PERFORMANCE OF GENETIC ALGORITHM USING CHROMOSOME REPAIRING FOR 2D STEEL FRAME STRUCTURE OPTIMIZATION

Anik Budiati[1], Mohammad Ghozi[2]

Engineering Faculty, Bhayangkara Surabaya University,
INDONESIA.

[1] anikbudiati2013@gmail.com, [2] mghozi@ubhara.ac.id

ABSTRACT

Chromosome repairing process may influence the performance of Genetic algorithm (GA)in optimizing steel structure.The purpose of this paper is to discuss differences between results of 2D steel frame structure optimization with and without chromosome repairing(CR). Optimization processes are carried out through 2 types of 2D steel structure model using genetic algorithm (GA)-SAP2000. The first structure is designed according to AISC-LRFD and the second is designed according to AISC-ASD. GACR method results weight 15.50% for first structure model and 14.25% for second structure model less than GA's. The proposed method saves 1.69% and 38.13% computation time than GA's for the first and second structure models, respectively. It is concluded that GA with CR is very useful for steel frame structure optimization.

Keywords: Optimization, SAP2000, genetic algorithm, steel structure, chromosome repairing

INTRODUCTION

The application of genetic computation to the automated design of structures has followed several phases. The major application of genetic algorithms (GA) is the automated design to find optimized design of steel frame structure. Excellent method was combining commercial FEM program with GA in parallel computing method (Ghozi, et al, 2011).

The repair chromosome process can be incorporated with GA method and influence the performance (Michalewich, 1996). It will be amazing to find out how it works for solving steel optimization problem. Because of advantages of commercial FEM program are well known for structure's design and its combination with GA is possible, so it will be necessary for using combination of chromosome repairing (CR)-GA for research in optimization. For this reason, the difference of optimization result with and without CR process will be discussed.

THEORIES

Column arrangement concept

Stronger column always placed below the column at upper story. The stronger column can be seen as the bigger value of cross sectional area (Ac), column's depth (dc), elasticity modulus (E), plastic modulus (Z33) or radius of gyration (from the same yield strength). Since column arrangement concept based on column's depth and columns cross sectional area, then it is important to arrange the columns from lower story to the top story to have smaller depth and smaller cross sectional area.

Optimization methods pursue the best profile configuration of structure but disregard the above mentioned problem. The fitness method can't differentiate between one structure with one failure in the bottom story column and the other structure with one failure column in the top story. Further more, it is necessary to use multiplier as constraint so the failure at lower column can be avoided.

SAP2000

SAP2000 is a tool which already used for analyzing structure. SAP2000 process or import the file input with extension MDB, XLS, TXT and SDB. SAP2000 could export analysis result and design to other file such as XLS, TXT and SDB. After input file being opened, SAP2000 will run analysis, save the results and design of all members and create output file (Computer and structures, Inc., 2000). The required data such as frame stress and joint displacements dan be read as indicators for acceptance criteria (Ghozi, et al, 2011).

Simple Genetic Algorithm

GA is a population-based global search technique based on the Darwinian Theory (Goldberg, 1989). Common operators used in GA are initialization of population, evaluate population, selection, mating, crossover, mutation, stopping criteria and get results (Gen & Cheng , 1997). The preliminary approach of GAs is Simple Genetic Algorithm (SGA). SGA guides the evolutionary search by a single population. Individuals are then encoded in a string scheme associated with one of the codes (binary, integer or real code). In the evolutionary search, the promising individuals are chosen from the population by a selection operation (roulette wheel, stochastic universal sampling, ranking, truncation, etc.). Then, the chosen individuals are applied to recombination and mutation operation (one point or multipoint crossover and mutation, uniform crossover, etc.). These operations (mutation, crossover and selection) are governed by related parameters (mutation and recombination probability rates, selection pressure, etc.). The population evolved by the application of these evolutionary operators is decoded. Then, the fitness values are computed by use of this population. The evolutionary search is executed to transmit (migration) the individuals (emigrant and immigrants) to the next populations until satisfying a predetermined stopping criteria (Gen & Cheng, 1997; Haupt, 2003).

Chromosome repairing

Chromosome repairing (CR) is one strategy to change chromosome to be feasible one (Michalewich, 1996). With this method, original unfeasible chromosome is replaced by new feasible chromosome. In this paper CR is deployed by GA method. So there are two GA, one is big GA for steel structure optimization process and little GA for CR process. Because there are two GA methods, this program is called nested programming. All of chromosome will be repaired in the last genertion (see Fig. 1). The chromosomes are repaired with objective function to minimize weight subjected to weight of best weight constraint, joint connection constraint and column's depth constraint. The best wight is taken from individual with no constraints violated. If there are no individual with no constraints violated, so the best weight is taken from the biggest weight. With CR strategy, repaired individual will have four characteristics: 1) Structure has smaller weight than the best weight obtained, 2) columns in upper story has smaller depth profile than column in lower story, 3) at every beam-column joint, beam's width is smaller than column's width, and 4) columns in upper story has smaller cross sectional area than column in lower story.

Repaired chromosomes shall not be a repetition of the chromosomes that have been evaluated. When there is a repetition of chromosomes then CR proceeds to perform a substitution. With this process, the chromosomes will be replaced with a new chromosome that fits the objective function.

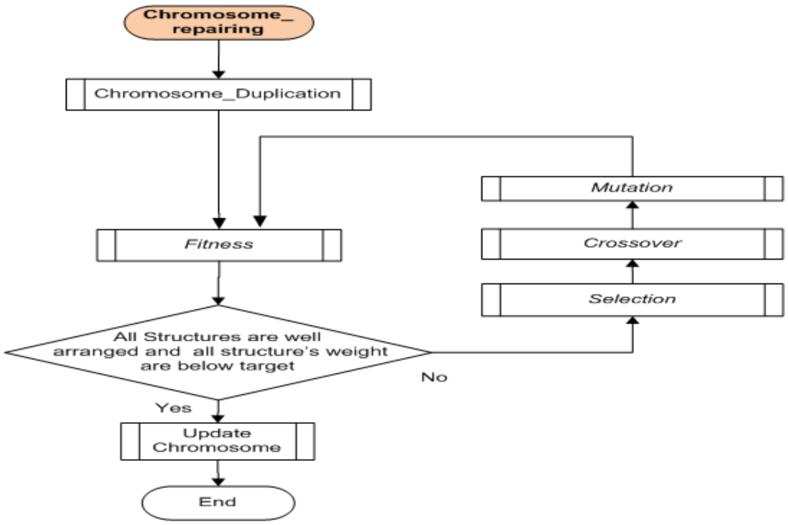


Figure 1. Flowchart of CR

Simple GA and SAP2000

Eventhough the structure model is simple, GA procedures are still processed in parallel computing method. Optimization problems are solved by using modification of GA-SAP2000 (Ghozi, et al, 2011). The modification is the addition of CR modul (see Fig. 2).

After the creation of initial population, the program commands PC to : 1) run SAP2000, 2) analyze input files, 3) design the input files, 3) close SAP2000. Each input file must have one output file. The message is to let PC to evaluate and calculate fitness value of each output file (see Figure 2). Data for of drift calculation are taken from "Joint Displacements" Table. Data for stress constraint calculation are taken from "Steel Design 1 – Summary Data AISC-ASD89" SAP2000 output file table. Raw data for drift ratio are taken from "Joint Displacements" SAP2000 output file table. This iteration is processed until the generation reaches 50 and 250 for first and second structure model, respectively.

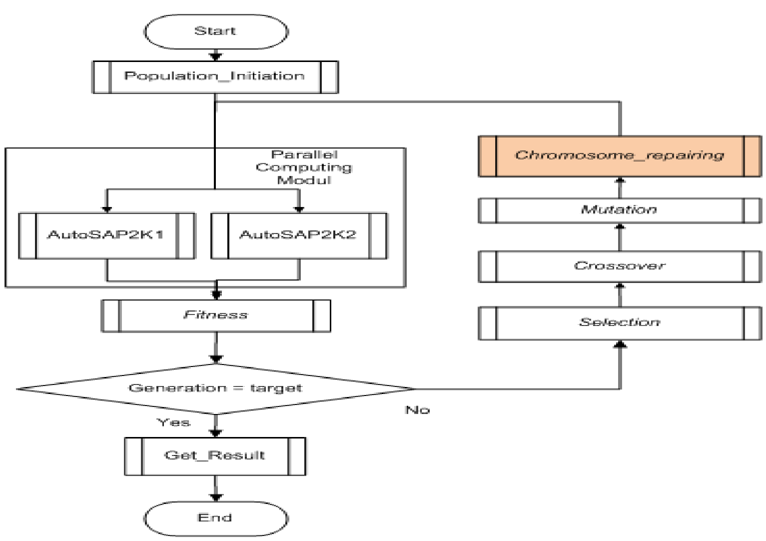
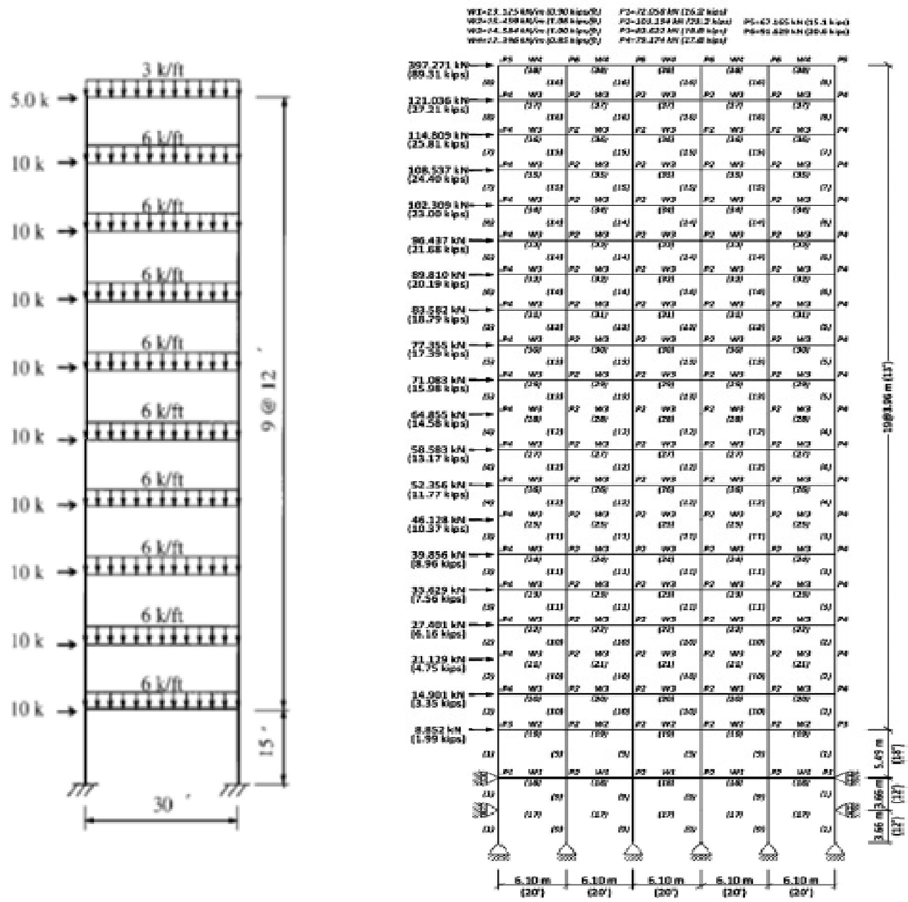


Figure 2. Flowchart of optimization using GACR

MATERIAL AND METHOD



(a) (b)

Figure 3. Structure models (a) Ten storey (Pezeshk, 2000), (b) 22 Storey (Safari, 2011)

Objective function for ten storey structure model is:

$$objfunc = \sum_{i=1}^{nelement} \rho A_i L_i \left(1 + \sum_{i=1}^{nelement} K\_stress_i + 5 \sum_{s=1}^{nstorey} K\_drift_s + \sum_{i=1}^{nelement} K\_slenderness_i + \sum_{i=1}^{nelement} K\_compactelement_i\right) \quad \ldots (1)$$

Where :

$\rho A_i L_i$: is element's weight

K_stress_i: is stress constraint according to AISC-LRFD.

K_drift_s : is drift constraint.

$K\_slenderness_{e}$: : is slenderness constraint.

$K\_compactelement_e$: is element's compact ratio constraint

Objective function for 22 storey structure model is:

$$objfunc = \sum_{i=1}^{nelement} \rho A_i L_i \left(1 + \sum_{i=1}^{nelement} K\_stress_i + 5 \sum_{j=1}^{njoint} K\_drift_j + \sum_{j=1}^{njoint} K\_columndepth_j + \sum_{e=1}^{nelement} K\_compactelement_e + \sum_{e=1}^{nelement} K\_slenderness_e + \sum_{j=1}^{njoint} K\_SCWBratio_j \right) \quad \ldots(2)$$

Where:

$\rho A_i L_i$: is weight of element

K_stress_i: is stress constraint according to AISC-ASD.

$K\_slenderness_i$: is slenderness constraint

K_drift_j: is drift constraint.

$K\_columndepth_j$: is column's depth constraint.

$K\_compactelement_e$: is element's compact ratio constraint

$K\_rasiobalokkolom_j$: is beam-column flens's width constraint.

$K\_SCWBratio_j$: is strong column weak beam constraint.

Objective function of CR is:

$$\boldsymbol{o}bjfunc' = 1 + \left\{ \sum_{e=1}^{nelement} K\_Weight_e + \sum_{j=1}^{njoint} K\_Columndepth_j + \sum_{j=1}^{njoint} K\_Columnarea_j + \sum_{j=1}^{njoint} K\_Beamdepth_j + \sum_{j=1}^{njoint} K\_BeamZ33_j + \sum_{j=1}^{njoint} K\_BeamColumnflenswidthratio_j \right\} \quad \ldots(3)$$

Where :

K_Weight_e: is weight constraint.

$K\_Columndepth_j$: is column's depth constraint.

$K\_Columnarea_j$: is column's area constraint.

$K\_Beamdepth_j$: is beam's depth constraint

$K\_BeamZ33_j$: is beam's plastic modulus constraint

$K\_BeamColumnflenswidthratio_j$: is Beam-Column flens ratio constraint

Parameters for CR process are crossover probability = 0.8 , mutation probability = 0.005 , Selection (Elitism) = 2 individuals, Selection (Roulette wheel) = total individu-2, Stopping criteria = stop CR process if all individual has fitness value =100.

Penalty function is used for calculating all constraints. If constraint is not violated then the objective function then constraint's value equal to 0, if not then constraint's value equal to 1.

RESULT AND DISCUSSION

Two optimization processes have been completed using GACR method. The results of GACR are then compared with result of GA and also statistical data are given for each GACR result.

Ten Storey Structure Model

For the ten storey structure model, optimization process with GACR results statistical data as shown in Table 1 and the objective function plot is shown in Figure 4.

Table 1. Statistical data of GACR of Ten storey structure model optimization

Statistical Data	*Value*
Best Weight	24667.04 kg
Average Weight	25448.68 kg
Worst Weight	26784.98 kg
Standard Deviation	426.70 kg
Coeficient of Variant	1.68%

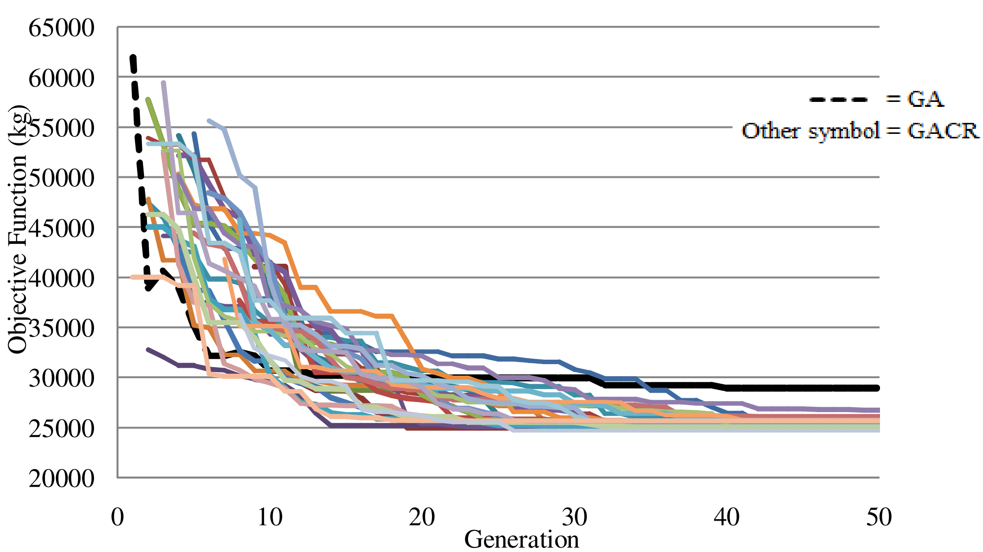


Figure 4. Objective function plot of ten storey optimization

For ten storey structure model optimization, GACR results structure weight ranged from 26784.98 kG to 24667.04 kG. It has average weight 25448 kG and the GACR results best structure's weight 15,50% lighter than GA and saves 1,69% computing time.

22 Storey Structure Model

For the ten storey structure model, optimization process with GACR results statistical data as shown in Table 2 and the objective function plot is shown in Figure 5.

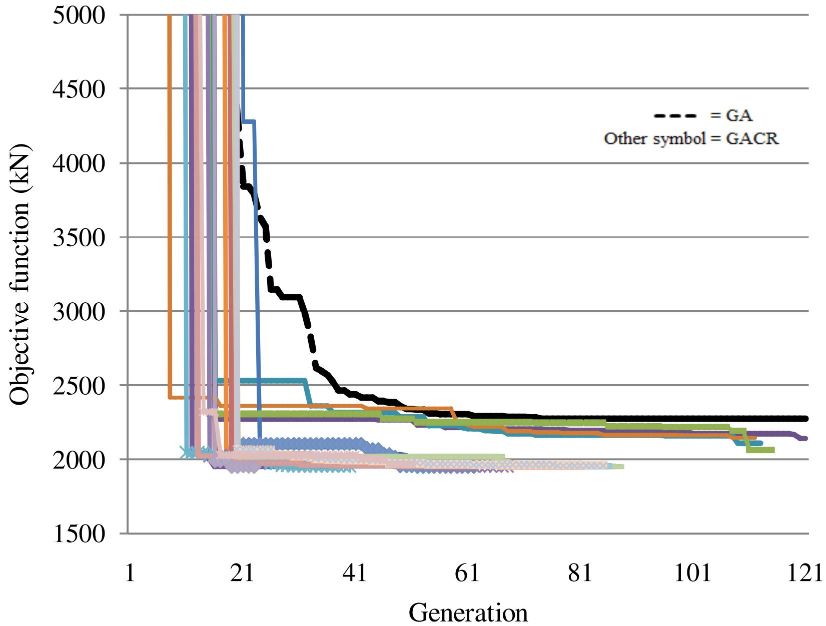


Figure 5. Objective function plot of 22 storey optimization

GACR for optimizing 22 storey structure model has been done 30 times. The structure's weight have statistica data shown in Table 2.

Table 2. Statistical data of GACR of 22 storey structure model optimization

Statistical Data	*Value*
Best Weight	1950.13 kN
Average weight	1993.01 kN
Worst weight	2145.04 kN
Standard Deviation	68.63 kN
Coeficient of variant	3.44%

For 22 storey structure model optimization, GACR results structure weight ranged from 2145.04 kN to 1950.13 kN. It has average weight 1993 kG and the GACR results best structure's weight 14,25% lighter than GA and saves 38,13% computing time.

CONCLUSION

GACR has already been applied to optimze two structure models. The results of GACR are then compared to GA's result. GACR method results weight 15.50% for first structure model and 14.25% for second structure model less than GA's. The proposed method saves 1.69% and 38.13% computation time than GA's for the first and second structure models, respectively. It is concluded that the GACR method is more robust and also faster in computing process.

REFERENCES

[1] American Institute of Steel Construction (1989). *Manual of Steel Construction Allowable Stress Design*. Chicago, USA.

[2] Computer and Structures, Inc.,(2000). SAP2000- *Integrated Finite Element Analysis And Design Structures : Steel Design Manual. version 7.4*. Revision May 2000. California, USA.

[3] Gen, M. & Cheng, R. (1997*). Evolutıonary Algorıthm And Engıneerıng Desıgn*. New York: John Wiley & Sons, Inc. A wiley-Interscience publication.

[4] Ghozi, M. et al., (2011). Performance of 2D Frame Optimization Considering the Sequence of Column Failure Mechanism Using GA-SAP2000. *Academic Research International, 1*(3), 394-402.

[5] Goldberg, D. E. (1989). *Evolutionary Algorithm İn Search, Optimization and Machine Learning*. Boston: Addition Wesley publishing company Inc.

[6] Haupt, R. L. & Haupt, S. E. (2004). *Practical Genetic Algorithm*. New York: John Wiley & Sons, Inc. A wiley-Interscience publication.

[7] Safari, D. et al., (2011). Optimum Design of Steel Frames Using A Multiple-Deme GA With Improved Reproduction Operators. *Journal of Constructional Steel Research, 67*(8), 1232–1243.