A New Multi-objective Multi-mode Model for Optimizing EPC Projects in Oil and Gas Industry

Vida Arabzadeh, Hassan Haleh, and S.M.R. Khalili

***Abstract*—** the objective of this paper is implementing optimization method to investigate time, cost and quality trade off in engineering and construction stages of an EPC project. The first step is to describe the results of research that has been conducted on optimization of grid composite structure used as grating system for platform in petrochemical equipment by using Multi Objective Genetic Algorithms (NSGAII) and Artificial Neural Networks (ANN). ANN is trained data sets taken from numerical analyses spread randomly over the design space. The trained network is then used to predict the values of the constraint function (performance and Cost). Then by using NSGAII the grid composite structure cost and performance are minimized simultaneously for a variety of geometrical and material variables. A set of near-optimum (in a Pareto sense) configurations is determined respectively. A platform fabrication stage is also considered for trading time and cost off by using NSGAII as second part of research. This study shows the ability of optimizing algorithms in EPC projects to minimize cost and time regarding to performance and quality. The applied method in this paper has been implemented successfully in real EPC project for construction grating system of petrochemical equipment.

Keywords-- Cost, Neural network, NSGAII Algorithm, grid composite structure, trade off project scheduling

I. Introduction

LIGHT but strong materials have been every engineer's dream. Owing to their high specific stiffness and strength, composite materials have been successfully employed in various industrial fields. Initially, the high cost has been an obstacle for the wide adoptions of advanced composites and the main application fields have been restricted to the aeronautic, structural and the oil and gas Industries. For example composites have been also gradually increasing their share in the automobile design where reinforced plastics are estimated to make up only 8% of the weight of the modern automobiles due to the high cost and the recycling problem [1].

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The optimal design of laminated composite plates for minimum weight has been investigated by several authors. Kam and Chang [2] studied the minimum weight design of the laminated composite plates subject to frequency, damping, and displacement constraints. Lee et al. [3] presented a minimum weight design of composite plates and hybrid composite plates with an aluminum layer subject to a concentrated load. The optimal design of the plate subject to frequency, specific damping capacity, and displacement constraints is presented. Walker et al. [4] studied the optimal design of symmetrically laminated composite plates for minimum deflection and weight. Many researchers [5–6] developed methods to determine the optimized laminate parameters, such as thickness and stacking sequence of layers for weight minimization and strength failure criterion. A genetic algorithm was used as a suitable optimization scheme for integer programming. A genetic algorithm has been used by many researchers [7-8] in stacking sequence optimization problems. In this study cost, performance and time are considered as primary design drivers for optimizing. One of significant result of present study is reducing the time of optimizing and makes it economically reasonable for practical usage. The required data are extracted from real case project of construction grating system for Arak petrochemical complex.

II. Platform System

Platforms provide proper, safe and effective space for inspectors, workers and engineers to reach different part of equipment during construction and operation period in oil and gas refineries. As these parts should be fabricated in huge numbers and with some restriction in term of time, quality and cost, it would be considered as important challenge in EPC projects. The usage of platform including variety of facilities such as stair ways, connection path and walking way for almost all petrochemical equipment.

A.Panel Configuration

The subject grid composite structure in this study shown in Figure 1.

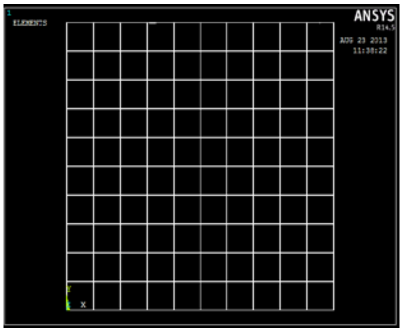

Fig.1 Configuration of grid composite structure

The panel is flat with dimensions 100 cm x 100 cm and with one edge clamped supported boundary condition. The grid networks are assumed to have rectangle as cross section. The geometrical attributions of the grid composite such as width of ribs, thickness (height) of the whole structure are varied between (2mm to 5mm) and (20mm to 50mm) respectively. Also the volume fraction of applied fibers is different (0.4 to 0.8) to study the effect of material properties in optimizing cost and performance of structure. The finite element software (ANSYS) is implemented to analysis of composite plate in.

B.Cost (Engineering stage)

The cost of fabrication in this study is all based on fiber volume fraction. This parameter affects composite properties as well density. So when we change the dimensional attributions (volume) of structure the weight of structure change regarding to applied fiber volume fraction. Density of composite would be computed by following formulation for given value of volume fraction:

$$\rho = \rho_f V_f + \rho_m (1 - V_f)$$

Which ρ, ρ_f and ρ_m indicate density of composite, fiber and matrix respectively. V_f is volume fraction for fiber. In this study for preparing set of input data for ANSYS and ANN, different arrangement for dimension and volume fraction are considered regarding to their resulted displacement and cost.

III. Non dominated sorting genetic algorithm (NSGA)-II

Genetic algorithms use a separate search space and solution space. The search space is the space of coded solutions, i.e. genotypes or chromosomes consisting of genes. More exactly, a genotype may consist of several chromosomes, but in most practical applications genotypes are made of one chromosome. The solution space is the space of actual solutions, i.e. phenotypes. Any genotype must be transformed into the corresponding phenotype before its fitness is evaluated. When solving a problem using genetic algorithms, first a proper representation and fitness measure must be designed. The initial population is filled with individuals that are generally created at random. Sometimes, the individuals in the initial population are the solutions found by some method determined by the problem domain. In this case, the scope of the genetic algorithm is to obtain more accurate solutions. Then each individual in the current population is evaluated using the fitness measure. If the termination criterion is met, the best solution is returned. From the current population individuals are selected based on the previously computed fitness values. A new population is formed by applying the genetic operators (reproduction, crossover, mutation) to these individuals. The selected individuals are called parents and the resulting individual's offspring. Implementations of genetic algorithms differ in the way of constructing the new population. Some implementations extend the current population by adding the new individuals and then create the new population by omitting the least fit individuals. Other implementations create a separate population of new individuals by applying the genetic operators. Moreover, there is GAs that do not use generations at all, but continuous replacement. Actions starting from step 2 are repeated until the termination criterion is satisfied. An iteration is called generation. In each generation, the genetic operators are applied to selected individuals from the current population in order to create a new population. Generally, the three main genetic operators of reproduction, crossover and mutation are employed. By using different probabilities for applying these operators, the speed of convergence can be controlled. Crossover and mutation operators must be carefully designed, since their choice highly contributes to the performance of the whole genetic algorithm. Crossover. New individuals are generally created as offspring of two parents (as such, crossover being a binary operator). One or more so-called crossover points are selected (usually at random) within the chromosome of each parent, at the same place in each. The parts delimited by the crossover points are then interchanged between the parents, as shown in Fig. 2 .The individuals resulting in this way are the offspring.

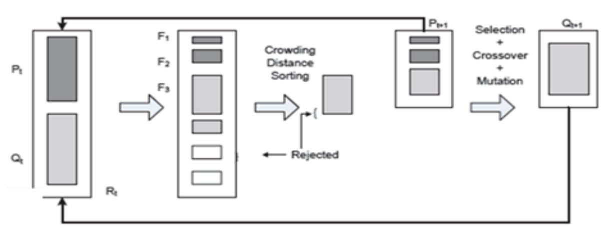

Fig. 2 NSGAII Procedure

IV. Methodology for performance and cost optimization

The applied method for optimizing the cost and performance is reviewed briefly in this section (Figure.3).

A. Finite element model is run to generate datasets randomly within the function space (upper and lower limit for each effective parameter). The FE model will be referred to the “exact” function f (X).

B. A number of datasets scattered in a partial function space for different attributions of grating plate. These data sets are used to train the neural network.

C. neural network is applied to fit the approximate function f (X) through the data points. The MATLAB Neural Network toolbox was used for this purpose. A neural network consists of a series of basic function evaluations (sigmoid functions) analogous. The neurons in an ANN are connected by synapses possessing "conductivities" or weights w_{ij}. A neural network can approximate a function when supplied with sample data from that function (1a from Fig.3). An iterative procedure is applied to reduce the network error $MSE(w_{ij}) = (\sum_L \sum_K (f(X, w_{ij}) - f(x))^2)/L$ where L the number of training sets and k the number of network outputs. ANN is preferred to polynomial fitting because of implementation n flexibility.

D. The approximated function supplies an output two order of magnitude faster than the FE model; this allows for extensive search algorithms such as genetic algorithms to be employed to search an optimal solution.

E. NSGAII is used to search for an optimal solution within the approximated function space as defined by the Neural Networks.

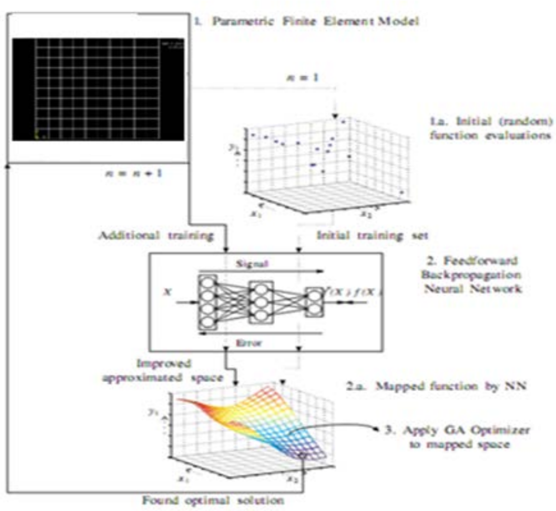

Fig. 3 Optimization strategy

V. NEURAL NETWORK-NSGAII ALGORITHM FOR GRATING PANEL OPTIMIZATION

In this paper two neural networks (Figure4) are architected to model the displacement as performance measurement of composite grating system and cost of fabrication regarding to fiber volume fraction and geometrical attribution (Table I and Table II). There are 200 extracted initial data from finite element software ANSYS to produce required material for training, test and validation stage in generating subject neural networks. The general aim of the training process is to teach the relations between input and output values to the program and get the results with the possible lowest errors (Figure5 and Figure6). The obtained FEM results at the previous section are used now as input and output data in each program (some of the input and output values were kept in order to be used for testing process after training). Training is completely a trial and error process and aims to get the appropriate network parameters to minimize the errors.

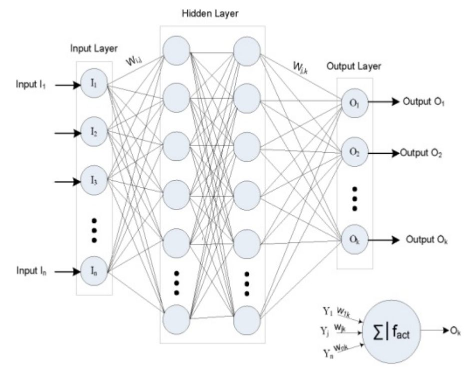

Fig.4 Overall configuration of neural network

TABLE I
FIRST NEURAL NETWORK PARAMETERS FOR MODELING THE DISPLACEMENT

Number of hidden layers	10
First parameter	Fiber volume fraction
Second parameter	Width of ribs
Third parameter	Height
Output	Displacement
Data division	Random
Training	Levenberg-Marquardt
Performance	Mean squared error
Epoch	18 Iteration

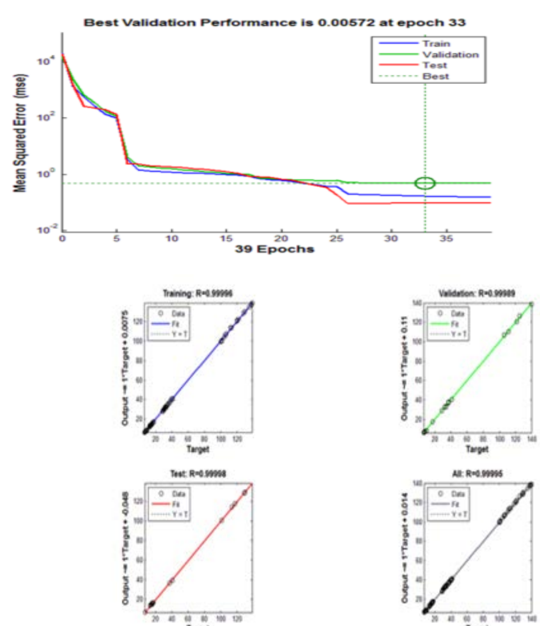

Fig. 5 Performance of neural network for modeling the displacement

TABLE II

SECOND NEURAL NETWORK PARAMETERS FOR MODELING THE COST

Number of hidden layers	10
First parameter	Fiber volume fraction
Second parameter	Width of ribs
Third parameter	Height
Output	Cost
Data division	Random
Training	Levenberg-Marquardt
Performance	Mean squared error
Epoch	16 Iteration

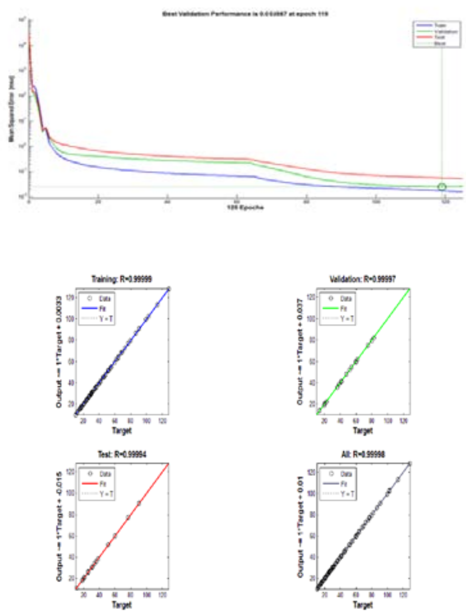

Fig. 6 Performance of neural network for modeling the cost

In the next step we trace to find optimum configuration for grid composite structure regarding fiber volume fraction, thickness of structure (Height) and width of ribs applied. We want to reach minimum deflection and minimum cost. Then, a multi-objective optimization under multiple constraints is treated. The objective function is formulated as a weighted sum of two design objectives (Figure 7).

$$Find: (Fiber\ volume\ fraction, Width\ of\ ribs, Height\ of\ panel)$$
$$Minimize: (F(x)), F(x) = 0.5\,P + 0.5\,C$$
$$subject\ to: Performance\ (Displacement) \leq 60mm\ and\ Cost\ \leq 130\$$$

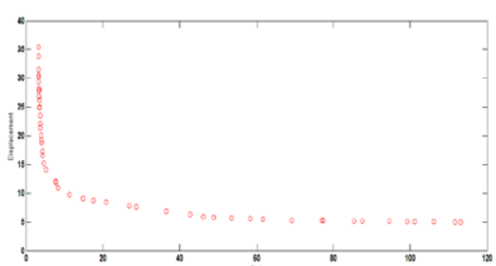

Fig. 7 Pareto front (NSGAII) for cost and performance of grid composite

VI. NSGAII FOR OPTIMIZATION COST AND TIME (CONSTRUCTION STAGE)

Platform fabrication for a refinery or even a unit of refinery included many activities needs to receive significant attention in term of time-cost trade off. A Project scheduling problems (PSP) is defined by its activities (each with a specific execution time) and by the precedence relations among them. The overall goal in project scheduling is to optimize a set of measure men functions subject to a set of precedence and resource constraints. In project scheduling, it is often possible to reduce the duration of some activities and thereby expedite the project duration with some additional costs. Project expedition decisions has traditionally involved time and cost trade-off considerations. However, it was recently suggested that the quality of a project should also be taken into consideration. In this study a time–cost–quality trade-off project scheduling problem for fabrication grating and steel structure parts for a platform system will be considered by using Multi-objective evolutionary algorithm. The required data (vendors and their offers for cost and completion period) are extracted from real case project of construction grating systems for Arak petrochemical complex. First of all main activities counterpart in fabrication of grating parts are listed with possible option regarding to time and cost to completion each activity (Table IV).

TABLE IV

PLATFORM FABRICATION ACTIVITIES

Activity Description	Activity Number	Requirement	Vendor Number	Time (Day)	Cost (US Dollar)
Mobilization	1	-------------	1	7	3200
			2	7	4150
			3	14	3123
Engineering	2	1	1	8	2323
			2	5	3453
			3	12	2980
Steel parts Fabricating	3	1,2	1	30	12000
			2	40	13200
			3	35	14230
NDT	4	3	1	3	7600
			2	2	6570
			3	3	6459
Composite part fabricating	5	4	1	15	11800
			2	17	12300
			3	21	11300
Assembly of steel structure in site	6	5	1	20	10550
			2	15	9980
			3	12	11200

In the next stage multi objective optimization method is performed to study time-cost trade off problem for platform construction project. The arrangement for decision making alternatives is as table 4. NSGAII is implemented to find pareto front regarding to cost and time. 48723$ and 73 days as output for NSGAII optimization (Figure8).

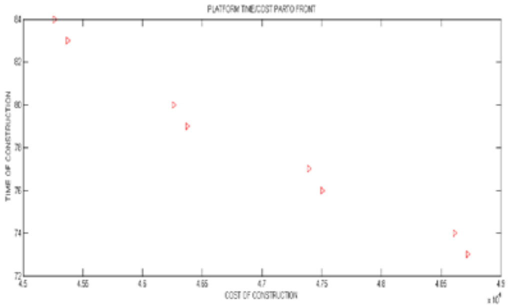

Fig. 8 Pareto front (NSGAII) for cost and time

TABLE III
ARRANGEMENT FOR VENDORS OF SPHERICAL STORAGE TANK

Activity	Assigned vendor for completion
Activity 1	1
Activity 2	2
Activity 3	1
Activity 4	2
Activity 5	2
Activity 6	3

VII. CONCLUSION

The use of neural networks and genetic algorithms for the optimization of grid composite panels has been investigated. In early designing stage of an EPC project there are some restrictions in term of preparation technical offer. So optimizing of the product is neglected in many cases because of project time scheduling. The main target of this research was to establish applicable optimizing procedure for industrial usage. The speed of the optimization makes the procedure attractive for its intended use in a multi-level strategy. It is expected that preparation time can be lowered and accuracy bounds can be narrowed significantly by implementing feedback of FE checked optimal solutions into the ANN training set.

In the next stage according to available data for construction grating system for Arak refinery petrochemical equipment, optimization method is implemented to solve time and cost trade off problem. Project management problems have been considered to be multi-objective problems including time and cost as objectives. In multi-objective problems, different objectives are commonly conflicting. The results show the increasing ability of making decision by authorized people during the project by using methahuristics methods to find the best arrangement of vendors to completion project within desired time and cost. Using multi objective optimization algorithms would be good strategy to help project managers to plan the project in any stage of project as well we giving decision makers the opportunity arrange their executive resources regarding the importance time and cost.

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