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COMBINING OF FIBERFILL AND THERMOPLASTIC POLYMERS

The article deals with an efficient and economic way of combination of the fiber composition from fiberglass waste and thermoplastic polymers. As the mixer of components the disk-extruder is used. The effectiveness of the proposed solutions was investigated and proved experimentally. The secondary composite materials having higher values of physical mechanical properties and longer fibers in the composition in relation to the analogous materials are gained in the screw extruder.

Introduction. For economic reasons, when utilized of glass-fiber plastic wastes by producing reinforced composition and molding products as matrix it is reasonable using off-test waste products of thermoplastic polymers and their mixtures; put into the composition the proportion of fibers as high as possible.

According to a famous model Kelli-Tisone [1], with a strong adhesive bond with the matrix tensile strength of polymer randomly reinforced with discrete fibers is proportional to strength and proportion of fibers that are longer than effective. At the same time, the average length of the glass fibers, extracted from waste glass by economically feasible methods usually does not exceed 10 mm.

In extrusion combining of brittle glass fibers with polymeric fibers intensity of fibers destruction increases with viscosity growth of the polymer melt and the proportion of the fibers introduced into it. The occurrence in the composition of a significant proportion of short fibers causes more intense deterioration of work surfaces of a screw and a cylinder of extruder. Additional costs for restoration expensive but fast wearing parts of the extruder also reduce technical and economic effect of utilization. As a result of it, products derived from waste glass and polymers, are uncompetitive in comparison with similar products for constructional purposes from primary and secondary unreinforced polymers.

Research aims at increasing the strength of the composite materials and articles for constructional purposes, moldable from waste of thermoplastic polymers from waste and their mixtures; and containing reinforcing fibers, selected from glass wastes, reducing the abrasive effects on the fiber extruder and as a result of it is to increase technical and economic efficiency of glassfiber plastic wastes and wastes of thermoplastic polymers.

Main part. Method of recycling secondary fiber composition includes several steps:

– dosed inlet and plastication of thermoplastic matrix polymer or polymer mixture in the plate-screw extruder-plasticator;

– dosed inlet of the reinforcing fibers and combining them with the melt of the matrix polymer or their mixture in the working cavity of the mixer-extruder;

– inlet of the kneaded composition from the working cavity of the mixer-extruder through the outlet opening and forming the resulting composition of the product.

The reinforcing fibers are aligned with the melt of the thermoplastic polymer or mixture of polymers in a disk-extruder. Matrix polymer melt is injected into the working cavity of disk-extruder in the periphery of the disk, and reinforcing fibers are injected into the middle part of the cavity through the hole in the case of disk extruder.

Disc-extruders allow to achieve high values of accumulated shear strain characterizing the mixing effect at relatively low energy consumption. The fibers introduced into such extruder, are evenly mixed with the matrix polymer melt thereby.

At the same time, disc-extruders are characterized by low values of the pressure generated at the outlet of the extruder. For economic reasons, it is necessary to have high efficiency combining the reinforcing fibers with the melt of the matrix polymer. This is achieved by increasing the frequency of rotation of the disk and reducing the gap between the rotor and the case. But in both cases, the shear rate increases, which leads to the destruction of the reinforcing fibers. This contradiction is eliminated by optimizing of the concurrency mode according to the maximum of the objective function:

$$F(D,r,\omega,h,d,\mu,n) = \\ = \dot{\gamma}(D,r,\omega,h,d,\mu,n) \cdot P_e(D,r,\omega,h,d,\mu,n), \quad (1)$$

where $\dot{\gamma}(D,r,\omega,h,d,\mu,n)$ – accumulated shear strain when moving the composition from the point insertion of the reinforcing fibers with the radial coordinate r to the outlet opening, the axis of which coincides with the axis of the disc; $P\ (D,r,\omega,h,d,\mu,n)$ – the proportion in the composition of the reinforcing fibers, the length of which exceeds effective; D – diameter of the disc; r – radial distance from the axis inlet to enter the reinforcing fibers to the outlet of the mixer-extruder; ω – disk angular velocity; h – the width of the working cavity of the mixer-extruder (the gap between the case and the disc); d – outlet diameter; μ and n – consistency index and exponent in the law of kneaded composition flow.

Accumulated shear deformation in the formula (1) is determined using known dependences on the parameters of the working cavity of disk-extruder and the angular velocity of the disk.

Thus, when combined components in a disk-extruder the accumulated shear deformation is associated with the parameters of extruder by ratio:

$$\dot{\gamma}(D,r,\omega,h,d,\mu,n)=\frac{\pi\omega\, h\,(D^3-d^3)}{12\,h\,\sqrt{3}\,Q_v(d,\mu,n)}, \quad (2)$$

where $Q_v(d,\mu,n)$ – volume flow of a nonlinear viscous fluid with a power-law flow through the channel of circular section with a diameter d.

The fraction of fibers, the length of which more than effective is:

$$P_e(D,r,\omega,h,d,\mu,n)= =1-F_б(L_e,D,r,\omega,h,d,\mu,n), \quad (3)$$

where $F_b(L_e,D,r,\omega,h,d,\mu,n)$ – the value of the function of fiber length distribution for a parameter L_v equal to, in turn, the effective length of the fiber segment, the molten polymer stretched at a shear rate:

$$\dot{\gamma}(r,\omega,h,d,\mu,n)=\frac{h\omega^2 r^2}{Q_v(d,\mu,n)}. \quad (4)$$

The length of the fibers obtained after extrusion in the composition with the polymer melt is distributed according to the parameters L_e and V_b by Weibull law [1–3]. The coefficient of variation of fiber length V_b has values close to 1. From these ratios, the proportion of fibers whose length is more efficient can be found.

The calculations on the proposed formulas show that in the central part of the working cavity disk-extruder shear rate is less than at the periphery, as they are inversely proportional to relative distance from the insertion point to the radius of the disk.

It is less devastating effect of the polymer melt when mixed with reinforcing fibers at low shear rates. However, if the fibers are introduced into the extruder near the disc axis, then the cumulative shear strain of the composition to its exit from the extruder may be insufficient for good combining reinforcing fibers with the melt: they may not be completely covered with the matrix polymer. Non-polymer fibers have a low reinforcing effect, and the strength of the composition can be even lower than the strength of the matrix polymer.

Taking into account this and the common correlations for the shear rate and accumulated deformation in the working cavity of the extruder is defined the proportion of fraction of fibers, which are longer than the critical from the distance axis of the disk to the point of entry of the reinforcing fibers.

Thus, we have the alternative effect of shear rate and accumulated shear strain on the effectiveness of combining components and destruction of fibers in the extruder-mixer. The influence of both factors involves the product of shear rate and proportion of fibers the length of which is more than effective, as a function of the location of the injection point of the reinforcing fibers (objective function).

Analysis of the objective function using the referred above known relations shows that in a wide range of characteristics of the viscous properties of the matrix polymer and the geometric parameters of the disk extruder – mixer extremum of the objective function when the mass fraction of fibers of 40 to 50 % is achieved if the reinforcing fibers are introduced into the working cavity of disk-extruder in the end case through the hole, spaced from the inlet for the melt of the thermoplastic matrix polymer or mixture of polymers and from the outlet axis for the composition at distance 0.3–0.7 radius of the disc.

Characteristic of the structure and properties of the composite material based on a blend of thermoplastic polymers ABC, PP and fibrous waste of ground glass-fiber plastic

Parameter	Position the insertion point of the pulp in fractions from the disk radius R relatively to its center		
	0.2 R	0.5 R	1 R
Fiber content:			
the average value, wt %	50	50	50
variation coefficient, %	10	8	8
Fiber length:			
the average value, mm	7.0	5.5	1.1
fraction part less than 4 mm, wt %	25	45	95
Average strength value, MPa:			
tensile strength	12	25	19
tensile bending	24	45	32

The device for carrying out the method comprises screw kneader – extruder of the thermoplastic matrix polymer or polymer mixture with a means of dosing for the input and output port plasticized polymer disc-extruder for combining melt of thermoplastic matrix polymer or polymer mixture with reinforcing fibers, reinforcing agents dosed input fibers into the working extruder disc cavity, for instance a screw feeder, an outlet for the withdrawal of the kneaded composition from the working cavity for molding products from obtained composition.

Working cavity in the disk-extruder is formed by a disk and peripheral and end parts of the case; inlet for the melt of the thermoplastic matrix polymer or mixture of polymers is located in a peripheral part of the case forming the working cavity, an outlet for the composition – on the axis of the case end, and a hole for dosed injection of reinforcing fibers into the working cavity of the disc extruder at the end of the case and spaced from the inlet opening for the melt of the thermoplastic matrix polymer or mixture of polymers and from the outlet axis for a composition at distance 0.3–0.7 radius of the disc.

Compound was extruded from the accumulator; shaped workpiece, from which plates were compressed with dimensions of 250×250×5 mm. Samples (20×20 and 100×100 mm) were cut from the plates for the evaluation of the structural parameters. Standard samples were cut for tensile and flexural strength testing.

After burning of the matrix polymer from the samples with dimensions of 100×100 mm fiber length was measured, its average value was found; the average value and the proportion of fibers were defined the length of which is less efficient (4 mm).

The table shows the results of the testing.

Conclusion. For comparison, from the same components and at the same process parameters compound was obtained downloading fiber in mixer-extruder, i.e., with random orientation with respect to the direction of a screw hole. The material obtained in the disk-extruder length of more than 95 wt %; the fibers are not less than the effective (4 mm), whereas the material obtained in combination in the screw extruder, this proportion is at least 50 %. The average length of the fibers in the material obtained from the compound by the proposed method is 25% higher.

The tensile strength of the material is above 26% and flexural tensile is 17% higher than in mixing in the screw extruder.

Comparison of the results shows that the goal of the study is achieved.

References

1. Ставров, В. П. Механика композиционных материалов: учеб. пособие. / В. П. Ставров – Минск: БГТУ, 2008. – С. 165.

2. Ставров, В. П. Механизмы разрушения стекловолокна при совмещении с полимерным расплавом в червячном экструдере / В. П. Ставров, Е. В. Шубенкова // The 4th International Symposium on Failure Mechanics of Materials and Structures, 20–23 Oct. 2007. – Augustów, 2007. – P. 251–254;

3. Ставров, В. П. Влияние режимов совмещения компонентов в червячном экструдере на прочность стеклоармированных термопластов / В. П. Ставров, Е. В. Шубенкова // Актуальные проблемы прочности: материалы 46-й Междунар. конф., 15–17 окт. 2007 г. В 2 ч. Ч. 1 / ВГТУ. – Витебск, 2007. – С. 270–274.

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