Fayoum University

Faculty of Engineering

Industrial Engineering Department

Optimal Design of Composite Bone Plate Using Finite Element Analysis and Genetic Algorithm

By

Eng. Mohamed Salem El-Sayed Ali

A Thesis Submitted to the

Faculty of Engineering, Fayoum University

In Partial Fulfillment of the Requirements for the Degree of

Master of Science
In
Manufacturing Engineering

Department of Industrial Engineering

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Abstract

The aim of this study is to obtain the optimum design of laminated glass-fiber Polyvinyl Chloride (PVC) -matrix composite bone plate based on genetic algorithm (GA). This plate used to fix tibial fractures. The selected model is a conventional structure of a bone plate made off stainless steel used to treat tibial fractures. The number of layers, fiber orientations, fiber volume fractions and layer thickness are considered as the optimization variables. Simplified micro-mechanics equations are used to estimate the stiffness and strength of each layer using the optimization variables and material constituent's properties. The lamina stresses for thin composite slips subjected to force and/or moment resultants are determined using the classical lamination theory. The first-ply failure strength is computed using the Tsai–Wu failure criterion.

A genetic algorithm is adapted to obtain the optimal design for plate model problem. The objective of that optimization problem is to maximize the load-carrying capacity under different loads. The results of the optimization work showed that the optimized plate is composed of 5 layers showing the volume fraction, fiber orientation and thickness of each layer.

The optimized structure (The number of layers, fiber orientations, fiber volume fractions and layer thickness) resulted from optimization process of the composite plate is then tested using finite element analysis. A compressive force equal to the body weight is assumed to be the applied force on the plate. The von mises stresses on the plate is calculated using finite element method. The results are then compared to different stresses value of the same plate made off different materials.

From this analysis, using optimized laminated composite material leads to 61% reduction in stress, 71% reduction in plate weight compared to the steel less one and 52% reduction in stress and, 49% reduction in plate weight compared to the titanium one.