УДК 678.067.5:678.674

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MODELING IMPREGNATION PROCESS OF GLASS FABRICS BY POLYESTER BINDER UNDER PRESSURE

The article gives analysis of the need for process simulation when developing new methods of making dimensional products from fiberglass, in particular, during the transition from hand-molding technology to pressure impregnation technology.

In this work the results of determining the basic parameters of filler (fiberglass), its behavior under applied compressive force and change pack porosity are presented. On the physical model we studied the way the resin passes through the porous space and defined coefficients of pro-determined permeability in two directions, time of impregnation of predetermined packet sizes, and degree of filling to a certain depth. The experimental results were compared with the results of numerical calculation of the modified body orthotropic theory of heat conduction. The results of calculation of the duration of impregnation for model plane models provide high of performance of convergence with the results of the experiment, which enables the use of numerical methods for simulation of the process as applied to real structures.

Using the experimental data obtained from the coefficients of permeability of fiber system, we calculated the time of full impregnation of the actual product. During the calculations, we have changed the source data for the applied pressure and, varying the circuit supplying and removing the binder, determined the optimal parameters for which the filling of the pore space of the fiber system does not exceed the lifetime of the binder.

Modeling allows us to observe the distribution of the binder in the flow of resin during the impregnation process. Application of numerical method allows us to achieve high quality products and to improve understanding of the production process.

Key words: fiberglass, impregnation, permeability, modeling, filling time.

Introduction. Fiberglass and products made of them occupy a special place among various synthetic materials. To use fiberglass widely it is necessary to develop automation and mechanization as well as innovation. The choice of manufacturing technology of a particular product is determined by a complex of physical and mechanical properties and the final cost of the resulting product. It is essential to provide serial production of items with guaranteed and controlled quality required.

Modern trends in the development of composite materials market is determined by the transition to cheaper manufacturing technologies while maintaining high product quality.

Main part. Currently, the majority of large-sized products are manufactured by contact molding, which has a number of disadvantages: manual labor, the lack of quality of the products, a large amount of waste. Infusion molding method is considered to be the most promising method for the manufacture of articles made of composite materials (CM) with the required performance, satisfying the criteria of economy and ecology.

The essence of this process is the use of differential pressure applied binder and runoff. The fibrous filler is laid on the surface of the punch and is pressed by the mould to the desired thickness. The image of a closed cavity pressurized injected binder that passes through the channels between the filler fibers carries their impregnation and go out through the drain. To improve the quality of impregnation the package of the filler may be pre-evacuated.

The transition from one technology to another one is a difficult task.

One of the main purposes of mathematical modeling of technological systems is to predict the basic characteristics and features of their functioning in industrial environment at the design stage.

The main parameters influencing the physical and mechanical properties of polymeric composite materials (PCM) is the modulus of elasticity of fiberfill, its volume content and the content of pores in the material.

The defining parameters for the simulation are subdivided into designing and technological. Design parameters are to be those which are laid at the stage of designing e.g. products and brands used in reinforcing and bonding materials, the required physical and mechanical properties of the product, the geometric dimensions, the ratio of the reinforcing material and a binder in the finished product etc. The technological parameters are the minimum viscosity of the binder and the maximum time of its life. One of the most important aspects of the monitoring process is the knowledge of processing modes of the binder.

It is impossible to construct an absolutely accurate model of a complex process. At the present time the generally accepted approach suggests using different models at the various levels and stages of simulations. This achieves a reasonable compromise: the complexity of the model – simulation accuracy. In addition, this approach allows you to carry out a comparison of simulation results with experimental data flexibly and efficiently and also clarify their original values, i.e. to carry out an iterative process of improving the structures taking into account the new settings and restrictions.

The object of study in this paper is a glass cloth of brand T 10–80 in production of JSC "Polotsk-Fiberglass" and a binder based on polyester resin for general purpose of grade PN-1 and MEKP hardener. The binder under normal conditions has a viscosity of 1.1 Pa · s and a gel time formation of 120 minutes.

Tissue fillers are elastic porous materials. When formed, filler product is subjected by deformation, thus changing the thickness of the package, its porosity and therefore, the degree of filling.

Even strips were cut out from the cloth with the size 50×50 mm in the warp direction, then they were placed in bags, consisting of 15, 20 and 30 layers between hard metal plates, loaded with compressive forces.

It is found that the change in relative thickness package is essentially independent of the number of layers and is expressed by the dependence of the type $y = 0{,}7 \cdot x^{-0{,}077}$ [1].

The porosity of the package is associated with its parameters in the following expression:

$$P = 1 - \frac{mn}{\rho H_p},$$

where P is relative volume porosity of package; m – weight per unit area of tissue fillers, kg/m^2; n – the number of layers of fabric in the packet; ρ – the density of the fibers from which the fabric is made, kg/m^3; H_p – package thickness at a compression pressure p, mm.

Impregnation of fiberfill with binder is decisive in the development of technology and equipment design of manufacturing of fiberglass. In connection with this important technological index of fiberglass filler is its permeability i.e a quantity characterizing the flow resistance of the fibrous porous medium in the flow of the binder. Fiberfill permeability coefficient depends on the content of the latter per volume unit and its orientation. Generally, the permeability coefficient is found experimentally in a study of the process model of Newtonian fluids in a porous sample, made of this type of filler.

To determine the permeability coefficients of the test system the installation realizing a two-dimensional fluid flow through the pore space was used (Fig. 1). This unit implements fluid flow while feeding it from the center.

Using the samples in a ring allows not only to simplify and accelerate the method of determining the coefficient of permeability of the fibrous filler, but to determine its deformability in a wide range of void fraction changes by changing the thickness of the sample simultaneously [2].

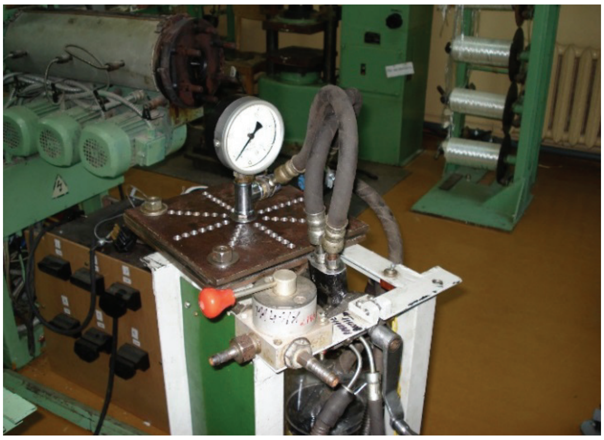

Fig. 1. General view of the installation for the study of impregnation process

It is shown that the coefficients of permeability of the system are not constant and depend on such factors as the flow direction (warp, weft), flow time, the degree of filling, supply pressure and viscosity of the fluid. In the process of flow the coefficients of permeability depending on the filling degree vary from $5.59 \cdot 10^{-12}$ to $9.77 \cdot 10^{-12}$ m^2 in the warp direction and from $1.25 \cdot 10^{-11}$ to $2.36 \cdot 10^{-11}$ m^2 in the weft direction.

Experimental results show that the permeability of the system depends on many parameters. It is also possible to achieve a state of equilibrium when the applied pressure is not sufficient for the further passage of the impregnation process.

Resin supply during impregnation can be done in two ways: from the center and perimeter channels. The experimental values of the permeability coefficients of the system were used in mathematical modeling of fluid flow through the pore space in the calculation of the time to reach the front of a certain depth.

The data obtained by the time of impregnating for the model sample indicates that the correlation between theory and experiment is quite close, suggesting the reliability of the results. The range of values does not exceed 10%.

The calculations revealed the pattern that the resin supply from the center of the filling time by order of magnitude greater than the supply of the resin on the periphery at constant pressure and viscosity.

The whole set of the results obtained show the value of computational models, makes it possible to apply the methods of mathematical modeling of real structures. Car roof MAZ was chosen as the product. Overall dimensions are 2,080×1,620 mm. The wall thickness of the product is 5 mm.

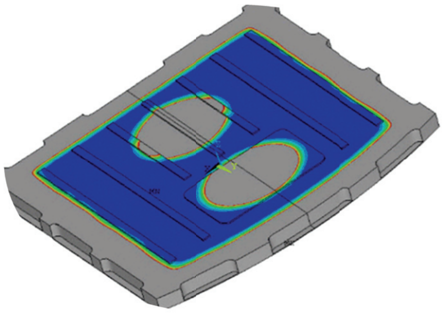

Fig. 2. The position of the front of the binder in the initial impregnation step

When the binder was applied on the perimeter the estimated impregnation time was 22 minutes. In order to reduce the impregnation time of the filler additional inlets in the heart shape were introduced. As a result, the impregnation time was reduced up to 10 minutes. Fluid front position in the initial impregnation stage and in the final impregnation step are shown in Fig. 2 and 3, respectively.

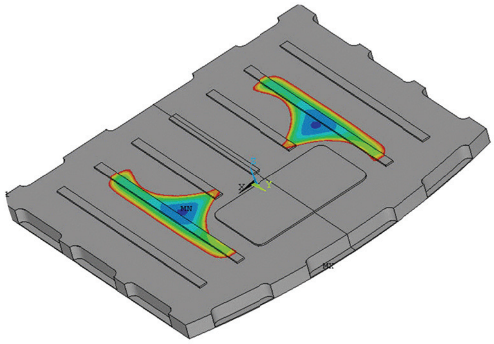

Fig. 3. The position of the front of the binder in the final impregnation step

Analysis of the experimental results. Using numerical simulation during the calculation, the optimum production scheme was determined, varying circuit supplying and removing the binder, location of the vacuum ports scheme filler styling, materials used (filler, binder) pressure. The distribution of the front of the binder, the presence of dry zones, the passage of the process can be estimated as a result of calculation.

Application of numerical method allows to achieve high quality products and to improve the understanding of the production process.

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Received 19.02.2016