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(71) Applicant: **RELIANCE INDUSTRIES LIMITED**
[IN/IN]; 3rd Floor, Maker Chamber-IV 222, Nariman
Point, Mumbai, Maharashtra 400021 (IN).

(72) Inventors: **SHUKLA, Devesh Kumar**; B-493, Sector – I,
Reliance Township, Reliance Industries Limited,
Vadodara, Gujarat 391345 (IN). **MATHUR, Ajit Behari**;
D-38, Sector – I, Reliance Township, Reliance Industries
Limited, Vadodara, Gujarat 391345 (IN). **GANDHAM,**
Satya Srinivasa Rao; M.I.G – 50, H No. 1-62-2, A. P. H.
B. Colony, Tadepalligudem - West Godavari District,
Andhra Pradesh 534101 (IN). **SATPATHY, Uma Sankar**;
House No. C-38, Sahayog Society, Refinery Road, Gorwa,
Vadodara, Gujarat 390016 (IN). **SARMA, Krishna**
Renganath; DF-43, Sector-I, Reliance Township, Reliance
Industries Limited, Vadodara, Gujarat 391345 (IN).
JASRA, Raksh Vir; B-245, Sundervan Society, Opp:
Durga Temple, New Sama Road, Vadodara, Gujarat
390008 (IN). **MEHTA, Gaurang Manilal**; B/9,
Mangalam Park, Nr. Rajesh Tower, Off: Gotri Road, Har-
inagar, Vadodara, Gujarat 390021 (IN). **PATEL,**

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(54) Title: A PROCESS FOR CONTINUOUS EXTRUSION OF A HIGH MOLECULAR WEIGHT POLYMERIC MATERIAL

(57) Abstract: A process for continuous extrusion of a high molecular weight polymeric material having high reduced specific viscosity is provided. Compaction of the high molecular weight polymeric material in the required form of tape/profile in molten form is achieved before the exit of the high molecular weight polymeric material from the extruder at the distal end without the use of a die-head. The elimination of the die-head as part of extruder helps in overcoming the processing limitations caused by very high reduced specific viscosity and flow resistance of the polymer melt.

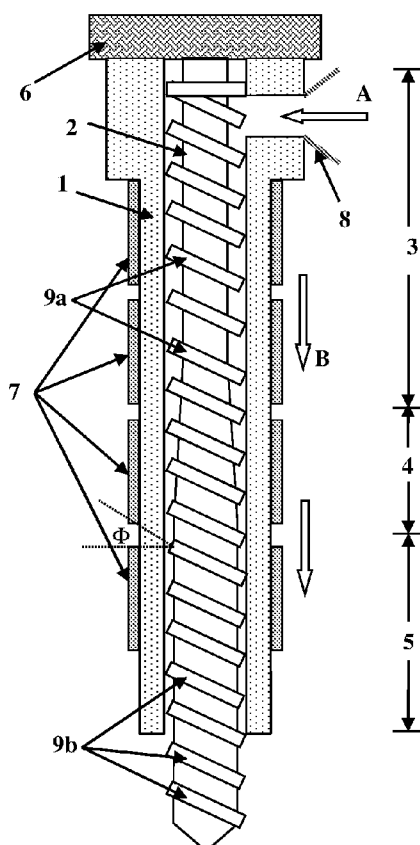


Figure 1



Nanubhai Fuljibhai; C/19, Gnyan Jyot Soc. Opp: Abhishek Soc. Gotri, Vadodara, Gujarat 390021 (IN). **SHAH, Amit Kumar Punamchand;** 65, Balajinagar Society, VIP Road, Nr Amitnagar Circle, Vadodara, Gujarat 390022 (IN). **AMIN, Yogini Maheshbhai;** B-35, Pavandham Society, Nr. Samta flats Subhanpura, Vadodara, Gujarat 390023 (IN). **PAREKH, Ashishkumar Indravadan;** A-19, Pushpam Tenament. OPP: Yash Complex Gotri, Vadodara, Gujarat 390021 (IN).

(74) **Agent: DEWAN, Mohan;** R.k.dewan & Co., Podar Chambers, S.a.brelvi Road, Fort, Mumbai, Maharashtra 400001 (IN).

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A PROCESS FOR CONTINUOUS EXTRUSION OF A HIGH MOLECULAR WEIGHT POLYMERIC MATERIAL

FIELD

The present disclosure relates to a process for continuous extrusion of a high molecular weight polymeric material with high reduced specific viscosity (RSV).
5

DEFINITIONS

As used in the present disclosure, the following terms are generally intended to have the meaning as set forth below, except to the extent that the context in which they are used indicate otherwise.

10 **Root diameter:** The root diameter is the measure of the diameter of the shaft of an extruder screw.

Flight: An extruder screw is machined out of a solid rod and, when finished, is like a shaft on which a helical screw is built. Each turn of the helix is called a flight and is like a thread of an Archimedean screw used for conveying materials.

15 **Helix angle:** The helix angle is the angle between the screw flight and the plane perpendicular to the axis of the screw.

Compression ratio: Compression ratio of a screw is defined as the ratio of the channel depth (or alternatively channel volume) in the feed section to that in the metering section.

20 **L/D ratio:** L/D (length over diameter) ratio is defined as the ratio of screw flight length over screw diameter.

The expression 'UHMWPE' for the purpose of the present disclosure refers to Ultra-High Molecular Weight Polyethylene, i.e., polyethylene having an average molecular weight above 0.3 million dalton.

The expression 'RSV' for the purpose of the present disclosure refers to reduced Specific Viscosity which is an indication of the polymer chain length and average molecular weight.
25

BACKGROUND

Ultra-high molecular weight polyethylene (UHMWPE) is a specialty material which has properties similar to linear polyethylene in addition to exceptionally low coefficient of friction, extremely high impact resistance even at low temperature, abrasion and wear resistance and good long term mechanical properties. This combination of properties makes UHMWPE suitable for manufacturing one of the strongest fibers and other oriented products suitable for various applications.

The high molecular weight of UHMWPE, however, results in extremely high melt viscosity and limits the polymer processability and thereby end use applications. Therefore, the conventional continuous melt processing techniques cannot be used conveniently with UHMWPE and only batch mode compression molding or ram extrusion technique is employed in molding of an UHMWPE article.

Many attempts have been made in the past in relation to continuous processing of the UHMWPE in melt, solid and solution states by conventional processing techniques. WO1992011125 A1 mentions a continuous production of a high modulus article by forcing polyethylene close to or at its melt temperature using a single screw extruder. This is used to process a polymer of MW 0.75 to 6 million dalton in which the elongation velocity gradient (EVG) should not exceed above 1.3 sec^{-1} for polyethylene (PE) having 0.50 to 1 million dalton average molecular weight (MW) and 0.4 sec^{-1} for polyethylene having 5-6 million dalton average MW. The polymer is lubricated with 2.5 to 7.5% of lubricant to avoid plug flow in passage. The extrudate is deformed and drawn in the direction of its elongation. The design of the passage of the die was made in a conical shape in which the cross sectional area diminishes in the forward direction of plastic flow.

WO2010063679 A1 mentions a process for making UHMWPE tape by extrusion of a mix of HMWPE and UHMWPE in the form of a gel prepared in combination with select solvents. The MW of UHMWPE is of the order of 0.8 million dalton. The design of the die is modified so as to include more than one inlet from the barrel through which the gel is supplied, one extrusion slit and a cavity made with multiple sections in width direction of the extrusion slit. The width of tape prepared by the above process is in the range of 30 mm to 100 mm.

WO2013034582 A1 teaches an extrusion technique wherein UHMWPE (MW 0.5-4.0 million dalton) is melt extruded at 160-170°C by capillary extruder with an extrusion speed of 0.5 to 5 mm/min.

US8642723 suggests processing of UHMWPE with melt viscosity more than 1000 Pa.s. The method of angular extrusion suggests “an extrusion channel formed at an angle along the extruding path”. A design of angular extrusion die in which strain-imposing feature lies at an angle $<180^\circ$ which provides the required forward and backward pressure to increased shear force experienced by the extruded material. The angle of the strain imposing feature of the angular extrusion die is less than 180° , however, the most preferred angle in the strain imposing feature is selected as 90° , 120° and 135° . The process as suggested in US8642723 is based on the ram extrusion method.

However, none of the processes are based on UHMWPE powder compaction using a conventional extruder and obtaining the finished form as tapes/profiles/extrudates.

There is, therefore, felt a need for a process for continuous extrusion of UHMWPE to obtain an extrudate in the form of a continuous tape or profile that alleviates the limitation due to high intrinsic viscosity associated with the conventional processes.

OBJECTS

Some of the objects of the present disclosure, which at least one embodiment herein satisfies, are as follows:

It is an object of the present disclosure to ameliorate one or more problems of the prior art or to at least provide a useful alternative.

An object of the present disclosure is to overcome the processing limitations caused by very high reduced specific viscosity and flow resistance of the polymer melt.

Another object of the present disclosure is to provide a continuous extrusion process for compacting ultra-high molecular weight polyethylene.

Still another object of the present disclosure is to provide a continuous extrusion process which does not require the use of a die-head.

Yet another object of the present disclosure is to provide an extruder for continuous extrusion of ultra-high molecular weight polyethylene.

A further object of the present disclosure is to provide a continuous process to draw an extrudate in the form of a tape or profile using an extruder which does not require the use of a die-head.

Other objects and advantages of the present disclosure will be more apparent from the following description, which is not intended to limit the scope of the present disclosure.

SUMMARY

The present disclosure provides a process for continuous extrusion of a high molecular weight polymeric material having high reduced specific viscosity. The process of the present disclosure comprises the following steps:

- extruding, without the need of a die-head, by conveying, through an extruder comprising an extruder screw rotating in a barrel, while maintaining a predetermined controlled temperature profile, the high molecular weight polymeric material, through a feed zone, a conveying/plasticizing zone and a compression/metering zone of said barrel, to obtain an extrudate;

wherein, the compression ratio of said extruder screw can be in the range of 2.5 to 4.5 for compacting the high molecular weight polymeric material and facilitating the free exit of the extrudate in the form of a tape or profile.

In accordance with the process of the present disclosure, the feed zone can be maintained at a temperature in the range from 30° C to 110° C; the conveying/plasticizing zone can be maintained at a temperature in the range from 110° C to 160° C; and the compression/metering zone can be maintained at a temperature in the range from 140° C to 230° C.

The extrudates thus obtained can be passed through at least one set of calendaring rollers for obtaining a stretched extrudate of high strength. The residence time of the high molecular weight polymeric material in the extruder can be in the range from 60 seconds to 600 seconds. The high molecular weight polymeric material of the process of the present disclosure can be ultra-high molecular weight polyethylene. The extrudates, so obtained, can

be in the form of a tape or profile and is shaped by the space between the last two flights at the exit of the extruder. The extrudates, obtained in the form of a tape or a profile, can be collected on a winder via a conveyor in the extrusion direction. The RSV of the high molecular weight polymeric material can be in the range of 3.0 dL/g to 75.0 dL/g.

5 Further, an extruder is disclosed for the continuous extrusion of a high molecular weight polymeric material. The extruder of the present disclosure comprises:

- a barrel '1' divided into a feed zone '3', a conveying/plasticizing zone '4' and a compression/metering zone '5', said barrel '1' having a hopper '8' at a proximal end and an opening at a distal end;
- 10 • a plurality of heaters '7' for heating the feed zone '3', the conveying/plasticizing zone '4' and the compression/metering zone '5' to predetermined temperatures; and
- an extruder screw '2' housed inside the barrel '1' configuring an annular space between inner wall of the barrel '1', and the outer surface of the extruder screw '2'; wherein;
- 15 ○ the extruder screw '2' is configured to rotate inside said barrel '1' and having a plurality of flights '9a' arranged helically on its outer surface,
- the root diameter of the extruder screw '2' is such as to provide a compression ratio between 2.5 and 4.5 for compacting the high
- 20 molecular weight polymeric material fed through the hopper '8' and exiting through the opening of said barrel '1'.

The extruder of the present disclosure is extended to accommodate at least two flights of the plurality of flights '9a' outside the barrel '1'. The root diameter of the extruder screw '2' continuously increases and the flight depth continuously decreases in the conveying/plasticizing zone '4' resulting in the reduction of the volume of the annular space and maintenance of the compression ratio.

25

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWING

A process for continuous extrusion of a high molecular weight polymeric material will now be described with the help of the accompanying drawing, in which:

Figure 1 illustrates an extruder with an extended extruder screw in accordance with the present disclosure.

DETAILED DESCRIPTION

The present disclosure provides a process for the continuous extrusion of a high molecular weight polymeric material having high RSV in the form of tape or profile using an extruder, without the use of a die-head, and thus overcomes the processing limitations caused by very high RSV.

In accordance with an embodiment of the present disclosure, there is provided an extruder, without a die-head, for the continuous extrusion of a high molecular weight polymeric material having a high RSV.

The extruder used for the continuous extrusion of a high molecular weight polymeric material having the high RSV is shown in **Figure 1**. As shown in the **Figure 1**, the extruder, without a die-head, comprises a barrel '1' with an opening at its distal end and a hopper '8' for introducing the feed into the barrel '1' at its proximal end. An extruder screw '2', housed inside the barrel '1' and configuring an annular space between the inner wall of the barrel '1', and the outer surface of the extruder screw '2'. The extruder screw '2' has a predetermined arrangement of flights '9a' that are arranged helically along the surface of the extruder screw '2'. The barrel '1' is divided into three zones: a feed zone '3', a conveying/plasticizing zone '4' and a compression/metering zone '5'. The zones are arranged from the proximal end to the distal end of the barrel '1'. These three zones of the barrel '1' are maintained at distinct predetermined temperatures with the help of a plurality of heaters '7' that are disposed along the length of the barrel '1' such that the temperature of the barrel '1' increases from the proximal end to the distal end. With the help of the plurality of heaters '7', the feed zone '3' is maintained at a temperature in the range from 30° C to 110° C; the conveying/plasticizing zone '4' is maintained at a temperature in the range from 110° C to 160° C to soften the high molecular weight polymeric material and the compression/metering zone '5' is maintained at a temperature in the range from 140° C to 230° C. Each of the three zones of the barrel '1' can have multiple heaters that provide gradually increasing temperatures from the feed zone '3' to the compression/metering zone '5'.

The extruder screw '2' of the extruder of the present disclosure is characterized by having a first constant root diameter in the feed zone '3' with an increasing root diameter in the

conveying/plasticizing zone '4' and a second constant root diameter in the compression/metering zone '5'. The second constant root diameter is larger than the first constant root diameter. In accordance with the present disclosure, the extruder screw '2' is defined by a plurality of flights '9a', typically helical, formed on its surface, disposed at an angle, the helix angle ϕ , along the length of the extruder screw '2' from the proximal end to the distal end. The root diameter of the extruder screw '2' is such as to provide a compression ratio between 2.5 and 4.5 for compacting the high molecular weight polymeric material fed through the hopper '8' and exiting through the opening at the distal end of the barrel '1'. The root diameter of the extruder screw '2' continuously increases inside the barrel '1' thereby, continuously decreasing the flight depth in the conveying/plasticizing zone '4' resulting in the reduction of the volume of the annular space and maintenance of the compression ratio for compacting the high molecular weight polymeric material.

A drive mechanism '6', which is functionally coupled to the extruder screw '2', is disposed at the proximal end of the barrel '1'. The drive mechanism '6' brings about the rotation of the extruder screw '2' with respect to the barrel '1'. The drive mechanism '6' is so adjusted that the extruder screw '2' is maintained at a rotational speed as required, preferably, in the range from 1 rpm to 50 rpm. The spacing between the last two consecutive flights '9b' outside the barrel '1', shapes the extrudate in the form of a tape or a profile which can be collected on a winder via a conveyor in the extrusion direction.

In one embodiment of the present disclosure, the extruder screw '2' has an extended length appearing outside the barrel '1' such that at least two helical flights 9b lie outside the barrel '1' for exit of the extrudate from the opening at the distal end.

In an exemplary embodiment of the present disclosure, the extruder screw '2' has an overall L/D ratio in the range of 15 to 50 with the screw diameter in the range of 25 mm to 65 mm. The compression ratio of the extruder screw '2' is in the range of 2.5 to 4.5.

In accordance with the present disclosure, there is provided a process for the continuous extrusion of a high molecular weight polymeric material having a high reduced specific viscosity. The high molecular weight polymeric material is introduced into the feed zone '3' of the extruder through a hopper '8' in a direction A as shown in the **Figure 1**. Barrel '1' is preheated to maintain the feed zone '3', the conveying/plasticizing zone '4' and the compression/metering zone '5' at predetermined temperatures using the plurality of heaters '7'. The high molecular weight polymeric material is then conveyed through the

conveying/plasticizing zone '4' and the compression/metering zone '5' in a direction **B** as shown in the **Figure 1** while compacting the high molecular weight polymeric material at the conveying/plasticizing zone '4' and the compression/metering zone '5'. Free exit of the extrudate of the softened high molecular weight polymeric material in the form of a tape or a profile is facilitated through the opening at the distal end in the form of a tape or profile. The extrudate, obtained in the form of a tape or a profile, can be collected on a winder via a conveyor in the extrusion direction. The residence time of the high molecular weight polymeric material in the extruder can be in the range of 60 seconds to 600 seconds. The extrudate, so obtained, can be passed through at least one set of calendaring rollers for obtaining a stretched extrudate in the form of a stretched tape having high strength.

In accordance with the process of the present disclosure, the reduced specific viscosity of the high molecular weight polymeric material is in the range of 3.0 to 75.0 dL/g.

In an embodiment of the present disclosure, the extrudate can be allowed to pass through a mechanical device having a pre-determined cross-section to shape the extrudate cross-section. In accordance with the present disclosure, the examples of the pre-determined cross-section can be circular, squared, and rectangular.

In accordance with the process of the present disclosure, the feed zone '3', conveying/plasticizing zone '4' and the compression/metering zone '5' are maintained at a temperature in the range of 30° C to 110° C, 110° C to 160° C and 140° C to 230° C respectively.

In an exemplary embodiment of the present disclosure, the high molecular weight polymeric material is ultra-high molecular weight polyethylene. The molecular weight of the ultra-high molecular weight polyethylene being processed ranges from 0.3 million to 15 million and can be used with or without any additives such as diluent, solvent or a processing aid.

In an exemplary embodiment, the process includes feeding a UHMWPE powder with an average molecular weight of 2.5 million, blended with a stabilizer in the range of 3000 ppm to 5000 ppm through the hopper '8' of the extruder into the feed zone '3'. The temperature profile of the extruder is kept as follows: feed zone '3' at 30 °C and 110 °C at two heating zones, conveying/plasticizing zone '4' at 135 °C and the compression/metering zone '5' at 168 °C. The rpm of the extruder screw '2' is fixed at 15. The extruder is without a die-head and the extruder screw '2' has an extended length appearing outside the barrel '1' such that at least two helical flights '9b' lie outside the barrel '1'.

In another exemplary embodiment of the present disclosure, 3 to 5 thousand ppm of antioxidant is mixed with the UHMWPE powder before feeding it through the hopper '8' to prevent degradation of the polymer. Other non-limiting examples of the additives include, fillers, colorants, flame retardants, processing aids, lubricants, reinforcements, antistatic agents and impact modifiers which can be mixed with the UHMWPE powder blended with stabilizers (3000–5000 ppm) before feeding it through the hopper '8'.

The process of present disclosure is especially advantageous for the manufacture of tapes or profiles of the UHMWPE in a continuous form. The material can be processed with or without any diluent, solvent, or a processing aid. Another advantage of the process is that it does not make use of a die-head.

The present disclosure is further illustrated herein below with the help of the following laboratory scale experiments. The experiments used herein are intended merely to facilitate an understanding of ways in which the embodiments herein may be practiced and to further enable those of skill in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of embodiments herein. These laboratory scale experiments can be scaled up to an industrial/commercial scale.

Experiments:

Experiment 1:

These experiments were carried out in the extruder explain herein above.

Extrusion of ultra-high molecular weight polyethylene (UHMWPE) powder, having an average molecular weight ~3.5 million dalton, bulk density 0.45 g/cc, density at ambient temperature of 0.933 g/cc, RSV 25 dL/g and melting point ~140 °C, was carried out in a Brabender PL-2000 Plasticoder attached with an extrusiograph (Model no 8271). The extrusiograph was equipped with a screw having a diameter 30 mm, length 825 mm, L/D 27.5, compression ratio 3.5, pitch load 21.5 mm in the feed zone '3' and 24 mm in the compression/ metering zone '5'. The extruder was also provided with four heaters '7' in which the temperatures maintained were room temperature, 110 °C, 135 °C and 168 °C in an increasing order from the feed to the compression section, respectively. The extruder screw '2' speed was set at 15 rpm. Initially, the dried UHMWPE powder material was continuously

fed through hopper. '8' Once the feed zone '3' of the extruder got packed with polymer material, further addition of the resin drove the material towards the conveying/ plasticizing zone '3' and the compression/ metering zone '5'. The sequential increase in temperature of the barrel '1' softened the polymer which ultimately got compacted due to a high
5 compression ratio of the extruder screw '2' and the product obtained was in the form of a continuous tape (thickness of ~1.7 mm) through the opening of a flange attached at the distal end of the barrel '1'. The thickness of the final tape was reduced up to ~1.00 mm.

The tensile strength (TS) and tensile modulus (TM) of the UHMWPE tape was measured by Universal testing machine (UTM) model no 3366 (M/S Instron Pvt Ltd) at room temperature
10 and compared with a compression molded sheet of the same material. The sizes of the sample and test conditions were taken as: 46 mm (L), 12.7 mm (w), 0.99 mm (t), 10 mm (Gauge length) and 50 mm/min (Crosshead speed). The TS and TM of the extruded tapes were found to be 0.048 GPa & 0.46 GPa respectively, which was very close to the properties of a compression molded sheet of the same material (TS 0.0417 GPa, TM 0.51 GPa). However
15 the density of tape was found to be 0.950 g/cc.

Experiment 2:

A similar experiment as described in experiment 1, was carried out by using the same polymer as used for Experiment 1 with different temperatures of the heaters '7'.

In a first condition, the temperature profile from the heater one to four was set at 80 °C, 135
20 °C, 180 °C and 195 °C respectively and the rotation of the extruder screw '2' was fixed at 5 rpm. A continuous smooth white tape with thickness of ~1.9 mm was obtained as **Set-I**.

Further, in a second condition, the fourth heater temperature was increased up to 210 °C and the extruder screw '2' rpm was decreased up to 2 rpm. The higher temperature at the distal end of barrel '1' and the reduced rpm of the extruder screw '2' facilitated the material for
25 more fusion. The extruded tape of this segment was marked as **Set-II** the thickness of which also measured ~1.9 mm.

In a third condition (**Set-III**) the temperatures of the first to fourth heaters were maintained at 80 °C, 135 °C, 200 °C and 200 °C respectively and the extruder screw '2' rpm was fixed at 5 rpm. The UHMWPE product was found to be more softened just after post extrusion and it
30 was manually pulled with some force in the softened stage which provided stretching in the tape to a certain extent.

In the above three set conditions, no flange was attached at the distal end of the barrel '1' and the extrudate was obtained through the annular space between the barrel '1' and the extruder screw '2'.

The tensile strengths (TS) of **Set I**, **Set II** and **Set III** tapes were determined by UTM (universal testing machine) at room temperature. The gauge length of the test piece and crosshead speed in UTM was kept as 50 mm and 50 mm/min respectively. The tensile strength(s) of Set I, Set II and Set III tapes so obtained are provided herein below in Table 1:

Table 1: Tensile strength(s) of the Set I, Set II and Set III tapes

S.No.	Sample	Tensile Strength (GPa)
1.	Set I	0.042
2.	Set II	0.032
3.	Set III	0.102
4.	UHM Sheet (compression molded)	0.037

From table 1 it was observed that the values of the tensile strength of **Set-I** and **Set-II** tapes are very close with the compression molded UHMWPE sheet. Further, it is observed that in the manually stretched tape (**Set-III**), the value of tensile strength is significantly greater than the value of tensile strength of the compression molded UHMWPE sheet.

TECHNICAL ADVANCEMENTS

The present disclosure described herein above has several technical advantages including, but not limited to, the realization of:

- an extrusion process to prepare UHMWPE tapes or profiles in a continuous form; and
- an extruder to shape UHMWPE in the form of tape or profile without the use of a die-head and thus overcoming the processing limitations caused by very high reduced specific viscosity and flow resistance of the polymer melt.

Throughout this specification the word “comprise”, or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated element, integer or step,

or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

The use of the expression “at least” or “at least one” suggests the use of one or more elements or ingredients or quantities, as the use may be in the embodiment of the invention to achieve one or more of the desired objects or results. While certain embodiments of the inventions have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Variations or modifications to the formulation of this invention, within the scope of the invention, may occur to those skilled in the art upon reviewing the disclosure herein. Such variations or modifications are well within the spirit of this invention.

The numerical values given for various physical parameters, dimensions and quantities are only approximate values and it is envisaged that the values higher than the numerical value assigned to the physical parameters, dimensions and quantities fall within the scope of the invention unless there is a statement in the specification to the contrary.

While considerable emphasis has been placed herein on the specific features of the preferred embodiment, it will be appreciated that many additional features can be added and that many changes can be made in the preferred embodiment without departing from the principles of the disclosure. These and other changes in the preferred embodiment of the disclosure will be apparent to those skilled in the art from the disclosure herein, whereby it is to be distinctly understood that the foregoing descriptive matter is to be interpreted merely as illustrative of the disclosure and not as a limitation.

CLAIMS:

1. A process for continuous extrusion of a high molecular weight polymeric material having high reduced specific viscosity, said process comprising the following steps:
 - extruding, without the need of a die-head, by conveying, through an extruder comprising an extruder screw rotating in a barrel, while maintaining a predetermined controlled temperature profile, the high molecular weight polymeric material, through a feed zone, a conveying/plasticizing zone and a compression/metering zone of said barrel, to obtain an extrudate;
- wherein, the compression ratio of said extruder screw is in the range of 2.5 to 4.5 for compacting said high molecular weight polymeric material and facilitating the free exit of said extrudate in the form of a tape or profile.
2. The process as claimed in claim 1, wherein
 - said feed zone is maintained at a temperature in the range from 30° C to 110° C;
 - said conveying/plasticizing zone is maintained at a temperature in the range from 110° C to 160° C; and
 - said compression/metering zone is maintained at a temperature in the range from 140° C to 230° C.
3. The process as claimed in claim 1, wherein said extrudate is passed through at least one set of calendaring rollers for obtaining a stretched extrudate having high strength.
4. The process as claimed in claim 1, wherein the residence time of said high molecular weight polymeric material in said extruder is in the range from 60 seconds to 600 seconds.
5. The process as claimed in claim 1, wherein the reduced specific viscosity of said high molecular weight polymeric material is in the range of 3.0 dL/g to 75 dL/g.
6. The process as claimed in claim 1, wherein said high molecular weight polymeric material is ultra-high molecular weight polyethylene.

7. The process as claimed in claim 1, wherein said extrudate is in the form of a tape or profile and is shaped by the space between the last two flights on said extruder screw at the exit of said extruder.
8. An extruder for continuous extrusion of a high molecular weight polymeric material, said extruder comprising:
- a barrel '1' divided into a feed zone '3', a conveying/plasticizing zone '4' and a compression/metering zone '5', said barrel '1' having a hopper '8' at a proximal end and an opening at a distal end;
 - a plurality of heaters '7' for heating said feed zone '3', said conveying/plasticizing zone '4' and said compression/metering zone '5' to predetermined temperatures; and
 - an extruder screw '2' housed inside said barrel '1' configuring an annular space between inner wall of said barrel '1', and the outer surface of said extruder screw '2'; wherein;
 - said extruder screw '2' is configured to rotate inside said barrel '1' and having a plurality of flights '9a' arranged helically on its outer surface,
 - the root diameter of said extruder screw '2' is such as to provide a compression ratio between 2.5 and 4.5 for compacting said high molecular weight polymeric material fed through said hopper '8' and exiting through said opening of said barrel '1'.
9. The extruder as claimed in claim 8, wherein said extruder screw '2' is extended to accommodate at least two flights of said plurality of flights '9a' outside said barrel '1'.
10. The extruder as claimed in claim 8, wherein the root diameter of said extruder screw '2' continuously increases and the flight depth continuously decreases in the conveying/plasticizing zone '4' resulting in the reduction of the volume of said annular space and maintenance of the compression ratio.
11. The extruder as claimed in claim 8, wherein said high molecular weight polymeric material is ultra-high molecular weight polyethylene.

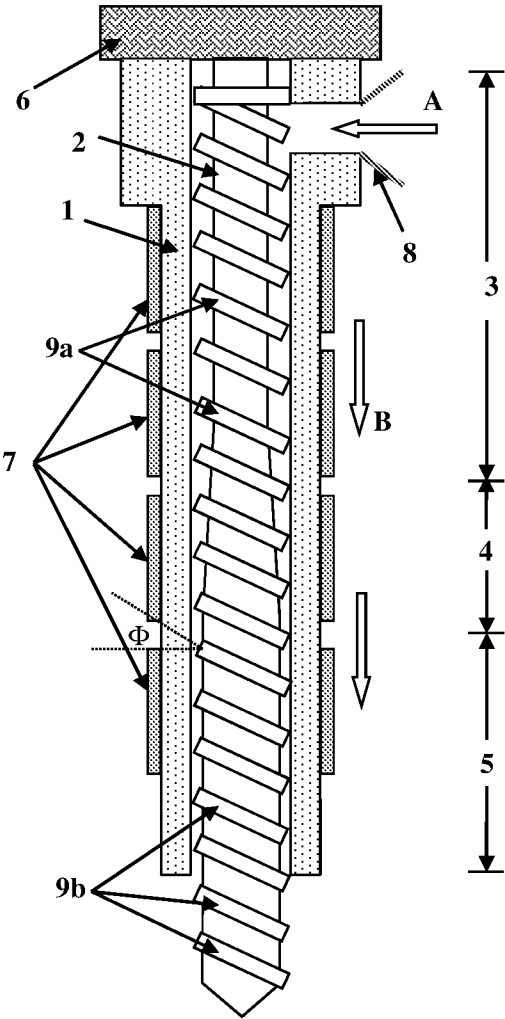


Figure 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2016/056890

A. CLASSIFICATION OF SUBJECT MATTER
C08L23/06 Version=2017.01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C08L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Patseer, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO1992011125 A1 Published on 09 July 1992 (WOODHAMS RAYMOND T, TATE KENNETH R) * abstract, [page 1, line 6], [page 1, lines 7-11], [page 9, line 15], [page 15, line 11, table 1]*	1-11
A	WO2010063679 A1 Published on 10 June 2010 (DSM IP ASSETS B.V.) *abstract, [page 1, lines 1-4], [page 2, lines 5-10]*	1-11
A	US 8642723 B2 Published on 04 February 2014 (THE TRUSTEES OF DARTMOUTH COLLEGE) *abstract*	1-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

22-02-2017

Date of mailing of the international search report

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Name and mailing address of the ISA/

Indian Patent Office
Plot No.32, Sector 14, Dwarka, New Delhi-110075
Facsimile No.

Authorized officer

Ankush Wankhede

Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2016/056890

Citation	Pub.Date	Family	Pub.Date
WO 1992011125 A1	09-07-1992	US US5399308 A	21-03-1995
		EP 0564457 A1	13-10-1993
WO 2010063679 A1	10-06-2010	JP 2012510383 A	10-05-2012
		US 2011212316 A1	10-09-2011
		EP 2352630 A1	10-08-2011
US 8642723 B2	04-02-2014	WO 2011035038 A2	21-07-2011