Steel and Composite Structures, *Vol. 22, No. 3 (2016) 521-535*
DOI: http://dx.doi.org/10.12989/scs.2016.22.3.521

A comparative study on optimum design of multi-element truss structures

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(*Received February 19, 2016, Revised June 16, 2016, Accepted October 14, 2016*)

Abstract. A Harmony Search (HS) and Genetic Algorithms (GA), two powerful metaheuristic search techniques, are used for minimum weight designs of different truss structures by selecting suitable profile sections from a specified list taken from American Institute of Steel Construction (AISC). A computer program is coded in MATLAB interacting with SAP2000-OAPI to obtain solution of design problems. The stress constraints according to AISC-ASD (Allowable Stress Design) and displacement constraints are considered for optimum designs. Three different truss structures such as bridge, dome and tower structures taken from literature are designed and the results are compared with the ones available in literature. The results obtained from the solutions for truss structures show that optimum designs by these techniques are very similar to the literature results and HS method usually provides more economical solutions in multi-element truss problems.

Keywords: AISC-ASD; harmony search algorithm; genetic algorithm; optimum design; truss structures

1. Introduction

In recent years, different many metaheuristic search techniques such as Genetic Algorithm (GAs), Harmony Search Algorithm (HS), Ant Colony Algorithm (ACO), Evolution Strategies (ESs), Particle Swarm Optimizer (PSO), Artificial Bee Colony Algorithm (ABC), Tabu Search Algorithm (TS), Simulated Annealing (SA) Algorithm, Cuckoo Search (CS) Algorithms and Teaching-Learning-Based Optimization Algorithm (TLBO) have been widely used in structural optimization by many researchers. In this study, Harmony Search and Genetic Algorithms, two powerful stochastic methods, are selected to use for optimum designs of different truss structures.

Lee and Geem (2004) introduced detailed information about one of the recent techniques, Harmony Search Algorithm (HS), depending on musical performance processes. Saka (2009) used this algorithm method for optimum design of steel sway frames according to BS5950. Değertekin *et al*. (2009) examined optimum design of geometrically non-linear steel frames with semi-rigid connections using a harmony search algorithm. Değertekin and Hayalioglu (2010) researched on harmony search algorithm for minimum cost design of steel frames with semi-rigid connections and column bases. Değertekin *et al*. (2011) focused on optimum design of geometrically nonlinear steel frames with semi-rigid connections using improved harmony search method. Toğan *et al*. (2011) studied optimization of trusses under uncertainties with harmony search. Artar (2016)

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http://www.techno-press.org/?journal=scs&subpage=6 ISSN: 1229-9367 (Print), 1598-6233 (Online)

researched optimum design of steel space frames under earthquake effect using harmony search.

On the other hand, Genetic Algorithm (GA), one of the first techniques, developed by Goldberg (1989) mimics biological processes such as reproduction, crossover and mutation. Rajeev and Krishnamoorthy (1992) used this method on some simple benchmark problems. This algorithm technique was applied to planar steel frames according to Turkish Building Code for Steel Structures by Daloğlu and Armutcu (1998). In later years, Genetic Algorithm was used for different structural problems such as a 72-bar transmission tower, a 112-bar steel dome and an industrial building by Erbatur *et al*. (2000). In the recent years, Genetic Algorithm has been widely used for various structural systems. (Kameshki and Saka 2001, Hayalioglu and Değertekin 2004, Değertekin *et al*. 2008). Toğan and Daloğlu (2008) studied an improved genetic algorithm with initial population strategy and self-adaptive member grouping. Artar and Daloğlu (2015a) investigated optimum design of composite steel frames with semi-rigid connections and column bases via genetic algorithm. Artar and Daloğlu (2015b) studied optimum design of steel space frames with composite beams using genetic algorithm. Artar and Daloğlu (2015c) focused on the optimization of multi-storey composite steel frames with genetic algorithm including dynamic constraints. Daloğlu *et al*. (2016) used genetic and harmony search algorithms for optimum design of steel space frames including soil-structure interaction.

Furthermore, several studies in literature have been carried out by using the other metaheuristic search techniques. Hasançebi *et al*. (2010) studied improving performance of simulated annealing in structural optimization. Aydoğdu and Saka (2012) researched optimum design of irregular steel space frames including element warping effect useing Ant Colony Optimization. Kaveh and Talatahari (2012) used a hybrid CSS and PSO algorithm method to solve optimal design of different structural problems. Hasançebi and Çarbaş (2014) researched bat inspired algorithm for discrete size optimization of steel frames. Dede (2014) used teaching-learning-based-optimization algorithm for optimum designs of truss structures. Hadidi and Rafiee (2014) studied minimum cost design of semi-rigid steel frames using harmony search based, improved Particle Swarm Optimizer.

In the literature, there are several studies available on space or planar trusses which are not complex problems. However, it is hard to see comparative studies on multi-element truss problems. In this study, two basic stochastic optimization techniques, Harmony Search and Genetic Algorithms are used to obtain optimum solutions of different truss structures such as a plane truss bridge, a truss dome, and a multi-element space truss towers. MATLAB incorporated with SAP2000-OAPI (Open Application Programming Interface) is used to obtain optimum designs of the structures. Three different truss problems taken from literature are separately solved by HS and GA. The profile sections determined in the analyses are compared with the ones available in previous studies. The results demonstrate the applicability and robustness of MATLAB-SAP2000 OAPI for different structural problems. Moreover, the minimum steel weights of multi-element truss structures designed by Harmony Search Algorithm (HS) are usually more economical than the ones obtained by Genetic Algorithm (GA).

2. Optimum design problem of steel trusses

The discrete optimum design problem of steel trusses for minimum weight is determined as follows

$$\min W = \sum_{k=1}^{ng} A_k \sum_{i=1}^{nk} \rho_i L_i \tag{1}$$

where W is the weight of the frame, A_k is cross-sectional area of group k, ρ_i and L_i are density and length of member i, n_g is total number of groups, n_k is the total number of members in group k.

The truss examples in the present study are subjected to the displacement and stress constraints of AISC-ASD (1989) specifications. In third example, multi-element truss tower, the constraints of cross-section areas for vertical members are also applied.

The displacement constraints are shown as below

$$g_j(x) = \frac{\delta_{jl}}{\delta_{ju}} - 1 \leq 0 \qquad j = 1,...,n \tag{2a}$$

where δ_{jl} is displacement of j^{th} degree of freedom, δ_{ju} is upper bound, n is number of restricted displacements.

The stress constraints are shown as below

$$g_m(x) = \frac{\sigma_m}{\sigma_{m,all}} - 1 \leq 0 \qquad m = 1,...,ne \tag{2b}$$

where σ_m and $\sigma_{m,all}$ are the computed and allowable axial stresses for m^{th} truss member, respectively.

The stress constraints taken from AISC–ASD (1989) are presented as below;

– For tension members, the allowable stress is defined as

$$\sigma_{t,all} = 0.6F_y \tag{3}$$

where F_y is yield stress.

– For compression members, the allowable stresses are calculated as

$$\lambda_m = \frac{K_m L_m}{r_m} \qquad m = 1,...,ne \tag{4}$$

$$C_C = \sqrt{\frac{2\pi^2 E}{F_y}} \tag{5}$$

$$\text{for inelastic buckling } (\lambda_m \geq C_c); \qquad \sigma_{c,all} = \frac{\left[1 - \frac{\lambda_m^2}{2C_c^2}\right]F_y}{\frac{5}{3} + \frac{3\lambda_m}{8C_c} - \frac{(\lambda_m^3)}{8C_m^3}} \tag{6}$$

$$\text{for elastic buckling } (\lambda_m \geq C_c); \qquad \sigma_{c,all} = \frac{12\pi^2 E}{\lambda_m^2} \tag{7}$$

where λ_m is the slenderness ratio, K_m is the effective length factor (K = 1.00 for truss member), r_m

is minimum gyration radii, C_c is the critical slenderness ratio parameter.

In the third example, the multi-element truss tower, the section area constraints for vertical members are applied as below

$$g_m(x) = \frac{A_{u,m}}{A_{l,m}} - 1 \leq 0 \qquad m = 1,...,ne \tag{8}$$

where $A_{u,m}$ and $A_{l,m}$ are the section areas of upper profile and lower profile, respectively.

3. Harmony search algorithm

One of the recent metaheuristic techniques, Harmony Search (HS) method developed by improvising a better musical harmony is applied to optimum design of steel structures. HS consists of three basic steps as expressed as below;

Step 1: Harmony memory matrix (HM) is initialized. It is filled with specified number of solutions as HMS (Harmony Memory Size). Each row of HM indicates the design variables. HMS is very similar to the total number of individuals in the population of the genetic algorithm. The form of this matrix is presented as below

$$H = \begin{bmatrix} x_1^1 & x_2^1 & .. & x_{n-1}^1 & x_n^1 \\ x_1^2 & x_2^2 & .. & x_{n-1}^2 & x_n^2 \\ .. & .. & .. & .. & .. \\ x_1^{HMS-1} & x_2^{HMS-1} & .. & x_{n-1}^{HMS-1} & x_n^{HMS-1} \\ x_1^{HMS} & x_2^{HMS} & .. & x_{n-1}^{HMS} & x_n^{HMS} \end{bmatrix} \begin{matrix} \rightarrow & \varphi(x^1) \\ \rightarrow & \varphi(x^2) \\ \rightarrow & .. \\ \rightarrow & \varphi(x^{HMS-1}) \\ \rightarrow & \varphi(x^{HMS}) \end{matrix} \tag{9}$$

where, x_i^j is the i^{th} design variable of j^{th} solution vector, n is the total number of design variables, $\varphi(x^j)$ is j^{th} objective function value.

Step 2: Harmony memory matrix is evaluated and their objective function values ($\varphi(x^1)$, $\varphi(x^2)$,..., $\varphi(x^{HMS-1})$, $\varphi(x^{HMS})$) are determined. The solutions in the harmony memory matrix are sorted according to the objective function values.

Step 3: New harmony memory matrix $x^{nh} = [x_1^{nh}, x_2^{nh}, ..., x_n^{nh}]$ is improvised. A new solution is carried out by selecting each design variable from either harmony memory matrix or the entire section list depending on harmony memory consideration rate (HMCR) which is between 0 and 1. The new value of the design variable selected from harmony memory matrix is checked whether this value should be pitch-adjusted or not depending on pitch adjustment ratio (PAR). HMS, HMCR and PAR are tried according to different values and these parameters in this study are selected as 20, 0.8 and 0.3, respectively. The detailed information about HS algorithm can be obtained from Lee and Geem (2004).

4. Genetic algorithm

Genetic Algorithm (GA) was proposed by Goldberg (1989). The main purpose is to minimize the objective functions. This algorithm method mimics natural biological processes such as

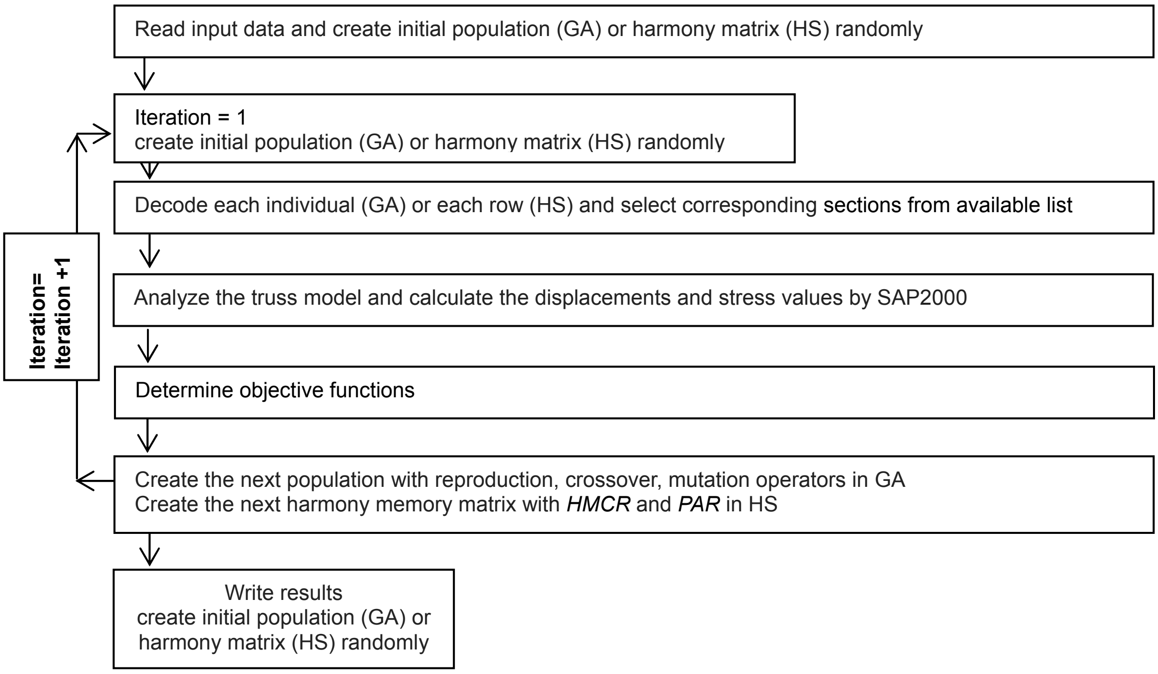


Fig. 1 The flowchart of MATLAB-SAP2000 OAPI for HS and GA

reproduction, crossover and mutation to get a stronger population for optimum solution. In this study, double point crossover is applied. GA steps used in the optimum designs are presented as below;

(1) Start with random initial population comprised of individuals which are coded as binary digits in MATLAB programming.
(2) Decode each individual in MATLAB programming and select corresponding profiles from available section lists in SAP2000 software.
(3) Analyze according to selected profiles by SAP2000 software.
(4) Determine objective functions in MATLAB programming.
(5) Apply reproduction, double-point crossover and mutation operators in MATLAB programming.
(6) Replace the initial population with the new population in MATLAB programming.
(7) Repeat all steps until the convergence is obtained.

The flowchart of MATLAB-SAP2000 OAPI for HS and GA methods are presented in Fig. 1.

5. Design examples

A comparative study on Harmony Search and Genetic Algorithms is researched with three different truss examples taken from literature. Moreover, the applicability and robustness of MATLAB incorporated with SAP2000-OAPI on minimization of truss weight is investigated in the examples. The design examples include a 113-member plane truss bridge, a 120-member truss dome and a 582-member space tower. For first and third examples, optimum cross sections are selected from a specified list including 128 W profiles taken from American Institute of Steel Construction (AISC) and material properties of the steel are modulus of elasticity, E = 203893.6 MPa, and yield stress, F_y = 253.1 MPa (Hasançebi *et al*. 2009). For second example, optimum cross sections are selected from a specified list including 30 pipe section taken from AISC and material properties of steel are E = 210000 MPa and F_y = 400 MPa (Lee and Geem 2004). In this study, harmony memory size and population size are taken as 20 for all solutions.

5.1 113-member plane truss bridge

113-member plane truss bridge is collected into 43 groups as seen Fig. 2. This three-span bridge has a total length of 560 ft. This problem was previously studied with different algorithm methods (Simulated Annealing (SA), Evolution Strategies (ESs), Genetic Algorithm (GAs), Particle Swarm Optimizer (PSO), Tabu Search (TS), Ant Colony Optimization (ACO) and Harmony Search Algorithm (HS)) by Hasancebi *et al*. (2009). Hasancebi *et al*. (2009) obtained the best optimum results of 113-member plane truss bridge by using Evolution Strategies (ESs). A point load of 80 kips (355.86 kN) is applied to each point on the upper chord. In this study, stress constraints of AISC-ASD and displacement constraints are imposed on the truss. Maximum

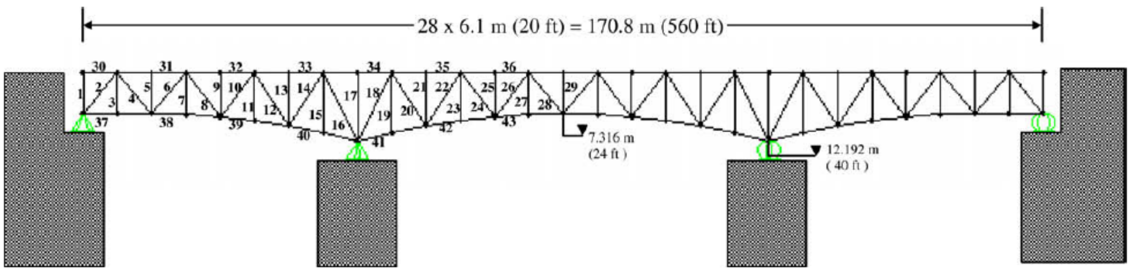


Fig. 2 113-Member plane truss bridge

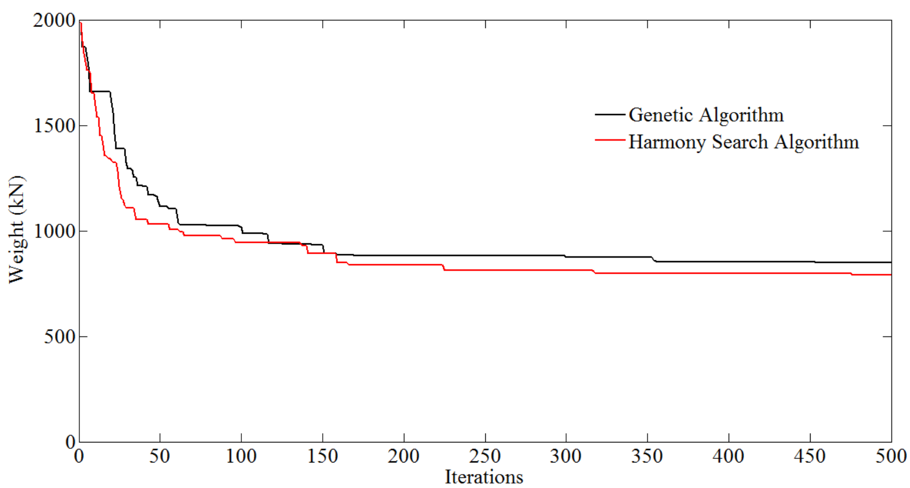


Fig. 3 The variations of the minimum weight with iteration steps

Table 1 Optimum design results

Group no	Hasançebi *et al*. (2009)	This study	
	Evolution Strategies (ESs)	Genetic Algorithm (GA)	Harmony Search Algorithm (HS)
1	W10×39	W10×30	W10×26
2	W12×72	W12×53	W16×50
3	W8×21	W8×13	W16×45
4	W8×21	W6×15	W5×16
5	W10×39	W12×30	W14×26
6	W8×21	W5×16	W16×36
7	W8×21	W12×30	W14×38
8	W12×65	W14×48	W14×30
9	W10×45	W12×35	W16×26
10	W8×35	W10×45	W10×45
11	W8×31	W6×12	W6×16
12	W14×99	W24×117	W18×65
13	W10×49	W14×48	W14×74
14	W10×49	W21×83	W14×53
15	W10×49	W12×53	W12×14
16	W14×159	W18×97	W14×90
17	W12×65	W8×48	W14×34
18	W14×176	W12×106	W14×132
19	W10×49	W8×31	W10×30
20	W12×79	W16×77	W16×77
21	W10×49	W16×67	W12×58
22	W14×120	W36×194	W27×161
23	W8×21	W12×19	W14×26
24	W14×68	W8×48	W16×40
25	W10×45	W16×45	W10×17
26	W12×79	W18×97	W18×130
27	W8×21	W6×25	W12×26
28	W8×35	W18×97	W16×45
29	W12×53	W36×194	W6×25
30	W10×49	W12×53	W10×45
31	W10×49	W21×50	W18×46
32	W12×40	W21×57	W21×68
33	W14×90	W16×100	W24×117
34	W10×88	W24×117	W12×87
35	W12×53	W18×106	W12×58
36	W10×88	W14×99	W16×77
37	W8×21	W18×55	W12×26

Table 1 Continued

Group no	Hasançebi *et al*. (2009)	This study	
	Evolution Strategies (ESs)	Genetic Algorithm (GA)	Harmony Search Algorithm (HS)
38	W6×25	W18×71	W10×54
39	W8×40	W6×20	W18×60
40	W14×90	W16×67	W18×130
41	W12×87	W16×67	W24×117
42	W8×21	W16×50	W10×19
43	W10×100	W16×67	W21×73
Max disp. (cm)	-	7.31	7.27
Total weight (kN)	810.778	854.476	788.342

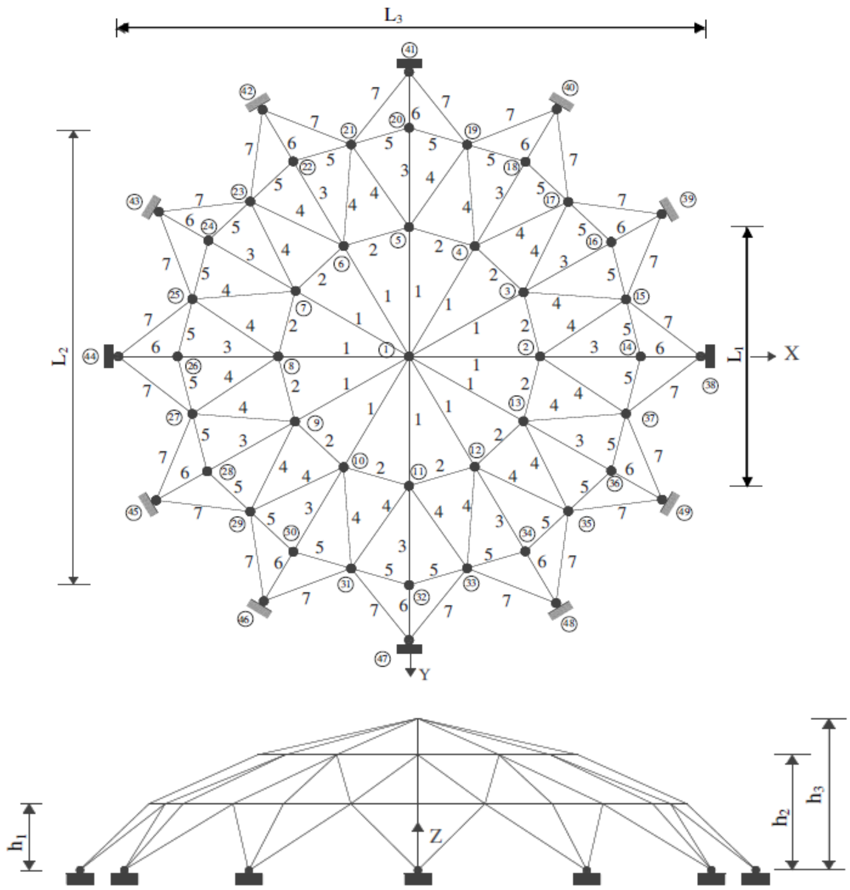
displacement is restricted to 7.31 cm which is equal to 1/1000 of the middle span of the truss bridge. Minimum weight, maximum displacement values and optimum cross-sections for HS and GA solutions are presented in Table 1 and these results are compared with literature results according to Evolution Strategies (ESs). Fig. 3 shows the variations of the weight with iteration steps.

As it is observed from Table 1 that the optimum *W* cross sections determined by GA and HS are very close to the results obtained by Hasançebi *et al*. (2009). In the optimum solution of GA, maximum displacement, 7.31 cm, is equal to the upper limit value. Moreover, this value is 7.27 cm for the optimum solution of HS. Therefore, it can be said that displacement constraints in this truss problem are very important determinants of optimum designs in addition to stress constraints. As shown in Table 1, the minimum weight obtained by HS, 788.342 kN, is about 2.7% lighter than the value of Hasançebi *et al*. (2009). On the other hand, this value obtained by GA, 854.476 kN, is about 5.3% heavier than the value of Hasançebi *et al*. (2009). It can be seen in Fig. 3. that the variations of minimum weight with iterations carried out by HS are usually lighter than the ones of optimum solutions of GA. Furthermore, it is observed from both solutions that MATLAB incorporated with SAP2000-OAPI introduces a suitable technique for practical solutions of optimum designs.

5.2 120-member truss dome

Fig. 4 shows a 120-member truss dome which is collected into 7 groups.

The required length information is also given in Fig. 4. This space truss problem was previously studied by Lee and Geem (2004), Toğan and Daloğlu (2008). Optimum designs are carried out by using a specified list including 30 pipe section taken from AISC. The vertical loading at the all unsupported joints is imposed on the truss dome as -13.49 kips (-60 kN) at node 1, -6.744 kips (-30 kN) at nodes 2-14 and -2.248 kips (-10kN) at the other nodes. The truss dome is subjected to stress constraints of AISC-ASD and displacement constraints. Maximum displacement is restricted to 0.1969 in. (0.50 cm). Minimum weight, maximum displacement values and optimum cross-sections for HS and GA solutions are presented in Table 2 and the results are compared with the ones previously carried out in literature. Fig. 5 shows the variations of the weight with iteration steps.



L_1 = 13883.89 mm; L_2 = 24085.55 mm; L_3 = 31775.91 mm;
h_1 = 3000 mm; h_2 = 5850.13 mm; h_3 = 7000 mm

Fig. 4 120-Member truss dome

Table 2 Optimum pipe profiles and their cross-section areas

	Literature results (cm^2)		This study (cm^2)	
Group no.	Lee and Geem (2004)	Toğan and Daloğlu (2008)	Genetic algorithm	Harmony search algorithm
1	21.27	17.29	PX3(19.48)	P3.5(17.29)
2	17.99	14.39	P3.5(17.29)	P4(20.45)
3	24.98	27.74	P2.5(10.97)	P2.5(10.97)
4	16.58	14.39	PX3(19.48)	P3(14.39)
5	7.41	5.16	PX2(9.55)	PX2(9.55)
6	21.49	20.45	PX2.5(14.52)	P3(14.39)
7	17.94	17.29	PX3.5(23.74)	PX3.5(23.74)
Weight kN	88.52	81.40	86.83	80.68

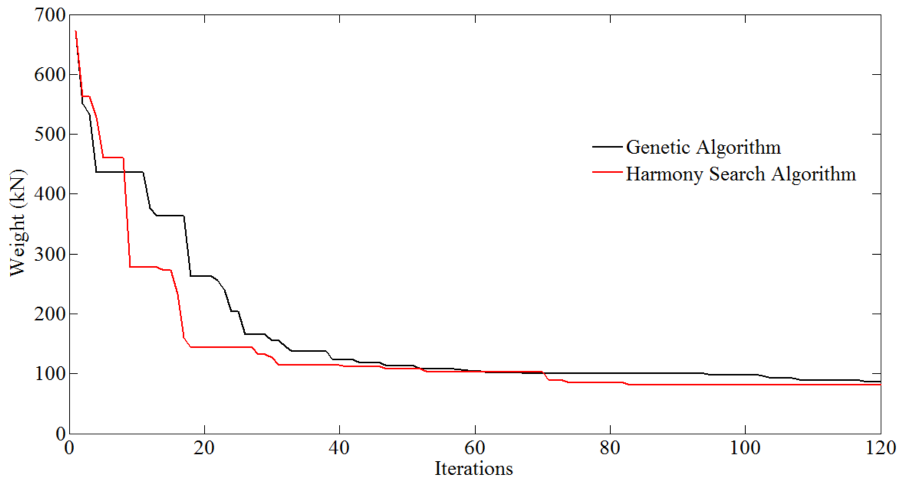
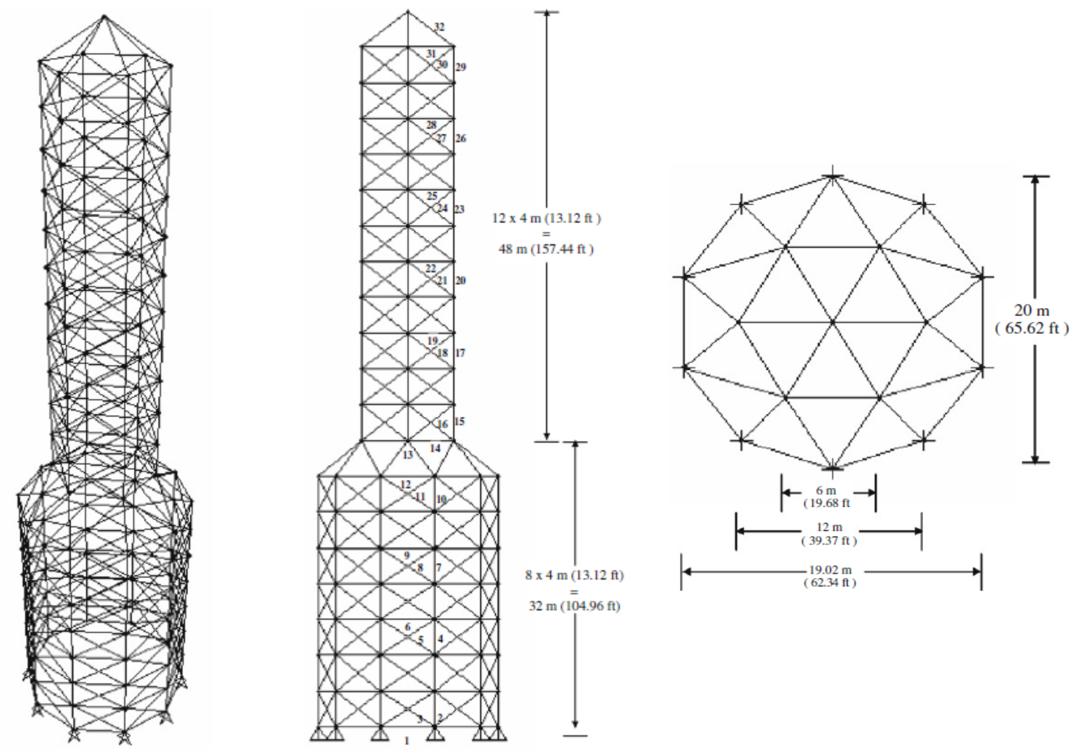


Fig. 5 The variations of the weight with iteration steps



(a) 3d view (b) Side view (c) Top view

Fig. 6 582-Member space truss tower

As it is seen in from Table 2 that the optimum Pipe sections obtained by the both algorithms (GA and HS) in this study are very similar to the literature results (Lee and Geem 2004, Togan and Daloglu 2008). The minimum weight of the optimum design by Genetic Algorithm, 86.83 kN, is between the ones of reference studies while the minimum weight obtained by Harmony Search Algorithm, 80.68 kN, is about 9% and 0.89% lighter than the ones of reference studies, respectively. It can be also observed from Fig. 5. that the variations of minimum weight with iterations carried out by Harmony Search Algorithm are usually lighter than the minimum values by Genetic Algorithm.

5.3 582-member space truss tower

582-member space truss tower as shown in Fig. 6. is collected into 32 groups. The steel tower with 80 m long was previously studied with different algorithm methods (SA, ESs, GAs, PSO, TS, ACO and HS) by Hasancebi *et al*. (2009) and the best results of the truss tower in their study were obtained by PSO. Lateral point loads of 1.12 kips (5 kN) is applied to each point in x and y directions and a vertical load of -6.74 kips (-30 kN) is applied to each point in z directions. The truss tower is subjected to stress constraints of AISC-ASD displacement constraints and section area constraints for vertical members. Maximum displacement is restricted to 8.00 cm. Minimum weight, maximum displacement values and optimum cross-sections for HS and GA solutions are presented in Table 3 and the results are compared with literature results according to PSO. Moreover, Fig. 7 presents the variations of the weight with iteration steps.

Table 3 Optimum design results

Group no	Hasancebi *et al*. (2009) Particle swarm optimizer	This study	
		Genetic algorithm	Harmony search algorithm
1	W8×21	W8×24	W10×12
2	W12×79	W24×117	W30×108
3	W8×24	W12×14	W8×10
4	W10×60	W18×71	W16×67
5	W8×24	W6×16	W8×15
6	W8×21	W8×18	W6×20
7	W8×48	W18×50	W16×50
8	W8×24	W6×15	W6×20
9	W8×21	W12×19	W10×15
10	W10×45	W12×35	W16×31
11	W8×24	W10×15	W5×16
12	W10×68	W18×86	W10×68
13	W14×74	W12×50	W16×67
14	W8×48	W16×45	W18×106
15	W18×76	W12×152	W16×100
16	W8×31	W12×16	W12×19
17	W8×21	W12×152	W16×89
18	W16×67	W6×12	W12×19
19	W8×24	W10×12	W12×35
20	W8×21	W12×106	W16×50

Table 3 Continued

Group no	Hasancebi *et al*. (2009) Particle swarm optimizer	This study	
		Genetic algorithm	Harmony search algorithm
21	W8×40	W8×21	W6×15
22	W8×24	W16×26	W14×30
23	W8×21	W8×48	W14×30
24	W10×22	W10×15	W8×10
25	W8×24	W6×12	W18×46
26	W8×21	W8×48	W14×22
27	W8×21	W6×20	W1×26
28	W8×24	W21×57	W10×39
29	W8×21	W8×40	W10×15
30	W8×21	W8×13	W8×13
31	W8×24	W10×15	W8×31
32	W8×24	W10×45	W16×26
Max disp. cm	-	7.85	7.66
Total weight kN	1618.8	1631.2	1579.8

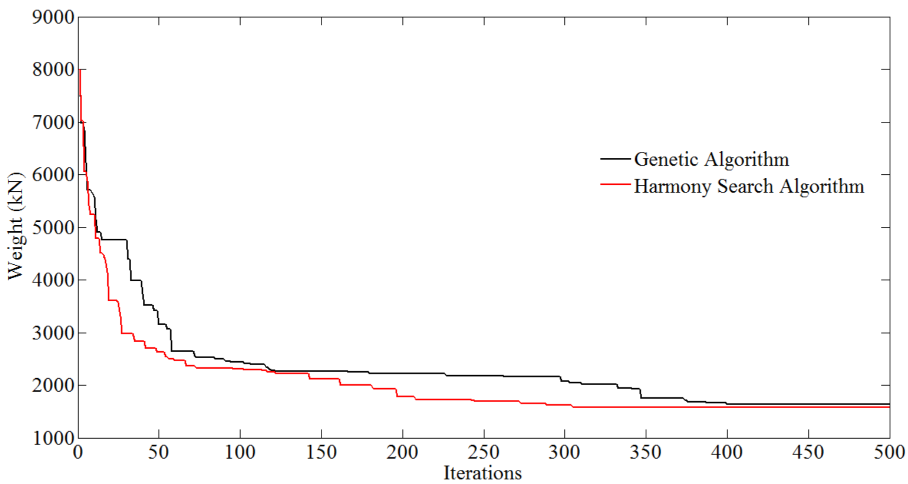


Fig. 7 The variations of the weight with iteration steps

As it is shown in Table 3 that the optimum wide flange sections (*W*) found by Genetic Algorithm and Harmony Search Algorithm methods are very close to the ones obtained by Hasancebi *et al*. (2009). In the optimum solution according to Genetic Algorithm, maximum displacement, 7.85 cm, is very near to the upper limit value, 8.00. The maximum displacement value is 7.66 cm in the solution performed by Harmony Search Algorithm. So, it can be said that displacement constraints in addition to stress constraints play very active roles in the optimum designs of the space truss tower. In this example, the constraints of section areas are also applied to vertical members. It can be also seen in Table 3 that these constraints are also important determinants in the optimum designs.

As seen in Table 3, The minimum weight of GA solution, 1631.2 kN, is 0.8% heavier than the value of Hasancebi *et al*. (2009), 1618.8 kN. On the other hand, the minimum value according to Harmony Search Algorithm, 1579.8 kN, is about %2.4 lighter than the minimum weight determined by Hasancebi *et al*. (2009). Fig. 7 shows that the variations of minimum weight with iteration steps according to Harmony Search Algorithm are mostly lighter than the ones according to Genetic Algorithm. It is observed from Table 3 that the large cross-sections are assigned to vertical members while the small cross-sections are assigned to diagonal members. Because, the vertical members in the truss tower are subjected to more axial stress than diagonal members. It indicates the applicability and robustness of MATLAB interacted with SAP2000-OAPI method for optimum designs.

6. Conclusions

In the present study, Harmony Search and Genetic Algorithms are performed in optimum designs of various truss problems such as a 113-member plane truss bridge, a 120-member space truss dome and a 582-member space truss tower by using MATLAB incorporated with SAP2000-OAPI. Stress constraints obeying AISC-ASD specifications and maximum displacement constraints impose on these trusses. In the third example, the constraints of cross-section areas are also applied. The results obtained from analyses are expressed in tabular and figures. The important conclusions drawn from this study are briefly summarized as follows;

- In first and third examples, the displacements are very important determinants of optimum designs in addition to stress constraints.
- The results of cross-sections carried out by the present work are very close to the reference results.
- In the truss bridge, the minimum weight obtained by Harmony Search Algorithm, 788.342 kN, is about 2.7% lighter than the minimum value of Hasancebi *et al*. (2009) obtained by Evolution Strategies. On the other hand, this value for the optimum solution of Genetic Algorithm, 854.476 kN, is about 5.3% heavier than the value of Hasancebi *et al*. (2009).
- In the truss dome, the minimum weight of the optimum design by Genetic Algorithm, 86.83 kN, is between the ones of reference studies while the minimum weight obtained by Harmony Search Algorithm, 80.68 kN, is about 9% and 0.89% lighter than the ones of the reference studies, respectively.
- In the truss tower, the minimum weight of GA solution, 1631.2 kN, is 0.8% heavier than the minimum value of Hasancebi *et al*. (2009) obtained by Particle Swarm Optimizer. On the other hand, the minimum value obtained by Harmony Search Algorithm, 1579.8 kN, is about %2.4 lighter than the minimum weight determined by Hasancebi *et al*. (2009).
- The all results prove that the applicability and robustness of MATLAB interacted with SAP2000-OAPI method for optimum designs of truss problems.

References

AISC – ASD (1989), Manual of Steel Construction: Allowable Stress Design, American Institute of Steel Construction, Chicago, IL, USA.

Artar, M. (2016), "Optimum design of steel space frames under earthquake effect using harmony search", *Struct. Eng. Mech., Int. J.*, **58**(3), 597-612.

Artar, M. and Daloğlu, A.T. (2015a), "Optimum design of composite steel frames with semi-rigid connections and column bases via genetic algorithm", *Steel Compos. Struct., Int. J.*, **19**(4), 1035-1053.

Artar, M. and Daloğlu, A.T. (2015b), "Optimum design of steel space frames with composite beams using genetic algorithm", *Steel Compos. Struct., Int. J.*, **19**(2), 503-519.

Artar, M. and Daloğlu, A.T. (2015c), "The optimization of multi-storey composite steel frames with genetic algorithm including dynamic constraints", *Teknik dergi*, **26**(2), 7077-7098.

Aydoğdu, İ. and Saka, M.P. (2012), "Ant colony optimization of irregular steel frames including elemental warping effect", *Adv. Eng. Softw.*, **44**(1), 150-169.

Daloğlu, A. and Armutcu, M. (1998), "Optimum design of plane steel frames using genetic algorithm", *Teknik Dergi*, **116**, 1601-1615.

Daloğlu, A.T., Artar, M., Özgan, K. and Karakas, A.İ. (2016), "Opitimum design of steel space frames including soil-structure interaction", *Struct. Multidisp. Optim.*, **54**(1), 117-131.

Dede, T. (2014), "Application of teaching-learning-based-optimization algorithm for the discrete optimization of truss structures", *Ksce. J. Civil Eng.*, **18**(6), 1759-1767.

Değertekin, S.O. and Hayalioglu, M.S. (2010), "Harmony search algorithm for minimum cost design of steel frames with semi-rigid connections and column bases", *Struct. Multidisc. Optim.*, **42**(5), 755-768.

Değertekin, S.O., Saka, M.P. and Hayalioglu, M.S. (2008), "Optimal load and resistance factor design of geometrically nonlinear steel space frames via tabu search and genetic algorithm", *Eng. Struct.*, **30**(1), 197-205.

Değertekin, S.O., Hayalioglu, M.S. and Gorgun, H. (2009), "Optimum design of geometrically non-linear steel frames with semi-rigid connections using a harmony search algorithm", *Steel Compos. Struct., Int. J.*, **9**(6), 535-555.

Değertekin, S.O., Hayalioğlu, M.S. and Görgün, H. (2011), "Optimum design of geometrically nonlinear steel frames with semi-rigid connections using improved harmony search method", *Mühendislik Dergisi, Dicle University, Department of Engineering*, **2**(1), 45-56.

Erbatur, F., Hasançebi, O., Tütüncü, İ. and Kılıc, H. (2000), "Optimal design of planar and space structures with genetic algorithms", *Comput. Struct.*, **75**(2), 209-224.

Goldberg, D.E. (1989), *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-Wesley, Reading, MA, USA.

Hadidi, A. and Rafiee, A. (2014), "Harmony search based, improved Particle Swarm Optimizer for minimum cost design of semi-rigid steel frames", *Struct. Eng. Mech., Int. J.*, **50**(3), 323-347.

Hasançebi, O. and Çarbaş, S. (2014), "Bat inspired algorithm for discrete size optimization of steel frames", *Adv. Eng. Softw.*, **67**, 173-185.

Hasançebi, O., Çarbaş, S., Doğan, E., Erdal, F. and Saka, M.P. (2009), "Performance evaluation of metaheuristic search techniques in the optimum design of real size pin jointed structures", *Comput. Struct.*, **87**(5-6), 284-302.

Hasançebi, O., Çarbaş, S. and Saka, M.P. (2010), "Improving performance of simulated annealing in structural optimization", *Struct. Multdisc. Optim.*, **41**(2), 189-203.

Hayalioglu, M.S. and Değertekin, S.O. (2004), "Design of non-linear steel frames for stress and displacement constraints with semi-rigid connections via genetic optimization", *Struct. Multidisc. Optim.*, **27**(4), 259-271.

Kameshki, E.S. and Saka, M.P. (2001), "Optimum design of nonlinear steel frames with semi-rigid connections using a genetic algorithm", *Comput. Struct.*, **79**(17), 1593-1604.

Kaveh, A. and Talatahari, S. (2012), "A hybrid CSS and PSO algorithm for optimal design of structures", *Struct. Eng. Mech., Int. J.*, **42**(6), 783-797.

Lee, K.S. and Geem, Z.W. (2004), "A new structural optimization method based on the harmony search algorithm", *Comput. Struct.*, **82**(9-10), 781-798.

MATLAB (2009), The Language of Technical Computing; The Mathworks, Natick, MA, USA.

Rajeev, S. and Krishnamoorthy, C.S. (1992), "Discrete optimization of structures using genetic algorithms", .

Struct. *Eng*. *ASCE*, **118**(5), 1233-1250.
Saka, M.P. (2009), "Optimum design of steel sway frames to BS5950 using harmony search algorithm", *J. onstr*. *Steel Res*., **65**(1), 36-43.
SAP2000 (2008), Integrated Finite Elements Analysis and Design of Structures; Computers and Structures, Inc., Berkeley, CA, USA.
Toğan, V. and Daloğlu, A.T. (2008), "An improved genetic algorithm with initial population strategy and self-adaptive member grouping", *Comput*. *Struct*., **86**(11-12), 1204-1218.
Toğan, V., Daloğlu, A.T. and Karadeniz, H. (2011), "Optimization of trusses under uncertainties with harmony search", *Struct*. *Eng*. *Mech*., *Int*. *J*., **37**(5), 543-560.

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