently of one another, may be H, optionally branched C₁ to C₃₄ alkyl/cycloalkyl, C₇ to C₃₄ alkaryl or C₆ to C₃₄ aryl, for example

- diphenylcarbonate,
 butylphenyl-phenylcarbonate,
 15 di-butylphenylcarbonate,
 isobutylphenyl-phenylcarbonate,
 di-isobutylphenylcarbonate,
 tert-butylphenyl-phenylcarbonate,
 di-tert-butylphenylcarbonate,
 20 n-pentylphenyl-phenylcarbonate,
 di-(n-pentylphenyl)carbonate,
 n-hexylphenyl-phenylcarbonate,
 di-(n-hexylphenyl)carbonate,

- cyclohexylphenyl-phenylcarbonate,
di-cyclohexylphenylcarbonate,
phenylphenol-phenylcarbonate,
di-phenylphenolcarbonate,
5 isooctylphenyl-phenylcarbonate,
di-isooctylphenylcarbonate,
n-nonylphenyl-phenylcarbonate,
di-(n-nonylphenyl)carbonate,
cumylphenyl-phenylcarbonate,
10 di-cumylphenylcarbonate,
naphthylphenyl-phenylcarbonate,
di-naphthylphenylcarbonate,
di-tert-butylphenyl-phenylcarbonate,
di-(di-tert-butylphenyl)carbonate,
15 dicumylphenyl-phenylcarbonate,
di-(dicumylphenyl)carbonate,
4-phenoxyphenyl-phenylcarbonate,
di-(4-phenoxyphenyl)carbonate,
3-pentadecylphenyl-phenylcarbonate,
20 di-(3-pentadecylphenyl)carbonate,
tritylphenyl-phenylcarbonate,
di-tritylphenylcarbonate,

preferably
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diphenylcarbonate,
tert-butylphenyl-phenylcarbonate,
di-tert-butylphenylcarbonate,
phenylphenol-phenylcarbonate,
30 di-phenylphenolcarbonate,
cumylphenyl-phenylcarbonate,
di-cumylphenylcarbonate,

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particularly preferably diphenylcarbonate.

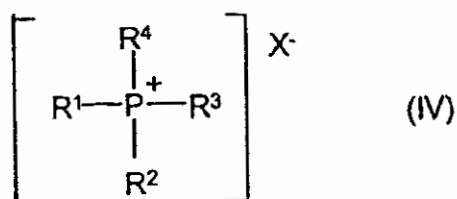
In addition, the phenolic compounds used as carbonates may also be used directly as hydroxyaryls in addition to one of the above-mentioned carbonates in order to influence the terminal group of the polycarbonate. Preferred mixtures are those with diphenylcarbonate. There is the possibility of adding the hydroxyaryl or the hydroxyaryl-carrying compound to the reaction at any moment, preferably at the start of the reaction, and the addition may be divided into a plurality of portions. The free hydroxyaryl content may be 0.4 to 17 mol%, preferably 1.3 to 8.6 mol% (based on the dihydroxy compound). Here the addition may be made both before the reaction and also completely or partially during the reaction.

The carbonic acid diesters are used in 1.02 to 1.3 mol, preferably 1.04 to 1.25 mol, particularly preferably 1.06 to 1.20 mol, based on 1 mol bisphenol. Mixtures of the above-mentioned carbonic acid diesters may also be used.

Ammonium or phosphonium catalysts, which for the purpose of this application are also jointly designated onium compounds, are used for the synthesis. They are preferably used in quantities of 10^{-8} to 10^{-3} mol, based on 1 mol bisphenol, particularly preferably in quantities of 10^{-7} to 10^{-4} mol.

Phosphonium salts, optionally in combination with other suitable catalysts, such as other onium compounds, alkali or alkaline-earth metal compounds, may be used as catalyst for the production of the oligocarbonates.

Phosphonium salts are those of formula (IV),



wherein R^{1-4} , which may be the same or different, represent C_1 to C_{10} alkyls, C_6 to C_{10} aryls, C_7 to C_{10} aralkyls or C_5 to C_6 cycloalkyls, preferably methyl or C_6 to C_{14} aryls, particularly preferably methyl or phenyl and X^- may be an anion such as hydroxide, sulphate, hydrogen sulphate, hydrogen carbonate, carbonate, a halide, preferably chloride, or an alkoxide of formula OR , wherein R may be C_6 to C_{14} aryl or C_7 to C_{12} aralkyl, preferably phenyl. Preferred catalysts are

tetraphenylphosphoniumchloride,
tetraphenylphosphoniumhydroxide,
10 tetraphenylphosphoniumphenolate,

particularly preferably tetraphenylphosphoniumphenolate.

Preferred quantities of phosphonium salt catalysts are 10^{-2} to 10^{-8} mol per mol
15 diphenol and the most preferred quantities of catalyst are 10^{-4} to 10^{-6} mol per mol diphenol. Further co-catalysts may optionally be used in addition to the phosphonium salt in order to increase the polymerisation rate. These include salts of alkali metals and alkaline-earth metals, such as hydroxides, alkoxides and aryloxides of lithium, sodium and potassium, preferably hydroxide, alkoxide or aryloxide salts
20 of sodium. Most preferred are sodium hydroxide and sodium phenylate. The quantities of co-catalyst may be in the range of 1 to 2,000 ppb, preferably 5 to 1,000 ppb and most preferably 10 to 500 ppb, calculated as sodium respectively. These may be used during production of the oligocarbonates or else first added prior to polycondensation.

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The oligocarbonates may be deliberately branched and may therefore contain small quantities of 0.02 to 3.6 mol% (based on the dihydroxy compound) of branching agents. Suitable branching agents include compounds suitable for polycarbonate production with three and more functional groups, preferably those with three or
30 more than three phenolic OH groups, for example 1,1,1-tri-(4-hydroxyphenyl)ethane and isatinbiscresol.

The oligocarbonates are the starting products for polycondensation to polycarbonates. Aryl carbonates or diphenols may be added prior to condensation in order to correct the final ratio of terminal phenolic OH groups to terminal aryl carbonate groups and deliberately achieve the desired and sought ratio of terminal groups in the finished polycarbonate. The terminal phenyl carbonate group may be partially altered by adding substituted monophenols, optionally also the diaryl carbonates thereof.

To modify the properties of the polycarbonates, auxiliaries and reinforcing agents may be added to the oligocarbonates prior to synthesis to high molecular polycarbonates. Examples of these include: heat and UV stabilisers, flow promoters, mould-release agents, flame retardants, pigments, finely dispersed minerals, fibrous material, for example alkyl and aryl phosphites, phosphates, phosphanes, low molecular carbonic acid esters, halogen compounds, salts, chalks, quartz powder, glass and carbon fibres, pigments and combinations thereof. Compounds of this type are described, for example, in WO 99/55772, pages 15 to 25 and in "Plastics Additives", R. Gächter and H. Müller, Hanser Publishers 1983.

Example

Oligocarbonate melt, produced from bisphenol A and diphenylcarbonate with tetraphenylphosphoniumphenolate catalyst, with a relative viscosity of 1,081, a
5 terminal OH group content of 0.55 % and a temperature of 270°C are fed into a reactor, as described above, via a pressure maintaining device. The reactor is heated to 270°C and is under a vacuum of 7.3 mbar. The rotor speed is 2.5 rpm; the mean residence time 45 minutes. The product continuously removed from the reactor by a gear pump has a relative viscosity of 1.171 with a terminal OH group content of
10 0.13 % and is conveyed via a heat exchanger heated with heat-carrying oil at 295°C into a further reactor, as described above, but equipped for higher melt viscosities. The vapour stream is partially condensed, the remainder being taken up in the vacuum station.

15 The second reactor is adjusted to 295°C and is under a vacuum of 1.3 mbar. The rotor speed is 0.8 rpm; the mean residence time 130 minutes. The vapours are diverted into the vacuum station. The polycarbonate continuously removed by means of a gear pump has a relative viscosity of 1.287 and terminal OH group content of 290 ppm. The YI value is determined on the polycarbonate. It is 1.42.

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YI was determined to ASTM E 313 on injection moulded samples 4 mm thick. The injection temperature was 300°C.

Claims

1. Process for producing polycarbonates from oligocarbonates which have been obtained by transesterification of diaryl carbonates with diphenols in the presence of catalysts, in which polycondensation is carried out with large specific surface areas and high film-forming rates, characterised in that a reactor with annular perforated disks is used, wherein the hole sizes of the annular perforated disks are determined by the formula $A = x(\eta^2/(\text{kg}^2 \text{ m}^{-5} \text{ s}^{-2}))^{1/3}$, in which x varies between $2 \cdot 10^{-3}$ and $3 \cdot 10^{-2}$, and wherein the annular perforated disks have a ratio of the total area of the ring to the area taken up by the webs between the holes of 2.2 to 6.5.
2. Process according to claim 1, wherein x is between $4 \cdot 10^{-3}$ and $1.6 \cdot 10^{-2}$.
3. **Process according to claim 1 or claim 2, wherein the ratio of the total area of the ring to the area taken up by the webs between the holes is 2.5 to 5.**
4. **Process according to any one of claims 1 to 3, characterised in that the metal faces surrounding the holes of the annular perforated disks are square or rectangular in cross-section with constant dimensions per disk.**
5. Process according to any one of claims 1 to 4, characterised in that the hole sizes and web widths in the reactor are adapted from entry to exit to the increase in viscosity in accordance with claim 2.
6. Process according to claim 1, characterised in that a reactor device in accordance with DE 44 47 422 C2, column 1, line 63 to column 7, line 39 is used.
7. Process according to any one of claims 1 to 6, characterised in that scoop elements are provided in the reactor in the low viscosity range for subsequent wetting of the annular perforated disks during rotation.

8. Process according to any one of claims 1 to 7, characterised in that the stators are equipped with horizontal transverse beams in the higher viscosity range in the reactor and are attached between the annular perforated disks.
- 5
9. Process according to any one of claims 1 to 8, characterised in that heating of the reactor is divided into vertical, disk-shaped zones in order to be able to adjust a temperature profile.
- 10
10. Process according to any one of claims 1 to 9, characterised in that heating of the individual sections of the reactor is separated horizontally in such a way that the vapour chamber and the sump chamber may be operated at different temperatures.
11. Process according to any one of claims 1 to 10, characterised in that the
- 15 oligomer melt is heated by a heat exchanger prior to entry into the reactor.
12. Process according to any one of claims 1 to 11, characterised in that the product inlet valve is placed in the final disk of the reactor in such a way that the melt is decompressed in the reactor chamber.
- 20
13. Process according to any one of claims 1 to 12, characterised in that the vapour outlet is attached to the reactor between 15° and 60° off the vertical in the direction of rotation of the rotor.
- 25
14. Process according to any one of claims 1 to 13, characterised in that all parts of the reactor which come into contact with the product are manufactured from an alloy with an iron content of less than 2%, a nickel content between 56 and 60% and a chromium content between 22 and 24%, preferably the material 2.4605.