MODELLING AND DESIGN OF RECYCLED FIBRE REINFORCED POLYMER COMPOSITE MATERIALS

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More than one million tons of glass fibre-reinforced plastics are annually produced in Europe. With a share of over 50% randomly fibre-reinforced and filled thermosets (SMC) make the largest group of such materials. Because of the growing public and political stress, the recyclability of glass-reinforced thermosets has become a strategic issue of the composite industry.

The aim of this investigation is to develop methods and program systems to design of recycled fibre reinforced composite materials with predicted properties. Such properties are tensile strength, flexural strength, tensile Young's modulus and impact resistance. Particle recycling implies an introduction of disintegrated glass fibre-reinforced plastics into a new material in a recycled form. The properties of such composite materials depend on the properties and geometry of their components. In the problems of design of such composite materials involving the search for the best reinforcement structures situations, as a rule, are mutually contradictory: improvement of one property is attained only by impairing another.

The solution of this problem is divided into the following stages: choice of control parameters and establishment of the domain of search, elaboration of plans of experiment, execution of the experiments, determination of simple mathematical models from the experimental data and design of composite material on the basis of the discovered mathematical models. In each of these stages it is possible to solve a problem by various methods. In the present investigation a approach for planning of experiments is used [1,2]. Mathematical models using data of experiments can also be obtained by various methods. Widely used method is polynomial approximation. In the present investigation another method to determine the simple mathematical models is used. This method is based on selection of simple functions using least squares [1,2]. The simple mathematical models obtained from data of experiments are used as objective functions and constraints in optimal design problem. In the present investigation, for optimization, penalty function method with random search and self training is used [1,2].

In 1990 some European firms founded ERCOM Composite Recycling GmbH, aiming at collecting and Shredding waste SMC parts to be reused in particle recycling. In the ERCOM's plant six fractions of SMC recyclates are produced: three powders *($P1<0,2$, $0,2<P2<0,5$, $P3>0,5mm$)* and three fibrous *($F1<0,5$, $0,5<F2<1,25$, $F3>1,25mm$)* [3]. In this investigation in the RTM process polyester resin and the recyclates of three fractions: two fibrous *(F1, F3)* and one powdery *(P1)* are used. For experimental investigation, 400 x 400 x 4 mm plates were produced. Each plate had a layer of glass mat *($300\ g/m^2$)* at the top and bottom. Samples for experiment, were cut out of these plates.

Numerical examples of modelling and design of recycled polymer composites are carried

out. Let us consider, an example, the design of recycled fibre reinforced composite, where as design parameters are used: amount of fibrous fraction $F3 \Rightarrow x_1$, amount of powder fraction $P1 \Rightarrow x_2$ amount of fibrous fraction $F1 \Rightarrow x_3$ and amount of polyester resin x_4. All plates have constant thickness. Therefore amount of resin (x_4) depend on the amount (combination) of fractions of recycled material $x_4=F(x_1, x_2, x_3)$.
We define the domain of search for the design parametrs by following constraints

$$200 \leq x_1 \leq 410 \qquad 50 \leq x_2 \leq 190 \qquad 20 \leq x_3 \leq 90 \tag{1}$$

In this domain of search plan of experiment with 15 points [1,2] was used. Using the data of experiment and program RESINT [1,2], simple mathematical models for flexural strength $y_1=f_1(x_1, x_2, x_3, x_4)$, tensile Youngs's modulus $y_2=f_2(x_1, x_2, x_3, x_4)$ and impact resistance $y_3=f_3(x_1, x_2, x_3, x_4)$ were obtained.
As objective of design of recycled fibre reinforced composite, the maximum of the flexural strength y_1 is determined

$$y_1 = f_1(x_1, x_2, x_3, x_4) \Rightarrow \max \tag{2}$$

under constraints on the domain of search (1) and following constraints

$$x_1 + x_2 + x_3 \leq 600 \qquad x_4 = F(x_1, x_2, x_3)$$

$$y_2=f_2(x_1, x_2, x_3, x_4) = 6 \qquad y_3=f_3(x_1, x_2, x_3, x_4) = 16$$

Here, predicted recycled material properties are: tensile Young's modulus $(y_2=6\ GPa)$ and impact resistance $(y_3=16\ kJ/m^2)$. Program SUPEX [1,2] gives the following optimal solution

$$y_1= f_1(x_1, x_2, x_3, x_4) = 113\ N/mm^2$$

with design variables as follows (in grams)

$$x_1 = 400; \qquad x_2 = 131; \qquad x_3 = 45 \qquad x_4= 147$$

Conclusions

It is possible to solve various optimal design problems of recycled fibre reinforced polymer composite materials using the program of approximation RESINT and the program of nonlinear programming SUPEX. The control functions may be stiffness, strength, damping and other properties of composite material. As input or control parameters may be Young's modulus of fibre and matrix, fibre volume fraction, type and amount of recycled fractions.

References

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