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Hybrid Taguchi-Harmony Search Algorithm for Solving Engineering Optimization Problems

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Harmony search algorithms have recently gained a lot of attention from the optimization research community. In this paper, an improved harmony search algorithm is introduced to solve engineering optimization problems. To demonstrate the effectiveness and robustness of the proposed approach, it is applied to an engineering design and manufacturing optimization problem taken from the literature. The results obtained by the new hybrid harmony search approach for the case studies are compared with a hybrid genetic algorithm, scatter search algorithm, genetic algorithm, and feasible direction method and handbook recommendation. The results of case studies show that the proposed optimization approach is highly competitive and that can be considered a viable alternative to solve design and manufacturing optimization problems.

Significance: This paper presents a novel hybrid algorithm based on harmony search algorithm and Taguchi method. The new approach is applied to the case studies for turning and milling and design optimization problems.

Keywords: Harmony Search Algorithm, Design Optimization, Taguchi method, Turning, Milling

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1. INTRODUCTION

For many decades, optimization of design and manufacturing parameters is major issue faced every day in industry. In order to design and manufacture higher-quality products and to be the winners in the competitive market, current optimization techniques must be improved. Different optimization techniques have been developed for solving various optimization problems in engineering area (Shin and Joo, 1992, Kilic et al., 1993, Cakir and Gurarda, 1998, Cakir and Gurarda, 2000, Yildiz et al., 2003, Yildiz et al., 2007, Yildiz, 2008). Recent advancements in optimization area introduced new opportunities to achieve better solutions for design and manufacturing optimization problems. Therefore, there is a need to introduce new methods to overcome drawbacks and to improve the existing optimization techniques to design and manufacture the products economically.

Since the stochastic search techniques such as genetic algorithm, simulated annealing, particle swarm optimization algorithm, ant colony algorithm and immune algorithm are more effective than the gradient techniques in finding the global minimum, they have been preferred in many applications of science (Saka, 1998, Liu et al., 2000, Nanthavanij and Kullpattaranirun, 2001, Dereli et al., 2001, De Castro and Timmis, 2003, Vijayakumar et al., 2003, Saka, 2003, Sonmez, 2007, Yildiz and Saitou, 2008).

One of the recent techniques is the harmony search algorithm develeoped by Geem et al. (2001). This approach is based on the musical performance process that takes place when a musician searches for a better state of harmony. (Lee and Geem 2004, Saka 2008, Fesanghary et al., 2008).

Fast convergence speed and robustness in finding the global minimum are not easily achieved at the same time. Fast convergence requires a minimum number of calculations, increasing the probability of missing important points; on the other hand, the evaluation of more points for finding the global minimum decreases the convergence speed. This leads to the question: 'how to obtain both fast convergence speed and global search capability at the same time.' There have been a number of attempts to answer this question, while hybrid algorithms have shown outstanding reliability and efficiency in application to the engineering optimization problems (Cho and Ahn, 2003, Wang et al., 2005, Ponnambalam et al., 2005, Sun et al., 2005, Yildiz and Ozturk, 2006, Yildiz et al., 2007, Yildiz, 2009a, Yildiz, 2009b, Yildiz ,2009c).

Therefore, the researchers are paying great attention on hybrid approaches to answer this question. Despite the fact that some improvements relating optimal design and optimization of cutting parameters in machining operations have been achieved, due to the complexity of machine and design parameters with conflicting objective and constraints, optimization of the machining economic problems and design optimization problems still present a matter of investigation. Therefore, in recent years, there has been an ever-increasing interest in the new hybrid optimization techniques for optimal design and manufacturing.

The aim of this research is to develop a new optimization approach for solving complex optimization problems in design and manufacturing area. In this research, a hybrid optimization approach is presented by hybridizing the harmony search algorithm with Taguchi method. The hybrid approach is evaluated with welded-beam design optimization problem taken from literature and compared with other optimization methods in the literature. Finally, the developed hybrid approach is applied to case studies for milling and turning. The results of the case studies show that the proposed algorithm converges rapidly to the global optimum solution and provides reliable and accurate solutions for even the most complicated of optimization problems.

2. HARMONY SEARCH ALGORITHM

The harmony search (HS) algorithm which is a metaheuristic optimization algorithm has been recently developed by Geem et al. (2001). The HS algorithm is simple in concept, few in parameters, and easy in implementation. It has been successfully applied to various benchmark and real-world problems (Lee and Geem, 2004, Mahdavi et al., 2007, Fesanghary et al., 2008). The steps in the procedure of harmony search are as follows:

Step 1: Initialize the problem and algorithm parameters.
Step 2: Initialize the harmony memory.
Step 3: Improvise a new harmony.
Step 4: Update the harmony memory.
Step 5: Check the stopping criterion.

For further details about these steps and harmony search (HS) algorithm can be found from Geem et al. (2001).

3. THE PROPOSED NEW HYBRID OPTIMIZATION APPROACH

In this paper, a novel hybrid approach (Hybrid Taguchi Harmony search algorithm-HTHSA) is developed for solving optimization problems in engineering area. The proposed approach hybridizes the harmony search algorithm with Taguchi method.

According to proposed hybrid approach based on harmony search algorithm and taguchi method process, solutions to engineering optimization problems with continuous design variables can be obtained by: (a) the intervals of design parameters are refined using Taguchi method to achieve better initialization in the harmony search algorithm, (b) an initial harmony memory is randomly generated for possible solutions within the refined range of design variables obtained by Taguchi method, (c) improvising a new harmony, (d) evaluating the objective function subject to the constraint functions, and (e) updating the initialized HM.

The HTHSA involves two stages of optimization: (a) refinement of design space of solutions using Taguchi's method (b) harmony search process using refined population size. Although the proposed approach is conducted in two stages, only the last stage is outlined in this paper. The first stage is with respect to previous research and more details about these stages can be found in the references of Yildiz and Ozturk (2006) and Yildiz et al. (2007). The pseudo codes of the proposed algorithm (HTHSA) are given as follows.

BEGIN
Step 1: Define Problem
Step 2: Taguchi Method
 Begin
  set the input parameters
  select suitable orthogonal array
  select suitable S/N ratio type
 While (not termination condition for experiments)**do**
  compute S/N ratios
  compute objective function values
  conduct matrix of experiments
 end,
 While (not termination condition for parameters)**do**
  compute contributions
  generate analysis of variance (ANOVA table)
 end,
End,
 Define new intervals for parameters

Step 2: Harmony search algorithm
Initialize the problem and algorithm parameters
Initialize the harmony memory
Improvise a new harmony
Update the harmony memory
Check the stopping criterion
end,
END.

4. ENGINEERING OPTIMIZATION EXAMPLES

In this section, the results of applications and discussions regarding the proposed approach are given through examples. Several case studies taken from design and manufacturing optimization literature will be used to demonstrate the function and capability of the proposed method. These examples have been previously solved using a variety of other techniques, which is useful to determine the quality of the solutions produced by the proposed approach.

4.1 Welded- Beam Design Problem

A welded beam design optimization problem, which is often used for the evaluation of optimization methods, is used to illustrate the implementation procedure of the proposed approach for solving optimization problems. The beam has a length of 14 in. and P=6,000 lb force is applied at the end of the beam (Deb, 1991, Coello, 2000). The welded beam is designed for minimum cost subject to constraints on shear stress, bending stress in the beam, buckling load on the bar, end deflection of the beam, and side constraints. The design variables are thickness of the weld h(x_1), length of the weld l(x_2), width of the beam t(x_3), and thickness of the beam b(x_4). The mathematical model of the welded beam optimization problem is defined as

Minimize

$$f_1(x) = 1.10471 x_1^2 x_2 + 0.04811 x_3 x_4 (14.0 + x_2) \quad (1)$$

Subject to:

$$g_1(x) = \tau_{max} - \tau(x) \geq 0\,; \quad (2)$$

$$g_2(x) = \sigma_{max} - \sigma(x) \geq 0 \quad (3)$$

$$g_3(x) = x_4 - x_1 \geq 0 \quad (4)$$

$$g_4(x) = 5 - 1.10471 x_1^2 x_2 - 0.04811 x_3 x_4 (14.0 + x_2) \geq 0 \quad (5)$$

$$g_5(x) = x_1 - 0.125 \geq 0 \quad (6)$$

$$g_6(x) = \delta_{max} - \delta(x) \geq 0 \quad (7)$$

$$g_7(x) = P_c(x) - P \geq 0 \quad (8)$$

$0,1<x_1<5$, $0,1<x_2<10$, $0.1<x_3<10$, $0,1<x_4<5$

The important stress conditions which were used in mathematical model are described as follows

Weld Stress- $\tau(x)$

The weld stress ($\tau(x)$), has two components. They are τ' and τ''. τ' is the primary stress whereas τ'' is secondary torsional stress. M is the moment which is created by Force (F). J is polar inertia moment. $\tau(x)$, τ' and τ'' are calculated from the following equations.

$$\tau' = \frac{P}{\sqrt{2} x_1 x_2}, \quad (9)$$

$$\tau'' = \frac{MR}{J} \quad (10)$$

$$M = P\left(L + \frac{x_2}{2}\right), \quad (11)$$

$$R=\sqrt{\frac{x_2^2}{4}+\left(\frac{x_1+x_3}{2}\right)^2}, \tag{12}$$

$$J=2\left\{\sqrt{2}x_1x_2\left[\frac{x_2^2}{12}+\left(\frac{x_1+x_3}{2}\right)^2\right]\right\} \tag{13}$$

The weld stress is given as following:

$$\tau(x)=\sqrt{(\tau')^2+2\tau'\tau''\frac{x_2}{2R}+(\tau'')^2} \tag{14}$$

Bar Bending Stress - $\sigma(x)$

The bar bending stress(σ_x) is calculated from the following equation.

$$\sigma(x)=\frac{6PL}{x_4x_3^2}, \tag{15}$$

Bar Buckling Load - $P_c(x)$

The bar buckling load is found from the following equation:

$$P_c(x)=\frac{4.013E\sqrt{\frac{x_3^2x_4^6}{36}}}{L^2}\left(1-\frac{x^3}{2L}\sqrt{\frac{E}{4G}}\right) \tag{16}$$

Bar Deflection - $\delta(x)$

The Bar Deflection formula is shown in the follow equation:

$$\delta(x)=\frac{4PL^3}{Ex_3^3x_4}, \tag{17}$$

Table 1. Optimal results for welded beam design (N/A not available)

Methods	Optimal Design Variables				Cost
	h	l	t	b	
Coello (2000a)	N/A	N/A	N/A	N/A	1.8245
Coello(2000b)	0..2088	3.4205	8..9975	0..2100	1.7483
Deb(1991)	N/A	N/A	N/A	N/A	2.38
Deb(2000)	0.2489	6.1730	8.1789	0.2533	2.4328
Lee and Geem (2004)	0.2442	6.2231	8.2915	0.2443	2.3807
Mahdavi et al. (2007)	0.20573	3.47049	9.03662	0.20573	1.7248
Fesanghary et al. (2008)	0.20572	3.47060	9.03682	0.20572	1.7248
The proposed approach	0.20573	3.47042	9.03649	0.205735	1.7248

The material properties and constant values like shearing modulus, young's modulus, etc. used above are given as follow: G=12x10^6, E= = 30x10^6 psi, L= 14 in P= 6000 lb, τ_{max}= 13,600 psi, σ_{max}=30,000 psi, δ_{max} =0.25 in.

Deb (1991, 2000) and Coello (2000a, 2000b) solved this problem using GA-based methods. Lee and Geem, Mahdavi et al. and Fesanghary et al. solved this problem using HS-based methods. The comparison of results are given in Table 1. Note that the approaches proposed by Lee and Geem (2004), Mahdavi et al. (2007) and Fesanghary et al. (2008) required 110,000, 200,000 and 90,000, respectively, evaluations of the fitness function to produce the result shown in Table 1. On the other hand, the proposed hybrid approach requires only 30,000 function evaluations to find the best known solution of 1.7248. The use of the proposed hybrid approach improves the convergence rate by computing the best value.

4.2 The Case Study for Turning

The mathematical formulation for turning problem used in this research was defined by Chen and Tsai (1996) and Chen (2004). The case study for the turning operation is optimized by the HTHSA. The constant values and parameters for case studies are given in Table 2.

Table 2. Data for the example of turning

D= 50 mm	L= 300 mm	d_t = 6.0 mm
VrU = 500 m/min	VrL=50 m/min	f_rU= 0.9 mm/rev
frL = 0.1 mm/rev	drU=3.0 mm	d_rL= 1.0 mm
VsU = 500 m/min	VsL=50 m/min	f_sU= 0.9 mm/rev
fsL = 0.1 mm/rev	dsU= 3.0 mm	d_sL= 1.0 mm
k_o= 0.5 $/min	k_t =2.5 $/edge	h_1= 7x10^{-4}
h_2= 0.3	t_c =0.75 min/piece	t_e = 1.5 min/edge
p= 5	q= 1.75	r= 0.75
C_0 = 6x10^{11}	T_U =45 min	T_L= 25 min
k_f = 108	μ= 0.75	υ=0.95
η= 0.85	F_U =200 kg f	PU= 5kW
λ= 2	ν=-1	Sc= 140
kq = 132	τ = 0.4	ϕ= 0.2
δ= 0.105	Q_U = 1000 ^{0}C	R_n= 1.2 mm
R_a= 10μ	k_1= 1.0	k_2= 2.5
k_3= 1.0		

Table 3. Comparison of the best results for turning problem (HTHSA: hybrid taguchi harmony search algorithm; HRGA: hybrid robust genetic algorithm; SS: scatter search; SA/PS: simulated annealing and Hooke-Jeeves pattern search; FEGA:float encoding genetic algorithm)

Methods	cost ($) ($d_t$ = 6mm)
HTHSA	2.0478
HRGA (Yildiz and Ozturk 2006)	2.0481
SS (Chen 2004)	2.0667
FEGA (Chen and Chen 2003)	2.2988
SA/PS (Chen and Tsai 1996)	2.2795

The total depth of cutting is set with d_t=6. The comparison of the results obtained by the HTHSA, against other techniques, is given in Table 3. It can be seen that better results for the best solutions are achieved for the turning optimization problem compared to HRGA (hybrid robust genetic algorithm), SS (scatter search), FEGA (float encoding GA) and SA/PS (simulated annealing and Hooke–Jeeves pattern search) as shown in Table 3. The results of this research indicate that HTHSA can offer a helpful potential as an alternative approach for applications to the optimization of design and manufacturing problems.

4.3 The Case Study for Milling

In this case study for milling operation, it is aimed that a part shown in Figure 1 is to be produced using CNC milling machine. At the same time, it is desired that optimum machining parameters be found with the maximum profit rate. Specifications of the machine, material and constant values and furthermore detailed information related to mathematical model can be found in Tolouei-Rad and Bidhendi (1997).

Table 4. Speed and feed rate limits

Operation No.	Operation type	Speed limits	Feed rate limits
1	Face milling	60–120 m/min	0.05–0.4 mm/tooth
2	Corner milling	40–70 m/min	0.05–0.5 mm/tooth
3	Pocket milling	40–70 m/min	0.05–0.5 mm/tooth
4	Slot milling 1	30–50 m/min	0.05–0.5 mm/tooth
5	Slot milling 2	30–50 m/min	0.05–0.5 mm/tooth

Table 5. Required machining operation

Operation No.	Operation type	Tool	a (mm)	K(mm)	Ra (µm)	F_c (per)
1	Face milling	1	10	450	2	1.56449.4
2	Corner milling	2	5	90	6	17117.74
3	Pocket milling	2	10	450	5	17117.74
4	Slot milling 1	3	10	32	-	14264.78
5	Slot milling 2	3	5	84	1	14264.78

Table 6. Tools data

Tool No	Tool Type	Quality	d(mm)	z	Price($)	la	ca
1	face mill	Carbide	50	6	49.50	45	5
2	end mill	HSS	10	4	7.55	0	5
3	end mill	HSS	12	4	7.55	0	5

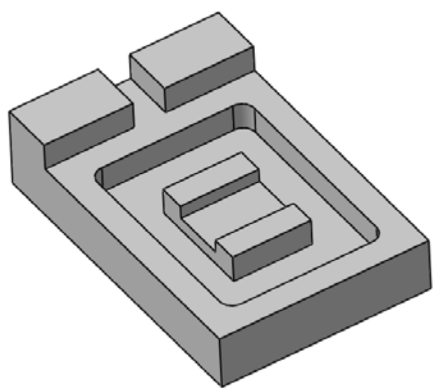

Figure 1. An example part

The speed and feed rate limits used for the case study are given in Table 4. The part shown in Figure 1 includes four machining features which are step, pocket and two slots. To manufacture the part, it is required five milling operation, listed in Table 5, which are face milling, corner milling, pocket milling, slot milling 1, and slot milling 2, respectively. The tools used for each operation and the data for tools are listed in Table 6. The goal is to find the optimum cutting conditions of each feature in order to machine the part with maximum profit rate. The HTHSA is applied to the case study.

The results obtained by the HTHSA are listed in Table 7 and compared with GA, the feasible direction method and handbook recommendations. By using the HTHSA, the total profit rate is increased with 293.09 %, 12.08 % and 5.32 % over handbook recommendations, feasible direction method and genetic algorithm, respectively.

Table 7. Comparison of the best results for milling operation

Method	C_u - Unit cost	T_u - Unit time	P_r - Profit Rate
Handbook	$18.36	9.40 min	0.71 /min
Method of feasible direction	$11.35	5.48 min	2.49 /min
Genetic algorithms	$11.11	5.22 min	2.65 /min
Proposed approach	$10.904	5.050 min	2.791 /min
Improvement over handbook	$7.456	4.35 min	2.081 /min
Improvement over method of feasible direction	$0.446	0.43 min	0.301 /min
Improvement over genetic algorithms	$0.206	0.17 min	0.141 /min
Improvement (handbook)	% 40.61	% 46.27	% 293.09
Improvement (method of feasible direction)	% 3.92	% 7.84	% 12.08
Improvement (genetic algorithms)	% 1.85	% 3.25	% 5.32

5. RESULTS AND DISCUSSIONS

In this research, a novel hybrid optimization approach based on harmony search algorithm and Taguchi method is developed. The hybrid approach is applied to the welded beam design problem, the optimization of machining parameters for minimization of unit production cost in turning and maximization of profit rate in milling. Table 1, 3 and Table 7 show that HTHSA provides the best result over all of the other methods. The unit production cost for turning is reduced and the profit rate for milling are increased using the proposed hybrid approach. The highly promising outcome of this research suggests that the proposed hybrid approach is an effective alternative for solving engineering optimization problems. The new optimization approach can also be extended to other real-world optimization problems in manufacturing and design area.

6. REFERENCES

1. Cakir, M.C. and Gurarda, A. (1998). Optimization and graphical representation of machining conditions in multi-pass turning Operations. Computer Integrated Manufacturing Systems, 11:157-170.
2. Cakir, M.C. and Gurarda, A. (2000). Optimization of machining conditions for multi-tool milling operations. International Journal of Production Research, 38: 3537- 3552.
3. Chen, M.C. and Tsai, D.M. (1996). A simulated annealing approach for optimization of multi-pass turning operations. International Journal of Production Research, 34: 2803-2825.
4. Chen, M.C. and Chen, K.Y. (2003). Optimization of multipass turning operations with genetic algorithms: a note. International Journal of Production Research, 41: 3385-3388.
5. Chen, M.C. (2004). Optimizing machining economics models of turning operations using the scatter search approach. International Journal of Production Research, 42: 2611-2625.
6. Cho K.K and Ahn BH (2003). A hybrid genetic algorithm for group scheduling with sequence dependent group setup time. International Journal of Industrial Engineering-Theory Applications and Practice, 10: 442-448.
7. Coello, C.A.C. (2000a). Use of a self-adaptive penalty approach for engineering optimization problems. Computer in Industry, 4: 113-127.
8. Coello, C.A.C. (2000b). Constraint-handling using an evolutionary multiobjective optimization technique. Civil Engrg. Environ. Syst. 17: 319–346.
9. Deb, K. (1991). Optimal design of a welded beam via genetic algorithms. AIAA Journal, 29: 2013–2015.
10. Deb, K. (2000). An efficient constraint handling method for genetic algorithms. Comput. Methods Appl. Mech. Engrg. 186: 311–338.
11. De Castro, L.N. and Timmis, J.I. (2003). Artificial immune systems as a novel soft computing paradigm. Soft Computing, 7: 526-544.
12. Dereli, T, Filiz, I.H, Baykasoglu, A. (2001). Optimizing cutting parameters in process planning of prismatic parts by using genetic algorithms. International Journal of Production Research, 39:3303-28.
13. Fesanghary, M., Mahdavi, M. Minary-Jolandan, M., and Alizadeh, Y. (2008). Hybridizing harmony search algorithm with sequential quadratic programming for engineering optimization problems. Computer Methods in Applied Mechanics and Engineering, 197: 3080–3091.
14. Geem, Z.W., Kim, J.H., and Loganathan, G.V. (2001). A new heuristic optimization algorithm: harmony search. Simulation, 76: 60–68.
15. Kilic, S.E., Cogun, C., and Sen, D.T. (1993). A computer-aided graphical technique for the optimization of machining conditions. Computer in Industry, 22:319-26.
16. Liu, B., Haftka, R.T., Akgun, M.A., and Todoroki, A. (2000). Permutation genetic algorithm for stacking sequence design of composite laminates. Computer Methods in Applied Mechanics and Engineering, 186: 357-372.
17. Lee, K.S., and Geem, Z.W. (2004). A new meta-heuristic algorithm for continues engineering optimization: harmony search theory and practice. Computer Methods in Applied Mechanics and Engineering, 194: 3902–3933.
18. Mahdavi, M., Fesanghary, M., and Damangir, E. (2007). An improved harmony search algorithm for solving optimization problems. Appl. Math. Comput., 188: 1567–1579.
19. Machining Data Handbook, 1, 3rd edition. Machinability Data Center, OH (1980).
20. Nanthavanij, S. and Kullpattaranirun, T. (2001). A genetic algorithm approach to determine minimax work assignments. International Journal of Industrial Engineering-Theory Applications and Practice, 8: 176-185.
21. Ponnambalam SG, Venkataraman R, Sudhan HH, Chatterjee PV. (2005). Hybrid search algorithms for a single-row layout in automated manufacturing systems. International Journal of Industrial Engineering-Theory Applications and Practice, 12 (2): 117-126.
22. Saka, M.P. (1998). Optimum design of steel grillage systems using genetic algorithms. Comput Aided Civil Infrastruct Eng, 13:233–238

23. Saka, M.P. (2003). Optimum design of pitched roof steel frames with haunched rafters by genetic algorithm. J Comput Struct 81:1967–1978.
24. Saka, M.P. (2008). Optimum geometry design of geodesic domes using harmony search algorithm. Advances In Structural Engineering, 10: 595-606.
25. Shin, Y.C. and Joo, Y.S. (1992). Optimization of machining conditions with practical constraints. International Journal of Production Research, 30: 2907-2919.
26. Sonmez, O.F. (2007) Shape optimization of 2D structures using simulated annealing. Computer Methods in Applied Mechanics and Engineering, 196:279-3299.
27. Sun TH, Lee LJH, Tien FC (2006). Solving single allocation uncapacitated p-Hub median problem with hybrid genetic algorithms. International Journal of Industrial Engineering-Theory Applications and Practice, 13 (3): 280-291.
28. Tolouei-Rad, M. and Bidhendi, I.M. (1997). On the optimization of machining parameters for milling operations. International Journal of Machine Tools & Manufacture 37: 1-16.
29. Vijayakumar, K. Prabhaharan, G., Asokan, P. and Saravanan, R. (2003). Optimization of multi-pass turning operation using ant colony system. International Journal of Machine Tools & Manufacture, 43: 1633-1639.
30. Wang, Z.G., Rahman, M., Wong, Y.S. and Sun, J. (2005). Optimization of multi-pass milling using parallel genetic algorithm and parallel genetic simulated annealing. International Journal of Machine Tools & Manufacture, 45: 1726-1734.
31. Yildiz, A.R., Ozturk, N., Kaya N., and Ozturk, F. (2003). Integrated optimal topology design and shape optimization using neural networks. Structural and Multidisciplinary Optimization, 25: 251 - 260.
32. Yildiz, A.R., Kaya, N., Alankus, O., and Ozturk, F. (2004). Optimal design of vehicle components using topology design and optimization. International Journal of Vehicle Design, 34: 387-398.
33. Yildiz, A.R., Ozturk, F. (2006). Hybrid enhanced genetic algorithm to select optimal machining parameters in turning operation. Proceedings of the Institution of Mechanical Engineers Part B Journal of Engineering Manufacture 220:2041-2053.
34. Yildiz, A.R., Ozturk, N., Kaya, N., and Ozturk, F. (2007). Hybrid multi-objective shape design optimization using Taguchi's method and genetic algorithm. Structural and Multidisciplinary Optimization 34: 277-365
35. Yildiz, A.R., (2008) Optimal structural design of vehicle components using topology and shape optimization. Materials Testing -MaterialPrufung, 50:224-228.
36. Yildiz, A.R., and Saitou, K. (2008). Topology Synthesis of Multi-Component Structural Assembly in Continuum Domain, DETC 2008, 3-5 August 2008, Newyork, USA.
37. Yildiz, A.R. (2009a) A novel hybrid immune algorithm for global optimization in design and manufacturing. Robotics and Computer Integrated Manufacturing, doi:10.1016/j.rcim.2007.08.002 (in press 2009a)
38. Yildiz, A.R. (2009b) A novel particle swarm optimization approach for product design and manufacturing. International Journal of Advance Manufacturing Technology- doi: 10.1007/s00170-008-1453-1(in press 2009b)
39. Yildiz, A.R. (2009c) An effective hybrid immune-hill climbing optimization approach for solving design and manufacturing optimization problems in industry. Journal of Materials Processing Technology, doi:10.1016/j.jmatprotec.2008.06.028 (in press 2009c).

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