

9608199-7 1

Process and device for producing extrudates from
ultra-high molecular weight polyethylene

THIS SHEET HAS BEEN
REPLACED

5 The present invention relates to a process for producing extrudates from ultra-high molecular weight polyethylene (PE-UHMW) on screw extruders and a device for carrying out this process.

10 PE-UHMW grades have a special position among polyethylenes. By these grades are meant linear polyethylenes obtained by the low pressure process and having an average molecular weight, measured by viscometry, of at least 1×10^6 g/mol, in particular 2.5×10^6 g/mol up to approximately 1×10^7 g/mol. A process for determining such high molecular weights is described, for example, in CZ-Chemische Technik 4 (1974), 129 ff.

15 Ultra-high molecular weight polyethylene is distinguished by a range of physical characteristic data which open up to it a variety of possible applications. Emphasis can be placed on its high wear resistance, its low coefficient of friction with respect to other materials and its out-
20 standing toughness behavior. Furthermore, it is remarkably resistant to numerous chemicals.

Because of its favorable mechanical, thermal and chemical behavior, PE-UHMW is used in a wide variety of fields of application as a versatile material. Examples which can
25 be quoted are the textile industry, mechanical engineering, the chemical industry and mining.

The possible uses of this material are limited by the fact that its processing in ram extruders and the conventional single-screw or multi-screw extruders to give
30 moldings does not always lead to satisfactory results.

In order to extrude PE-UHMW as gently as possible, i.e. without impairing its mechanical properties, ram extruders are widely used. Despite its many advantages, this processing method does not meet all requirements. In



- 2 -

THIS SHEET HAS BEEN
REPLACED

particular, the ram-stroke marks occurring on the molding are troublesome and not always tolerable.

The hollow bodies and profiles produced from PE-UHMW on screw extruders do not have these disadvantages. However, the high molecular weight polymer is greatly overheated even at medium screw speeds. As a consequence of the high viscosity of the melt, which is only slightly reduced even with increase of temperature, a very large proportion of the mechanical energy supplied to the screw is transformed by friction into heat. The heating of the material which this causes can be so significant that it leads to thermal damage to the plastic as a result of degradation or decomposition, i.e. by cleavage of the molecular chains, and thus to a reduction in the average molecular weight. Whereas the throughput, i.e. the amount of extrudate transported per unit time, increases approximately proportionally to the screw speed, the temperature increases overproportionally. For this reason, PE-UHMW can only be extruded on screw extruders of conventional design at low screw speed. However, the process then becomes uneconomical and unsuitable for many industrial fields of application.

EP-A-01 90 878 discloses the processing of ultra-high molecular weight polyethylene in a single-screw extruder. The process consists in extruding molten PE-UHMW through a die with a length/diameter ratio of at least 10. The extrudates are taken off with a stretch ratio of at least 1, preferably 8 to 30:1. This method is only suitable for producing stretched filaments with a small diameter and at very low output rates.

The object was therefore to discover conditions for the extrusion of PE-UHMW and to match them to one another such that the above-described disadvantages are avoided. This object is achieved by the present invention. It consists of a process for producing extrudates from pulverulent or small-particulate ultra-high molecular

This Sheet Has Been Replaced



THIS SHEET HAS BEEN REPLACED

- 3 -

weight polyethylene with an average molecular weight, measured by viscometry, of at least 1×10^6 g/mol in a single-screw extruder the screw shaft of which is arranged into a feed zone, a transition zone, and a discharge zone. It is characterized in that the feed zone is a two-flight screw section and is formed from a transport region the length of which is 4 to 16 times the screw diameter and from a decompression region the length of which is 5 to 18 times the screw diameter, the transition zone consists of a shearing region the length of which is 1 to 2.5 times the screw diameter and the discharge zone comprises a mixing region the length of which is 1 to 4 times the screw diameter.

The new process not only ensures that the polymer is processed gently, i.e. without thermal degradation: in addition, profiles having perfect surfaces which are free of voids and pores and have no internal stresses are obtained. The chosen screw geometry also ensures that the polymer is transported without disturbance over the entire speed range available to the extruder and is continuously fed to the shaping die. It permits a high material throughput and is correspondingly very economical.

According to the invention, the PE-UHMW is used in a pulverulent or small-particulate form. By this is meant the particles obtained in the polymerization process, but also particles, comminuted by mechanical treatment or other means or else coarsened, of the direct polymerization product.

The conveying of the PE-UHMW through the extruder takes place at temperatures of 140 to 300°C, preferably 160 to 180°C. The required heat is fed to the material in two ways: internally due to its mechanical stressing, as frictional heat, and externally via heating devices.

According to the invention, the feed zone is designed as

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

- 4 -

a two-flight screw part and is subdivided into two regions. In the first region the thermoplastic is received, transported and compressed. The length of the feed zone is 4 to 16 times and preferably 4 to 8 times the screw diameter. It is followed by a second region in which, by changing the flight depth of the lands, a decompression takes place. This region has a length of 5 to 18 times, preferably 6 to 12 times, the screw diameter. The width of the lands is constant over the entire feed zone and is 0.05 to 0.09 times, preferably 0.055 to 0.065 times, the screw diameter. The ratio of the flight depth in the feed zone to the flight depth in the discharge zone is 0.6:1 to 1:1, preferably 0.68:1 to 0.76:1, the maximum flight depth over the entire length of the screw being 2.5 to 6, preferably 3.5 to 5 mm.

From the feed zone the PE-UHMW, already heated above the crystallite melting range by the frictional forces, passes into the transition zone. The latter consists of a shearing region formed by a shearing element of conventional design. Preferably the shearing element is provided with longitudinal grooves. In it, the melt stream flows through a defined shearing gap completing the plastication and the homogenization of the thermoplastic. The length of the shearing region is 1 to 2.5 times, preferably 1.5 to 2 times, the screw diameter. The screw clearance, i.e. the distance of the shearing element from the barrel wall, is 0.20 to 0.50 mm, preferably 0.25 to 0.35 mm.

In a proven embodiment of the new process, a transport region can follow the shearing region of the feed zone. The transport region is designed as a single-flight screw section and has a length of up to 4.5 times, preferably 3 to 4 times, the screw diameter. The land width is 0.08 to 0.15 times, in particular 0.10 to 0.12 times, the screw diameter.

The material coming from the transition zone is received

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

- 5 -

by the discharge zone or metering zone. The latter has the function of a mixing region and its length corresponds to 1 to 4 times, in particular to 2 to 3 times, the screw diameter. Preferably the mixing region is formed by a screw part provided with knobs or pins.

It has proven suitable for the mixing region in the transition zone also to be followed by a single-flight screw part as transport region. The length of the transition zone is up to 2 times the screw diameter and the land width is, as in the transport region of the transition zone, 0.08 to 0.15 times, in particular 0.10 to 0.12 times, the screw diameter. After leaving the transition zone, whether directly via the mixing region or via the transport region, the thermoplastic material is fed to the die.

The invention further relates to a device for carrying out the new process. It comprises a barrel tube in the bore of which a screw shaft is rotatably mounted and which is provided, in the coolable feed region, with pockets or grooves extending in the longitudinal direction and which has a heatable transport part and an adjoining die.

This device is characterized in that the screw shaft has two flights in the feed region and is formed by a transport region with a length which is 4 to 16 times, preferably 4 to 8 times, the screw diameter and by a decompression region with a length which is 5 to 18 times, preferably 6 to 12 times, the screw diameter, in that, in a transition zone, the screw shaft consists of a shearing region the length of which is 1 to 2.5 times, preferably 1.5 to 2 times, the screw diameter and in that, in a discharge zone, the screw shaft comprises a mixing region the length of which is 1 to 4 times, preferably 2 to 3 times, the screw diameter.

In proven embodiments of the new device, in the

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

- 6 -

transition zone, the shearing region and/or, in the discharge zone, the mixing region are in each case followed by a transport region in the form of a single-flight screw section. The length of the latter is, in the transition zone, up to 4.5 times, preferably 3 to 4 times, the screw diameter and, in the discharge zone, up to 2 times the screw diameter.

The device according to the invention is provided in the feed region with a number of axial grooves distributed uniformly around the circumference of the barrel, which axial grooves, in the region of the feed opening, can be enlarged in the form of pockets. The length of the grooves, which are preferably rectangular in cross section, is 3 to 3.5 times the screw diameter. They have a depth of 4.5 to 6 mm, in particular 5 to 5.5 mm, and a width of 5 to 8.5 mm, in particular 6 to 7 mm. The number of grooves is dependent on the diameter of the screw. For a screw diameter of 150 mm, for example, it is 6 to 12, preferably 8 to 10.

In a proven embodiment of the new device, the pockets are 15 to 20 mm longer than the diameter of the screw and their depth is 2 to 4 mm, preferably 3 to 3.5 mm. The pockets merge into the grooves at an angle of 6 to 9°, preferably 7 to 8°.

In order to ensure a continuous stream of pulverulent or small-particulate material, the feed opening should have a length of 1.4 to 1.8 times, preferably 1.5 to 1.6 times, the screw diameter and its width should be approximately equal to the screw diameter or exceed it by up to 4 mm.

The material leaving the barrel is plasticated and fed to the shaping die. The die is provided with heating and cooling devices which permit the heat to be supplied and/or removed in a controlled manner. The temperatures along the die are between 300°C at the inlet and 130°C at

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

- 7 -

the end, preferably between 180 and 140°C. In the direction of the die outlet, the cross section of the flow channel tapers. This results in a pressure rise in the die land, which pressure rise is adjusted by corresponding adjustment of the cross-sectional size such that the thermoplastic particles sinter together into a homogeneous mass and the moldings obtain a smooth surface.

The extrudate emerging from the die is led into a cooling die in which its surface is cooled down to temperatures below the crystallite melting point, i.e. below approximately 130°C. After leaving the cooling die, the moldings are guided by appropriate devices, e.g. braking lips or braking flaps or by suitable measures, such that a force acting opposite to the extrusion direction results. This force ensures, in the cooling zone, that the molding comes into contact on all sides with the coolant separated from it by a wall, so that the heat removal takes place uniformly and the occurrence of stresses in the molding is avoided. Further cooling takes place, corresponding to the prior art, in a water bath which is uniformly temperature controlled or subdivided into different temperature zones.

In a special embodiment of the device for carrying out the process, the extrudate is shaped into strands by means of an apertured plate. The thickness of the apertured plate is conventionally 10 to 50 mm, preferably 30 to 40 mm and the bores have diameters of 1.5 to 5 mm, in particular 2 to 4 mm, diameter. They are expediently equipped with conical inlets, the inlet angle being 0.5 to 5°, preferably 0.8 to 1.5°. The strands emerging from the apertured plate are pelletized by means of conventional commercial pelletizing devices, such as strand pelletizers, hot-cut pelletizers, water-cooled die face pelletizers or underwater pelletizers.

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACEDPatent claims

1. A process for producing extrudates from pulverulent
to small-particulate ultra-high molecular weight
polyethylene having an average molecular weight,
measured by viscometry, of at least 1×10^6 g/mol in
a single-screw extruder the screw shaft of which is
arranged into a feed zone, a transition zone and a
discharge zone, wherein the feed zone is a two-
flight screw section and is formed from a transport
region the length of which is 4 to 16 times the
screw diameter and a decompression region the length
of which is 5 to 18 times the screw diameter, the
transition zone consists of a shearing region the
length of which is 1 to 2.5 times the screw diameter
and the discharge zone comprises a mixing region the
length of which is 1 to 4 times the screw diameter.
2. The process as claimed in claim 1, wherein, in the
feed zone, the length of the transport region is 4
to 8 times the screw diameter and the length of the
decompression region is 6 to 12 times the screw
diameter, in the transition zone, the length of the
shearing region is 1.5 to 2 times the screw diameter
and, in the discharge zone, the length of the mixing
region is 2 to 3 times the length of the screw
diameter.
3. The process as claimed in claim 1 or 2, wherein, in
the transition zone, the shearing region is followed
by a transport region which is designed as a single-
flight screw section and the length of which is up
to 4.5 times, preferably 3 to 4 times, the screw
diameter.
4. The process as claimed in one or more of claims 1 to
3, wherein, in the discharge zone, the mixing region
is followed by a transport region which is designed
as a single-flight screw section and the length of
which is up to 2 times the screw diameter.

This Sheet Has Been Replaced



THIS SHEET HAS BEEN
REPLACED

- 2 -

5. The process as claimed in one or more of claims 1 to 4, wherein the ratio of the flight depth of the screw in the feed zone to the flight depth in the discharge zone is 0.6:1 to 1:1, preferably 0.68:1 to 0.76:1.
6. The process as claimed in one or more of claims 1 to 5, wherein the maximum flight depth over the entire length of the screw is 2.5 to 6 mm, preferably 3.5 to 5 mm.
7. The process as claimed in one or more of claims 1 to 6, wherein the screw clearance in the shearing region of the screw is 0.20 to 0.50 mm, preferably 0.25 to 0.35 mm.
8. A device for carrying out the process as claimed in any of claims 1 to 7, comprising of a barrel tube in the bore of which a screw shaft is rotatably mounted and which is provided, in the coolable feed region, with pockets or grooves extending in the longitudinal direction and which has a heatable transport part and an adjoining die, wherein the screw shaft has two flights in the feed region and is formed by a transport region with a length which is 4 to 16 times, preferably 4 to 8 times, the screw diameter and by a decompression region with a length which is 5 to 18 times, preferably 6 to 12 times, the screw diameter, wherein, in a transition zone, said screw shaft consists of a shearing region the length of which is 1 to 2.5 times, preferably 1.5 to 2 times, the screw diameter and wherein, in a discharge zone, said screw shaft comprises a mixing region the length of which is 1 to 4 times, preferably 2 to 3 times, the screw diameter.
9. The device as claimed in claim 8, wherein, in the transition zone, the shearing region is followed by a transport region in the form of a single-flight



THIS SHEET HAS BEEN
REPLACED

- 3 -

screw section the length of which is up to 4.5 times, preferably 3 to 4 times, the screw diameter.

10. The device as claimed in claim 8 or 9, wherein, in the discharge zone, the mixing region is followed by a transport region in the form of a single-flight screw section the length of which is up to 2 times the screw diameter.
11. The device as claimed in one or more of claims 8 to 10, wherein the grooves in the feed region are rectangular in cross section, their length is 3 to 3.5 times the screw diameter, their depth is 4.5 to 6 mm, in particular 5 to 5.5 mm, and their width is 5 to 8.5 mm, in particular 6 to 7 mm.
12. The device as claimed in one or more of claims 8 to 11, wherein the pockets are 15 to 20 mm longer than the diameter of the screw and their depth is 2 to 4 mm, preferably 3 to 3.5 mm.
13. The device as claimed in one or more of claims 8 to 12, wherein the die is designed as an apertured plate with a thickness of 10 to 50 mm, preferably 30 to 40 mm, and is provided with bores of 1.5 to 5 mm, preferably 2 to 4 mm, in diameter.

This Sheet Has Been Replaced

