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(54) Title: DISPERSION SECTION

(57) **Abstract:** Dispersion section, suitable for rotatable incorporation into the barrel (4) of an extruder (2), of which the enveloping shell has the shape of a cylinder and in the external surface of said section at least a pair of spiral channels is present, consisting of an inlet channel (18) and an outlet channel (20), which are each bounded by a first (38) and a second flank (40), which channels each have an input end and an output end, the inlet channel (18) of each pair having an open input end and a closed output and the outlet channel (20) having an open output end and a closed input end. The section is characterised in that the first flank (38) is wider than the second (40) and fits with a first radial clearance (36) in the extruder barrel, and wherein the ratio of the length of the first flank (38) and the first radial clearance (36) is between 25 and 750.



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DISPERSION SECTION

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The invention relates to a dispersion section, suitable for rotatable incorporation in the barrel of an extruder, of which the enveloping shell has the shape of a cylinder, and in the external surface of said section at least a pair of spirally shaped channels is present, consisting of an inlet channel and an outlet channel, which are each bounded by a first and a second flank, which channels each have an input end and a discharge end, with the input end of the inlet channel of each pair being open and the discharge end closed while of the outlet channel the discharge end is open and the inlet end closed.

Such a dispersion section is known from US-A-3,411,179, which teaches that such a section gives good dispersive mixing of thermoplastic materials.

In many applications, thermoplastic materials are melted and mixed with other materials with the aid of an extruder after which the mixture is brought into in a desired shape. An example of another material are fibres which are dispersed in a thermoplastic material in an extruder for manufacturing fibre-reinforced thermoplastic objects. DE-A-2,461,631 describes the use of a known dispersion section, called Egan dispersion section, in an extruder in a process for manufacturing fibre-reinforced thermoplastic objects. In this publication no further details are given of the dimensions of the dispersion section.

Due to the forces occurring, fibre degradation also takes place during dispersion. To obtain a material with good mechanical properties the dispersion of the fibres in the thermoplastic material should be as homogeneous as possible while fibre degradation should be minimal. The disadvantage of the known dispersion section is that a very homogeneous dispersion cannot be achieved without the occurrence of fibre degradation that has a strongly adverse effect on the mechanical strength of the material.

The invention aims to provide a dispersion section that, when

incorporated in an extruder screw, gives less fibre degradation than the known dispersion section upon dispersion of the fibres in a thermoplastic material to a certain measure of homogeneity.

This aim is achieved according to the invention in that the first
5 flank is wider than the second one and with a first radial clearance fits in the extruder barrel, and wherein the ratio of the width of the first flank and the first radial clearance lies between 25 and 750.

During the transport over this dispersion section of a
composition containing a thermoplastic material and fibres, such a dispersion
10 section, incorporated in an extruder screw, is found to effect homogeneous dispersion of fibres in the thermoplastic material with less fibre degradation than when the known dispersion section is used. As a result, the dispersed material possesses better mechanical properties, such as for example the Izod impact strength, than a corresponding material obtained with the known dispersion
15 section.

The dispersion section according to the invention is particularly
suitable for the homogeneous dispersion of bundles of glass fibres or other fibres,
like natural polymeric fibres, in which the bundle as a whole or each of the fibres
in it, separately or in smaller subgroups, are surrounded by a thermoplastic
20 material.

Examples of other fibres suitable for processing with the
dispersion section according to the invention are aramid, carbon and steel fibres.

Such bundles can be manufactured for example by
impregnating and/or enveloping a long fibre bundle with melted thermoplastic
25 material and chopping the impregnated and/or enveloped bundle obtained into rod-shaped pieces of suitable length, hereafter indicated as granulate. With the dispersion section according to the invention, fibres with a length between 0.1 mm and a length equal to the length of the first flank of the dispersion section can be processed. In practice, in fibre-reinforced thermoplastic moulded articles fibres
30 with a length between 5 and 50 mm are applied, and preferably fibres with a length between 10 and 30 mm.

Examples of thermoplastic materials that can be mixed
homogeneously in combination with one or more of the said types of fibres while
using the dispersion section according to the invention are polypropylene,
35 polyethylene, polyamides, polyethylene terephthalate, polybutylene terephthalate,

polyphenyl sulphide, thermoplastic urethanes, polyoxymethylene and polycarbonate.

The invention will be elucidated with reference to the following Drawings. In these Drawings Fig. 1 is an open view of an extruder, in which a dispersion section according to the invention forms part of the extruder screw; Fig. 2 is a cross-section of the dispersion section from Fig. 1 along the line A-A; Fig. 3 is a development on the dispersion section from Fig. 1; Fig. 4 is a cross-section along the line B-B in Fig. 3; Fig. 5 is a development on a dispersion section, in which the first flank is provided with a raised part running along the inlet channel; and Fig. 6 is a cross-section along the line C-C in Fig. 5.

In Fig. 1, 2 is an extruder with a cylindrical barrel 4 with axis 6 and an extrusion die 8. In the barrel an extruder screw is rotatably incorporated. In general such a screw consists of a number of screw sections capable of rotation around a common axis that each fulfil a specific function or combinations of functions. Examples of such functions are transport, melting, mixing and dispersion. In barrel 4 in Fig. 1 are shown a transport section 10 and a cylindrical dispersion section 14, which are rotatable around axis 6. The enveloping shell of the dispersion section, conceived as passing through the points with the largest radial cross-section, is at a first radial distance 16 from shell 4. Further 18 is a first channel that forms a pair with a second channel 20. The screw direction of the channels relative to the direction of rotation of the screw indicated by arrow 22 and thus to the dispersion section in the extruder has been so chosen that the dispersion section exerts a forward force on the material in the channels and thus also has a transport effect.

The pitch angle, that is the angle between the axial direction 6 and the direction of the bounding walls 24 and 26 of the channels, is between 30 and 60°, and preferably between 40 and 50°. This angle is indicated by α in Fig. 3 and Fig. 5.

The channels may have a rectangular cross-section with a flat base, but the channels may also have a curved cross-section, for example in the form of a circle segment. One skilled in the art will know how to choose, if the need arises, the shape and area of the cross-section depending on the desired transport capacity of the dispersion section. It is also possible for the cross-

sectional area of the channels to vary along their longitudinal direction, for example the depth or the width of the inlet channel can decrease from the open end. Inlet channel 18 is open on the inlet side 28 and closed on the outlet side 30. Outlet channel 20 is closed on inlet side 32 and open on outlet side 34. Open here
5 means that there is a direct connection with a preceding or following element, for example a screw section or extruder die, so that on an open side material can directly enter a channel or material can be discharged from a channel to a following element. On a closed side such material transport is not possible and with a continuing supply of material from the preceding screw section the material
10 will have to leave the channel and be transported to an adjacent channel through the rotary movement of the dispersion section relative to the extruder barrel over a flank, called the kneading or overflow flank.

The design of the channels as described ensures that material fed to the dispersion section enters inlet channel 18, which is open on the inlet
15 side 28, thereof and is transported in a forward direction by the rotary movement of the dispersion section and thus fills inlet channel 18. The material in channel 18, which is closed on the outlet side 30, can only leave this channel through the clearance 36 between first flank 38 and the barrel 4 of extruder 2. The width of clearance 36 will hereafter be denoted as H. In clearance 36 the material comes
20 into contact with the inside of the barrel 4, as a result of which its velocity will be checked and it will remain behind relative to the rotation of the dispersion section. Flank 38 is bounded by walls 25 and 27, which slope down to the base of channel 18 and channel 20, respectively. Second flank 40 is higher than flank 38 and fits almost sliding into barrel 4, so that this flank 40 ensures that the material that
25 remains behind in clearance 36 relative to the movement of flank 38 is again scraped off and entrained, the material entering channel 20. This flank is bounded by two walls 26 and 24, which slope down to the base of channel 18 and channel 20, respectively. Because outlet channel 20 is open on the outlet side 34, the material can subsequently be discharged through this channel from the dispersion
30 section to the following screw section or, in the case described, to the die 8 of the extruder.

The material, which contains a thermoplastic material and fibres, is thus transported from inlet channel 18 to outlet channel 20 over the first flank 38. Due to the difference in velocity between the material that is in contact with the
35 stationary inside wall and the material that is in contact with the flank 38, which

moves relative to the inside wall, shearing of the material takes place. The degree of shearing that takes place should be high enough to ensure that the fibres reaching channel 20 are sufficiently dispersed. This is achieved through a suitable choice of the above-mentioned distance H and the width of the first flank 38. To
5 this end, the width of the first flank 38, which in the development of Fig. 3 and of Fig. 5 is indicated with L, is greater than that of the second flank 40. L generally lies between 0.2 and 0.8 x the circumference of the dispersion section. The ratio between L and the above-mentioned clearance H, L/H, should be between 25 and 750 and is preferably between 50 and 300. At lower values the shearing that takes
10 place generally appears to be insufficient for bringing about good dispersion of the fibres. At higher values too much fibre degradation occurs so that the reinforcing effect of the fibres in the composition is lost.

A third relevant dimension of the dispersion section is the length A thereof, which is understood to be the distance from the input end of the inlet
15 channel to the discharge end of the outlet channel measured in the axial direction. This length A is preferably chosen to be between 2 and 10 times the diameter D of the dispersion section at the location of the second flank 40. The values of A in combination with those of H are preferably so chosen that there is no pressure drop across the dispersion section during the intended operation. For this it is
20 necessary that the transport capacity of the dispersion section is at least equal to the flow rate of the quantity of material supplied by the preceding screw section. The transport capacity Q per revolution of the extruder screw over the first flank is calculated with the formula

25
$$Q = 1/2 \cdot v \cdot H \cdot A/n \text{ (vol/rev)}$$

in which v is the peripheral velocity $\pi \cdot D \cdot n$ of the dispersion section and n the number of revolutions per minute of the extruder screw. Using the given formula, the requirements specified for H.A. and those for L/H, one skilled in the art can
30 readily calculate suitable dimensions of the dispersion section at a given supply Q per revolution by the preceding screw section.

The ratio L/H is a measure of the shearing that is imposed. A further advantage of the dispersion section according to the invention now is that through a suitable choice of these quantities L and H the shearing effected by the

section can easily be set to a desired value. This can take place for example by first determining the suitable shearing to be imposed in order to obtain a desired dispersion of a certain material as the required numerical value for the L/H ratio using an apparatus by means of which a defined shearing can be imposed on a material, for example a Couette apparatus. Subsequently, in conjunction with the diameter D from that defined value, the suitable values of L and H for the dispersion section can be determined.

The dimensions of the feed and discharge channels, for these must supply and remove the material, and in particular the cross-sectional areas thereof, are so chosen that their transport capacity corresponds to the capacity calculated above for the first flank.

To prevent material from channel 20 returning over second flank 40 into channel 18, the clearance 42 between flank 40 and the barrel 4 of extruder 2 is chosen to be so small that flank 40 fits virtually sliding into barrel 4, which means that at the prevailing pressures, in combination with the viscosity of the material, transport through that space is negligible relative to the transport via the channels over the first flank 38. This clearance as a rule lies between $10^{-4} \times D$ and $10^{-2} \times D$ and is very suitably chosen between $0.3 \times 10^{-3} \times D$ and $3 \times 10^{-3} \times D$. Also to avoid material transport over the dispersion section otherwise than via the channels, the dispersion section is preferably provided with upright edges 44 and 46 along the circumference of the ends, which leave only such small clearances 16 between these edges and the extruder barrel that transport through that space is negligible at the prevailing pressures in combination with the viscosity of the material. In practice, edges 44 and 46 usually provide the bearing of the dispersion section in the extruder barrel. The clearances 16 are chosen in the same area as defined above for the clearance 42. Through the choice of the dimensions of the spaces between the extruder barrel and the flanks and upright edges as described it is ensured that all material must pass the dispersion section via inlet channel 18, first flank 38 and outlet channel 20. As a consequence, virtually all the material is subjected to the desired shearing, which is necessary for good dispersion of the fibres in the thermoplastic material.

As the diameter of the extruder increases, the size H of the clearance 36 may also increase, in general virtually proportionally. If this results in H getting a size comparable to the diameter of the granulate used in the unmelted state, the granulate can be transported in unmelted condition over flank 38 so that

the desired dispersion of the fibres is not achieved. To prevent this in such a case, at the location of the boundary between the inlet channel 18 and the first flank 38, a raised part, indicated by 50 in Figs. 5 and 6, can be provided, which leaves a clearance between that raised part and the extruder barrel that is smaller than the diameter of the unmelted granulate. Suitable values range from 0.1 to 0.8 x the diameter of the granulate. Smaller values hinder the exit also of the melted material, at larger values also only partially melted material can enter clearance 36. Preferably the above-mentioned clearance is between 0.3 and 0.5 x the diameter of the unmelted granulate. This design allows melted material and fibres to pass, while insufficiently melted granulate cannot. That is thus forced to remain in inlet channel 18 and will after some time be melted completely there, following which the melted material can as yet pass the raised part and, while passing the first flank 38, be subjected to the desired shearing.

At an increasing extruder diameter the width L of the first flank 38 can also increase, preferably almost proportionally to the increase in said diameter. If this width now becomes larger than is necessary for bringing about the required shearing, the introduction of a second pair of channels can be considered, each pair then preferably covering half of the surface area of the circumference of the dispersion section. The dimensions described above then apply to each pair of channels and associated flanks separately. Thus, the material to be dispersed can enter the dispersion section through two inlet channels, from each of which the material can overflow to the associated first flank, from there enter the corresponding second channel and thus exit from the dispersion section along two outlet channels. This considerably increases the transport capacity in comparison with the situation in which only one pair of channels with associated flanks is present in a dispersion section that is otherwise equally large.

In Fig. 2, 48 indicates the direction of rotation of the screw. 18 and 20 indicate the inlet channel and the outlet channel. When the dispersion section turns in the indicated direction, the material fed into inlet channel 18 will reach clearance 36 and further outlet channel 20 over flank 38.

In Fig. 3 the reference figures have the same significance as in the preceding figures. L indicates the width of flank 38 and α the angle between the axial direction and flank direction.

In Fig. 4 the reference figures have the same significance as in the preceding Figures.

In Fig. 5 the reference figures have the same significance as in the preceding figures. 50 indicates a raised part that prevents the entry of
5 unmelted material into clearance 36.

In Fig. 6 the reference figures have the same significance as in the preceding Figures.

The invention also relates to a process for dispersing fibres in a thermoplastic material with the aid of an extruder that is provided with a screw
10 composed of one or more screw sections, which comprises feeding the fibres and the thermoplastic material to the extruder and transporting and processing the total of the supplied fibres and the thermoplastic material with the aid of the screw sections.

Such processes are generally known in themselves, but do not
15 lead to the obtaining of a mixture in which the fibres are homogeneously dispersed in the thermoplastic material without an undesirable degree of fibre degradation occurring. The objects manufactured with the mixture obtained with the aid of the known process generally possess inadequate mechanical properties.

20 It has now been found that if at least one of the screw sections in the extruder is a dispersion section according to the invention as described above, mixtures are obtained that can be used to manufacture objects the mechanical properties of which are improved relative to objects manufactured from a mixture obtained with the aid of the known dispersion section.

25 The thermoplastic material and fibres of suitable length can be fed separately to the extruder. It is also possible to feed fibres or fibre bundles of suitable length that have already separately or as a bundle been provided with an enveloping layer of a thermoplastic material. This enveloping layer can even be chosen to be so thick that there is no longer any need to feed more thermoplastic
30 material because the desired fibres: thermoplastic material ratio is already present in the enveloped fibres or fibre bundles supplied.

Upon leaving the extruder the mixture homogeneously dispersed in the extruder can be processed into fibre-reinforced objects according to techniques known in themselves. Examples of such techniques are injection
35 moulding, with the material being injected directly into a mould from the extruder

die, or extrusion compression moulding, with the material being able to flow freely from the extruder and a suitable quantity of extruded material always being taken up, placed in a mould and compressed therein to give it the desired shape. The material can also be processed using other methods known for the processing of thermoplastic materials.

Furthermore the invention relates to an extruder, provided with a screw composed of one or more screw sections, in which at least one of the screw sections is a dispersion section according to the invention.

It has been found that with such an extruder mixtures can be obtained that can be used for the manufacture of objects the mechanical properties of which are improved relative to objects manufactured from a mixture obtained with an extruder in which a dispersion section according to the prior art is present. The dimensions and further properties of the dispersion section as required and as can be applied advantageously, as such and relative to the extruder, are as defined above.

The invention will be elucidated on the basis of the following Examples and comparative experiments.

Examples I and II

In a 60 mm extruder (type PMS60 of Plastik Maschinenbau) with a length/diameter ratio of 25 and a screw composed of a feed section with a depth of thread of 6 mm and a dispersion section according to the invention with a length of 240 mm, a dispersing flank L with a length of 120 mm and a clearance H between the dispersing flank and the extruder barrel of 0.6 mm, a glassfibre-filled polypropylene was processed.

To this extruder 36 kg/h of a composition consisting of 70 wt% polypropylene with a melt index of 20 g/10 min. and 30 wt% long-glass granulate with a length of 12 mm was fed. The glass was present in bundles of 2400 tex at a diameter of 18 μ m for the separate filaments in the bundle. The cylinder temperature of the extruder had been set to 250°C. The round outlet in the extruder die had a diameter of 30 mm.

A part of the mixture flowing out as a strand from the extruder was compressed in a Fontijne® press at a pressure of 8 MPa and a moulding

temperature of 40°C in a time of 1 minute to form a flat sheet with a thickness of 2.3 mm.

On suitable test specimens, taken from the compressed sheet cooled to room temperature, the IZOD value according to ISO R180-4A and the strength and modulus according to ISO 527/2 were determined. The degree and uniformity of the dispersion of the glass fibres in the polypropylene matrix were visually assessed using a scale of 1-10.

The above procedure was repeated with a throughput of [60-] kg/h.

The results are shown in Table 1.

Comparative experiments A and B

Examples I and II were repeated, but now instead of a mixing section according to the invention an Egan mixing section with three pairs of channels was incorporated in the extruder screw, the slit width between the extruder barrel and the flanks of the mixing section being 0.3 mm. The results are also shown in Table 1.

Table 1

Example/ experiment	Throughput	IZOD	Strength	Dispersion
	kg/h	kJ/m ²	Mpa	-
I	36	42	35	9
A	36	32	33	9
II	60	46	37	9
B	60	33	34	9

The Table shows that when use was made of the dispersion section according to the invention a material was obtained that, with the same quality of the dispersion, has better mechanical properties than the material that was obtained with the known mixing section.

CLAIMS

1. Dispersion section, suitable for rotatable incorporation into the barrel of an extruder, of which the enveloping shell has the shape of a cylinder and
5 in the external surface of said section at least a pair of spiral channels is present, consisting of an inlet channel and an outlet channel, which are each bounded by a first and a second flank, which channels each have an input end and an output end, the inlet channel of each pair having an open input end and a closed output and the outlet channel having an
10 open output end and a closed input end, wherein the first flank is wider than the second and fits with a first radial clearance in the extruder barrel, and wherein the ratio of the length of the first flank and the first radial clearance is between 25 and 750.
2. Dispersion section according to claim 1, wherein the said ratio is between
15 50 and 300.
3. Dispersion section according to anyone of claims 1 or 2, wherein the first flank is provided with a raised part running along the inlet channel.
4. Process for the dispersion of fibres in a thermoplastic material with the aid of an extruder provided with a screw composed of one or more screw
20 sections, which process comprises the feeding of the fibres and the thermoplastic material to the extruder and the transporting and processing of the total of the supplied fibres and the thermoplastic material with the aid of the screw sections, wherein at least one of the screw sections is a dispersion section according to any one of claims 1-3.
- 25 5. Process according to claim 4, wherein the fibres and the thermoplastic material are fed in the form of a fibre-containing granulate.
6. Extruder, provided with a screw composed of one or more screw sections, in which at least one of the screw sections is a dispersion section according to any one of the claims 1-3.

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INTERNATIONAL SEARCH REPORT

International Application No

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A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 B29C47/64 B29C47/00

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)

IPC 7 B29C

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)

WPI Data, EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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