(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 June 2012 (14.06.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/076512 A1

(51) **International Patent Classification**:
B29C 45/00 (2006.01) ***F16H 55/06*** (2006.01)
B29B 13/06 (2006.01) ***F16C 33/20*** (2006.01)

(21) **International Application Number**:
PCT/EP2011/071888

(22) **International Filing Date**:
6 December 2011 (06.12.2011)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
10194093.0 8 December 2010 (08.12.2010) EP

(71) **Applicant** *(for all designated States except US)*: **DSM IP Assets B.V.** [NL/NL]; Het Overloon 1, NL-6411 TE Heerlen (NL).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **FEIJTS, Pascal Jozef Maria** [NL/NL]; Julianalaan 3, NL-6042 JD Roermond (NL). **GABRIELSE, Wouter** [NL/NL]; Parkweg 35, NL-6212 XN Maastricht (NL).

(74) **Agent**: **DORRESTIJN, Antoon**; P.O. Box 4, NL-6100 AA Echt (NL).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

WO 2012/076512 A1

(54) **Title**: AN APPARATUS COMPRISING A GEAR OF A THERMOPLASTIC POLYMER COMPOSITION

(57) **Abstract**: An apparatus, comprising a gear of an unreinforced polymer composition containing PET, which gear has been fabricated by injection moulding. In a preferred embodiment the PET has after injection moulding a relative solution viscosity of between 1.5 and 2.1, determined by diluting 1 gram of polymer in 125 grams of solvent at 25°C, the solvent consisting of 7.2 parts by weight 2,4,6 trichlorophenol and 10 parts by weight phenol.

AN APPARATUS COMPRISING A GEAR OF A THERMOPLASTIC POLYMER COMPOSITION

The invention relates to a n apparatus comprising gear of a thermoplastic polymer composition. Gears of thermoplastic polymer compositions are well known in the art and have found wide acceptance since many years.

Gears of thermoplastic polymers have replaced metal gears in many apparatus. Examples of such apparatus are domestic appliances, for instances DVD players, washing machines and kitchen equipment, but also apparatus used in cars, like for example a system for opening and closing windows, fuel pumps and other electric equipment serving in cars.

One of the most important advantages of gears of thermoplastic polymers is their cost effective fabrication process by injection moulding, while metal gears often have to be cut and grinded. Furthermore it is simple to integrate other parts in the gears, the gears have a good ability to dampen shocks and impact loads, offer weight reduction and noise reduction and are able to run without or with a minimum of lubrication.

The polymeric materials of choice for gears are traditionally nylon (PA) and acetal resins (polyoxymethylene abbreviated by POM). Gears of PA resist high temperatures, provide a high noise reduction and have a high shock and impact resistance. Gears of POM have a very low moisture uptake and therefore a high dimension stability. The gears of POM have good mechanical properties at low temperatures, which makes them very suitable for critical applications at low temperatures, where high forces have to be transferred and high accuracy is important, for example in small and complex gears, worm gears and helical gears. A disadvantage of gears of POM however is the relatively low thermal resistance, so that POM gears can not be used at elevated temperatures, in general not above 80 ºC.

Sprockets and bearings of thermoplastic polyester have been produced by cutting them from a stock shape of post-condensated polyester.

The post condensated polyester has a very high polymeric weight, which makes the polymer strong enough for such applications. However such products have not found wide acceptance, since they have a costly fabrication process.

Object of the present invention is to provide an apparatus comprising a further gear of a thermoplastic polymer, the gear having adequate properties and being economical to produce.

Surprisingly this object is obtained by an apparatus comprising a gear of an unreinforced polymer composition containing polyethylene terephthalate (PET), which gear has been fabricated by injection moulding.

The gear is very cost effective, since it is fabricated by an injection moulding process. It is very surprising that the injection moulded gear of PET shows adequate properties for use in an apparatus, for example a high strength, high dimensional stability, but also a low coefficient of friction and a high wear resistance. This while in the long time that gears of a thermoplastic polymer exist an apparatus comprising a gear of an unreinforced polymer composition containing PET , which gear has been fabricated by an injection moulding process has never been reported. It is true that in US-4,435,546 in the examples the injection moulding of a gear wheel of a polymer composition comprising a specific polyester copolymer has been reported. However the gear was a test specimen, used to test the injection moulding properties of the polymer composition and no indication was given that a gear of an unreinforced polymer composition comprising PET, which gear was injection moulded, is so useful for use in an apparatus.

The gear of the apparatus according to the invention has furthermore accurate dimensions, resists high temperatures and resists humid conditions.

Unreinforced means in the context of the present application that the polymer composition contains at most 5 weight % a reinforcement agent, such as for example glass fibers or other further mineral fibers, carbon fibers or whiskers, like for example wolastonite. Preferably the amount of reinforcing agent is at most 2 weight percent, more preferably at most 1 weight percent. Most preferably the polymer composition does not contain any of the above-mentioned reinforcing additives. Although the strength of composition is enhanced by the reinforcing additives, the wear resistance is negatively influenced.

In the context of the present invention polyethylene terephthalate resin is understood to be the condensation product of ethane diol and terephthalic acid. Such a PET resin is obtainable by direct esterification of ethane diol and terephthalic acid or by transesterification of ethane diol with the dimethyl ester of terephthalic acid, thus comprising the esterified residues of ethane diol and terephthalic acid.

The polyethylene terephthalate that is used in the polymer composition of the gear of the apparatus according to the invention is a polyester produced from terephthalic acid or an ester thereof and ethylene glycol as main monomers. The polyethylene terephthalate can also contain small amounts of other

diacids, like isophtalic acid, or other diols, like diethylene glycol as comonomers. Preferably the composition contains at least a polyethylene terephthalate homopolymer. A polyethylene terephthalate homopolymer is herein understood to contain less than 5 mole% of monomers other than terephthalic acid or an ester thereof and ethylene glycol. The advantage of such a homopolymer is a higher melting point and better crystallisation behaviour. More preferably the polyethylene terephthalate contains less than 4 mol%, even more preferably less than 3 mol% and most preferably less than 2 mol% of comonomer.

Preferably at least 50 weight % of polyethylene terephthalate in the composition is a homopolymer, more preferably at least 75 weight %, more preferably at least 90 weight %, more preferably at least 95 wt. %, more preferably at least 98 wt. %, more preferably at least 99 wt. %.

Preferably the composition contains at least 50 weight % of polyethylene terephthalate, more preferably at least 75 weight %, more preferably at least 90 weight %, more preferably at least 95 wt. %, more preferably at least 98 wt. %, more preferably at least 99 wt. %.

For injection moulding of the gear of the apparatus according to the invention the standard injection moulding equipment for injection moulding of PET may be used.

Preferably the PET in the polymer composition used to produce the gear of the apparatus according to the invention has a relative solution viscosity (RSV) before injection moulding of between 1.6 and 2.2, more preferably between 1.7 and 2.1, even more preferably between 1.8 and 1.95 (determined by diluting 1 gram of polymer in 125 grams of solvent at 25°C, the solvent consisting of 7.2 parts by weight 2,4,6 trichlorophenol and 10 parts by weight phenol). Preferably the PET in the polymer composition after injection moulding of the gear of the apparatus according to the invention has a relative solution viscosity (RSV) of between 1.5 and 2.1, more preferably between 1.6 and 2.0, even more preferably between 1.75 and 1.85.

In this way a gear is provided that shows very good mechanical properties, especially good resistance against impact and shocks.

The polymer composition of the gear of the apparatus according to the invention may comprise additives to lower the friction, for example graphite, molybdenum sulphide and PTFE. However the gears show also without these additives already a very low friction. Also the difference between dynamic and static friction is very low.

The gear preferably contains a web that contains less than 30 % of openings, more preferably less than 20 % of openings, more preferably less than 10 % of openings, most preferably no openings at all. In this way a very strong gear is obtained by the injection moulding process.

The web is the part of the gear between the gear ring and the axel or opening to receive the axel. The % of openings in the web is calculated from the total surface of openings in the web and the total surface of the web in side view of the gear (parallel to the direction of the axel).

Especially suitable gears of the application according to the invention have a diameter between 10 and 80 mm. The gears may be worm gears, helical gears or spur gears. Preferably the gears are helical gears, even more preferably the gears are worm gears. This is because such gears must have very accurate dimensions and dimensional stability and also must be able to withstand high forces and the gears according to the invention have shown to be able to fulfil these conditions.

The invention is also directed to a process for injection moulding the gears according to the invention.

The polymer composition used in the injection moulding process according to the invention preferably contains less than 0.015 wt. % of water, more preferably less than 0.01 wt. %, more preferably less than 0.005 wt. %, even more preferably less than 0.002 wt. %., even more preferably less than 0.0015 wt. %. Surprisingly it has been shown that because of the very low water content of the composition during injection moulding of the gears, the gears fabricated from the composition show improved mechanical properties, like resistance to impact and shocks. The composition may be dried by using the normal methods for drying polymer compositions containing PET, however by extending the drying time to obtain the very low water content in the composition. The composition is for example dried at a temperature of 100 – 130 ºC, preferably at a temperature of between 115 and 125 ºC. The drying time may be at least 8 hours, preferably between 10 and 14 hours. An example of a suitable process of drying the composition includes the process for dehumidifying PET in a hopper dryer or a stand alone dryer with regenerating desiccants attaining a dew point of between - 30 and - 40 ºC of the circulated hot air in the dryer. After drying the composition is preferably directly transported to the hopper of the injection moulding machine.

Good results are obtained if the temperature of the surface of the mould cavity is between 120 and 150 ºC, more preferably between 125 and 150 ºC,

more preferably between 130 and 150 ºC, most preferably between 135 and 145 ºC. The melt temperature of the polymer composition is preferably between 265 and 290 ºC, more preferably between 270 and 285 ºC, most preferably between 275 and 280 ºC.

Examples of apparatus according to the invention include electric equipment serving in cars, for instance apparatus for window lifting equipment, wiper systems and seat recliner systems, aircos and systems operating air valves in cars and also domestic appliances, like for example coffee machines, mixers, kitchen machines, DVD players, washing machines but also printers, paper shredders etc.

Materials used:

Arnite™ A04 900, polyethylene therephthalate (PET) having a RSV of 1.93 delivered by DSM, the Netherlands

Akulon™ S223-D, polyamide 66 delivered by DSM, the Netherlands.

Drying of the PET

PET was dried just before injection moulding in a stand alone hot air dryer for 12 hours at a temperature of 120 ºC. Hot air was circulated and dried to obtain a dew point of – 30 ºC. The water content after drying was 0.0015 wt. %.

Injection moulding

Gears having a diameter of 41 mm were injection moulded using an Engel ™ 80 ton injection moulding machine.

For the PET the melt temperature was 275 ºC and the mould cavity temperature was 120 respectively 140 ºC.

For the PA66 the melt temperature was 290 ºC and the mould cavity temperature was 80 ºC.

Testing of the gears

The gears were mounted in a testing apparatus containing an electromotor and a steel gear mounted on the output axle of the electromotor. The steel gear has a matching geometry to the PET gear of the apparatus according to the invention and to the PA66 gear (the plastic gears). Both plastic gears were adjusted in the apparatus so that the gears were driven by the steel gear.

The rotational speed of the gears was 1500 rpm. The gears were not lubricated. The plastic gears were rotating against a brake system providing a counter torque.

Example I, comparative experiment A

The PET gear and the PA66 gear were tested as explained above at 23 ºC and 80 ºC for 10^6 cycles. After that the dimensions of the teeth of the gears were measured. Both the PET and the PA66 gear showed an acceptable wear pattern and so passed the test.

Example II

PET gears were tested at different counter torques provided by the brake system. The torque whereby the gear failed after about 10^6 cycles by braking of teeth was determined. During injection moulding the water content of the PET composition was 0.015 wt. % and the mould cavity temperature was 120 ºC. The outcome of the test was a torque of 0.6 Nm.

Example III

Like example III, however the water content of the PET was 0.0015 wt. %. The torque was 1.2 Nm. It is clear that when the PET composition has been dried, that the resulting gear has an increased durability.

Example IV

Like example III, however the mould cavity temperature is 140 ºC. The torque was 1.4 Nm. It is clear that when the PET composition has been injection moulded at a mould temperature that has been increased from 120 to 140 ºC, the resulting gear has an increased durability.

CLAIMS

1. An apparatus comprising a gear of a polymer composition containing polyethylene therephthalate (PET), containing at most 5 wt. % of a reinforcing agent, characterised in that the gear has been fabricated by injection moulding.
2. An apparatus comprising a gear according to claim 1, wherein the polymer composition contains at most 2 wt. % of a reinforcing agent.
3. An apparatus comprising a gear according to claim 1, wherein the polymer composition contains at most 1 wt. % of a reinforcing agent.
4. An apparatus comprising a gear according to any one of claims 1 - 3, wherein at least 50 wt. % of the PET in the polymer composition is a homopolymer.
5. An apparatus comprising a gear according to any one of claims 1 - 5, wherein the PET used in the injection moulding process of the gear has a relative solution viscosity of between 1.6 and 2.2, determined by diluting 1 gram of polymer in 125 grams of solvent at 25°C, the solvent consisting of 7.2 parts by weight 2,4,6 trichlorophenol and 10 parts by weight phenol.
6. An apparatus comprising a gear according to any one of claims 1 - 5, wherein the PET after injection moulding has a relative solution viscosity of between 1.5 and 2.1, determined by diluting 1 gram of polymer in 125 grams of solvent at 25°C, the solvent consisting of 7.2 parts by weight 2,4,6 trichlorophenol and 10 parts by weight phenol
7. Process for the production of the gear as defined in any one of claims 1 – 6, wherein the polymer composition contains less than 0.01 wt. % of water.
8. Process for the production of the gear as defined in any one of claims 1 – 6, wherein the polymer composition contains less than 0.005 wt. % of water.
9. Process for the production of the gear as defined in any one of claims 1 – 6, according to any one of claims 7 or 8, wherein the temperature of the surface of the mould cavity is between 120 and 150 ºC.
10. Process for the production of the gear as defined in any one of claims 1 – 6, according to any one of claims 7 – 9, wherein the melt temperature is between 265 and 290 ºC.
11. Gear as defined in any one of claims 1 – 6 or produced according to the process of any one of claims 7 – 10, wherein the gear is a worm gear or a helical gear.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/071888

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C45/00 B29B13/06 F16H55/06 F16C33/20
ADD.

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)
B29C B29B F16H F16C

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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 435 546 A (BIER PETER [US] ET AL) 6 March 1984 (1984-03-06)	1-6
Y	column 1, line 30 - column 2, line 59 column 8, line 51 - column 11, line 37; examples 1-4	7-11

X	WO 2006/030810 A1 (POLYPLASTICS CO [JP]; BESSHO MINORU [JP]; MOCHIZUKI AKIHIRO [JP]) 23 March 2006 (2006-03-23)	1,11
Y	paragraphs [0001] - [0003], [0008], [0017] - [0019]; claim 12; figures	11

X	US 4 670 203 A (CHANG SHAO CHI [JP]) 2 June 1987 (1987-06-02)	1-6
Y	column 1, line 55 - column 2, line 31 column 3, line 21 - column 4, line 68; example 9; table 9	7-11

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] 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

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"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	Date of mailing of the international search report
29 February 2012	08/03/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kopp, Christian

3

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/071888

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 272 475 A (CHI CHANG S) 9 June 1981 (1981-06-09) column 1, line 11 - line 29 column 4, line 4 - line 29	7-11
Y	DD 290 618 A5 (NAGEMA VEB K [DE]) 6 June 1991 (1991-06-06) page 1 - page 2	7-11
Y	DE 103 33 648 A1 (KREYENBORG VERWALTUNGEN [DE]) 2 September 2004 (2004-09-02) paragraph [0001] - paragraph [0008]	7-11
Y	GB 2 287 213 A (NISSEI PLASTICS IND CO [JP]) 13 September 1995 (1995-09-13) page 1, line 1 - page 4, line 17; figures	7-11

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2011/071888

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4435546 A	06-03-1984	NONE	
WO 2006030810 A1	23-03-2006	JP 4407929 B2	03-02-2010
		JP 2006082434 A	30-03-2006
		WO 2006030810 A1	23-03-2006
US 4670203 A	02-06-1987	DE 2638840 A1	17-03-1977
		US 4670203 A	02-06-1987
		US 4863652 A	05-09-1989
US 4272475 A	09-06-1981	JP 53099268 A	30-08-1978
		US 4272475 A	09-06-1981
DD 290618 A5	06-06-1991	DD 290618 A5	06-06-1991
		NL 9002577 A	16-07-1991
DE 10333648 A1	02-09-2004	NONE	
GB 2287213 A	13-09-1995	CA 2143041 A1	08-09-1995
		GB 2287213 A	13-09-1995
		HK 1001887 A1	07-04-2000
		JP 2673491 B2	05-11-1997
		JP 7241851 A	19-09-1995