Impregnating fibrous fillers with reinforced thermoplastic melts

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Impregnating reinforcing fibres with thermoplastic melts is a crucial stage of producing reinforced thermoplastics. In a number of cases, introducing dispersed fillers into the matrix significantly increases adhesion and mechanical properties of reinforced plastics; however, difficulties arise when impregnating fibres with highly viscous melts, especially those than contain dispersed fillers of their own. We studied the viscosity of a styrene-acrylonitrile copolymer melt reinforced with the following dispersed fillers: nanodiamonds and a layered aluminosilicate; we also investigated how this melt impregnates a nonwoven carbon fibre material. We show that there is a minimum thermoplastic melt viscosity when the filler content is 0.5 % (in terms of mass) and that filtration rate and permeability as functions of impregnation pressure and reinforcement ratio also feature extrema. This bidirectional effect of impregnation pressure and reinforcement ratio upon filtration parameters and permeability characteristics of the fibrous filler may stem from the interaction of reinforcement particles and the walls of the capillary system formed by the fibres through which the melt flows. When the linear dimensions of particles or their agglomerates become comparable to the capillary channel dimensions, the melt flow velocity as a function of pressure deviates from the classical values. Both actual channel constriction (a geometrical factor) and a drag effect of more viscous adsorbed layers are possible in this case.

Keywords: *impregnation, thermoplastics, viscosity, carbon fibres, filtration, permeability*

REFERENCES

[1] Karbushev V.V., Konstantinov I.I., Parsamyan I.L., Kulichikhin V.G., Popov V.A., George T.F. *Advanced Materials Research*, 2009, vol. 59, pp. 275–278.
[2] Gorbatkina Yu.A., Ivanova-Mumzhieva V.G. *Mekhanika kompozitnykh materialov — Mechanics of Composite Materials*, 2012, vol. 48, no. 2, pp. 161–170.
[3] Brantseva T.V., Ilin S.O., Gorbunova I.Yu., Antonov S.V., Körber M.L. *Mekhanika kompozitnykh materialov — Mechanics of Composite Materials*, 2014, vol. 50, no. 5, pp. 923–932.
[4] Bernet N., Michaud V., Bourban P.-E., Manson J.-A.E. *J. Comp. Mat*., 1999, vol. 33, no. 8, pp. 751–772.
[5] Bates P.J., Taylor D., Cunningham M.F. *Appl. Comp. Mat*., 2001, vol. 8, no. 3, pp. 163–178.
[6] Stavrov V.P., Kremnevskaya E.I., Stavrov V.V., Tkachev V.M. *Mekhanika kompozitnykh materialov — Mechanics of Composite Materials*, 1997, vol. 33, no. 4, pp. 555–564.
[7] Kolosov A.E. *Mekhanika kompozitnykh materialov — Mechanics of Composite Materials*, 1987, vol. 23, no. 5, pp. 878–886.
[8] Kotomin S.V., Antonov S.V., Kulichikhin G.V., Körber M.L., Kulichikhin V.G. *Vysokomolekulyarnye soedineniya — Polymer Science, Ser. A*, 1998, vol. 40, no. 7, pp. 1191–1197.

[9] Kotomin S.V., Avdeev N.N. *Kolloidnyy zhurnal — Colloid Journal*, 1999, vol. 61, no. 3, pp. 336–343.
[10] Kotomin S.V., Barankova T.I., Gorbunova I.Yu., Filippova T.N. *Vse materialy. Entsiklopedicheskiy spravochnik — Polymer Science, Series D*, 2016, no. 2, pp. 6–12. DOI: 10.1134/S1995421216030114
[11] Kulichikhin V.G., Tsamalashvili L.A., Plotnikova E.P., Barannikov A.A., Körber M.L., Fischer H. *Vysokomolekulyarnye soedineniya — Polymer Science, Ser. A*, 2003, vol. 45, no. 6, pp. 944–954.
[12] Kulichikhin V.G., Semakov A.V., Karbushev V.V., Platé N.A., Picken S.J. *Vysokomolekulyarnye soedineniya — Polymer Science, Ser. A*, 2009, vol. 51, no. 11, pp. 2044–2053.

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