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Aspect Ratio Optimization & Modal Analysis of Plate By Integrating PSO in Matlab with Ansys – An Automation Approach

KEYWORDS: Particle Swarm Optimization, Aspect Ratio, ANSYS, MATLAB, Modal Analysis

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ABSTRACT *An iterative approach between Particle Swarm Optimization (PSO) in MATLAB & ANSYS is performed on a Beam and the obtained results are compared with Design Optimization in ANSYS. This iterative approach is extended for a plate. In this work, the objective is to arrive at best aspect ratio (a/b) for an assumed thickness of a plate that can withstand applied transverse load. Further for each thickness with its best aspect ratio, modal analysis is performed.*

1. INRODUCTION TO PSO

PSO which is an evolutionary global algorithm has gained popularity recently. Similar to other existing Evolutionary Algorithms (EA), PSO is a population-based optimization method Distinct from other EAs where knowledge is destroyed between generations [1]; individuals in the population of PSO retain memory of known good solutions as the search for better solutions continues. Hence, PSO has higher speed of convergence than other evolutionary search algorithms. The other advantage of PSO is that it's easy to implement and there are fewer parameters to adjust. The velocity vector of each particle is calculated according to the formula:

vik = wvik-1+c1r1(pik-1 - xik-1)+c2r2(pgk-1 - xik-1)

where the superscript i denotes the particle and the subscript k the iteration number; v denotes the velocity and x the position; r_1 and r_2 are uniformly distributed random numbers in the interval [0,1]; c_1 and c_2 are the acceleration constants; w is the inertia weight; p^i_{k-1} is the best position of particle i and p^g_{k-1} the global best position attained by the swarm at iteration k-1. The position of each particle at iteration k is calculated using the formula:

$x^i_k = x^i_{k-1} + v^i_k$

2. METHODOLOGY

In this paper, two approaches are presented. 1) In first approach, a Design optimization of Beam is carried out in ANSYS. 2) In second approach, an iterative procedure involving implementation of PSO in MATLAB integrating it with Ansys Parametric Design Language (APDL) code for obtaining optimization of beam is presented (see fig (1)). Above mentioned approaches were extended to optimize a Plate.

The iterative approach is validated with work of Amrita et al [2] done on beam structure. The present work involves in

(a) Performing Stress analysis in ANSYS &

(b) Optimization in Matlab.

(c) Modal Analysis for optimum aspect ratio

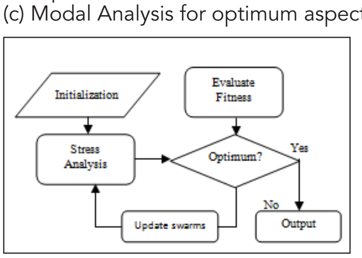

Fig (1) Procedure for the iterative based optimum design

3. PROBLEM DESCRIPTION

Two practical optimization problems are taken and they are optimized by using two methods. One method is by using Design Optimization in ANSYS. In the other method, ANSYS input file is generated and is merged with MATLAB optimization program to obtain the optimum result

3.1 PROBLEM 1

A force of 1000N is applied on beam (fig 2). Objective of the problem is to minimize the weight of the beam without exceeding the allowable stress. It is necessary to find the cross sectional dimensions of the beam in order to minimize the weight of the beam. The maximum stress anywhere in the beam cannot exceed 200 MPa. The beam is to be made of steel with a modulus of elasticity of 200 GPa.

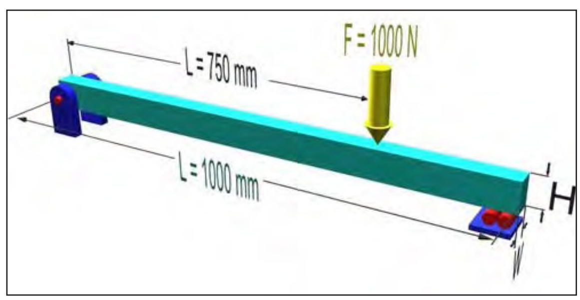

Fig (2) Beam Problem

3.1.1 Problem Formulation:

Let W, H be width and height of the beam.

Weight of the beam (Objective Variable), W= ρg * Volume of the beam As 'ρg' is constant, volume of beam is Objective variable, V = LWH Subject to $0 \leq \sigma max \leq 200\times10^6$ $0 \leq W \leq 50$ mm & $0 \leq H \leq 50$ mm Where σmax is the maximum absolute value of stress.

3.1.2. RESULTS:

a) Results Obtained Using Design Optimization:

The problem has been solve by using Design Optimization in ANSYS and the results are shown in fig 3.Variation of height(H) and width (W), with the number of iterations are shown in figures 4.

b) Results Obtained Using Matlab Linked With Ansys APDL:

An ansys file is created for the problem and it is run from matlab using PSO constrained algorithm. The results obtained are given in Fig 5:

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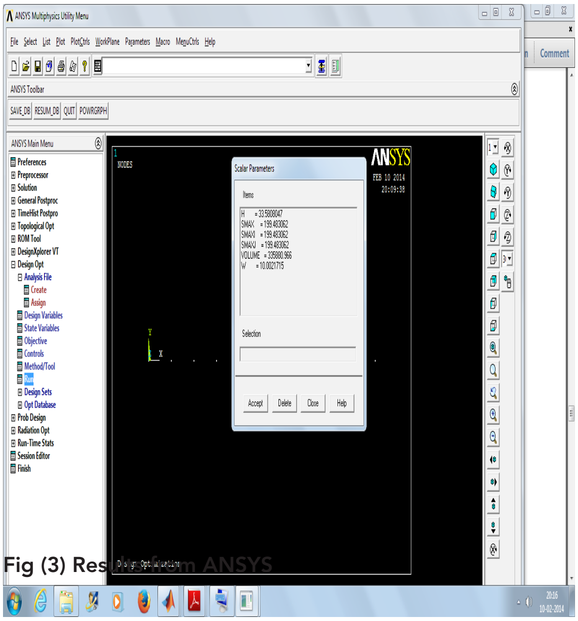

Fig (3) Results from ANSYS

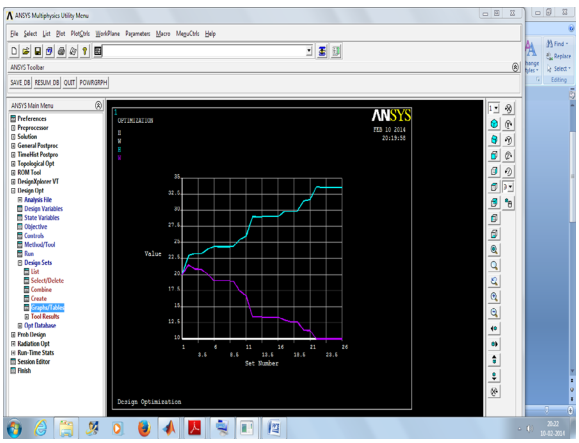

Fig (4) Variation of H and W with iterations

3.1.3. RESULT ANALYSIS

The two problems are optimized by using two methods. One method is by using Design Optimization in ANSYS. In the other method, ANSYS input file is generated and is merged with MATLAB optimization program to obtain the optimum result .The results obtained from both the methods are compared. It was found that the result obtained from the second case is better than that obtained from the first case.

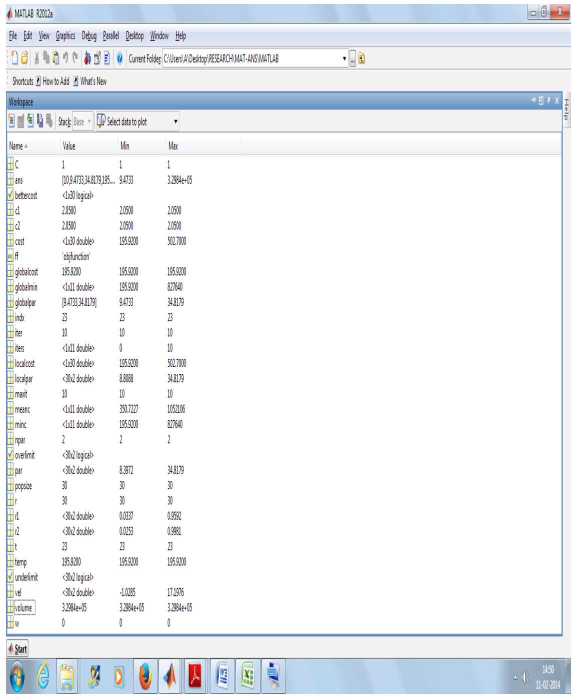

Fig (5) Results from Iterative Method using Particle Swarm Optimization

Method Used	W mm	H mm	σmax (Mpa)	Vol (m^3)
Ansys [Amrita et al]	13.14	29.2	199.94	384540
Ansys (present study)	10.00	33.5	199.48	335880
Ansys +Matlab Optimization [Amrita et al]	10.00	33.5	199.99	335411
Ansys +Matlab Optimization [present study]	9.473	34.8	195.92	329840

Table (1) Result comparison of Beam

3.2. PROBLEM 2:

A thin rectangular plate (a x b mm) is considered and optimum aspect ratio (a/b) are obtained for thickness (thk) of 1mm, 2mm, 3mm, 4mm & 5mm.

CASE I

In this case, a rectangular plate is simply supported at its two ends and uniform transverse load p= 0.1MPa is applied considering b = 40 mm .The obtained results are shown in fig (6) & Table (2)

CASE II

In this case, a rectangular plate is simply supported at its two ends and uniform transverse load p= 0.2MPa is applied considering b = 40 mm .The obtained results are shown in fig (7) & Table (3)

CASE III

In this case, a rectangular plate is clamped at its two ends and uniform transverse load p= 0.1MPa is applied considering b = 40 mm .The obtained results are shown in fig (8) & Table (4)

CASE IV

In this case, a rectangular plate is clamped at its two ends

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and uniform transverse load p= 0.2MPa is applied considering b = 40 mm .The obtained results are shown in fig (9) & Table (5)

Modal Analysis is performed for the optimum aspect ratio of the all thickness. See Table 6.

4. CONCLUSION

An optimum design of plate for Case-I,II,III & IV with thickness 5 mm having aspect ratio 6.35,4.55, 7.38 & 5.28 respectively found to be optimum. Further modal analysis for this same case revealed a deflection of 5, 6.802, 5.916 & 7.36 mm respectively at 5th Mode. The results obtained were found to be good with an error in stress up to 1%.As weight minimization is a major concern in aerospace industry, ship building, Civil structures,etc., The proposed iterative approach implementing PSO in MATLAB and integrating it with APDL code in ANSYS can be implemented to meet the requirement of weight reduction in major engineering applications.

RESULTS OF ISOTROPIC SIMPLY SUPPORTED ON BOTH SIDES RECTANGLAR PLATE – CASE 1

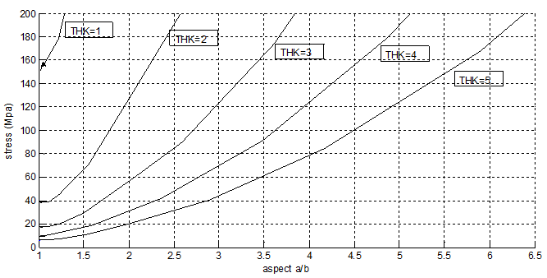

FIGURE (6) ASPECT RATIO VS STRESS FOR SIMPLY SUPPORTED PLATE WITH TRANSVERSE LOAD OF 0.1 MPa

thickness	1	thickness	2	thickness	3	thickness	4	thickness	5
aspect	stress	aspect	stress	aspect	stress	aspect	stress	aspect	stress
1.02	151.04	1.02	37.76	1.02	16.80	1.02	9.42	1.02	6.02
1.22	178.00	1.23	45.33	1.23	20.30	1.59	18.62	1.22	7.12
1.48	260.07	1.55	71.59	1.49	29.47	2.36	41.74	1.53	11.05
		2.06	134.69	2.07	60.38	3.48	90.84	2.00	20.31
		2.62	206.43	2.59	89.51	4.88	180.19	2.89	40.59
				3.61	173.93	6.41	307.79	4.17	84.56
				4.81	311.80			5.89	167.51
								7.74	287.43

TABLE (2) ASPECT RATIO & STRESS VALUES INDICATING STRESS/ASPECT FOR SIMPLY SUPPORTED PLATE WITH TRANSVERSE LOAD OF 0.1 MPa

RESULTS OF ISOTROPIC SIMPLY SUPPORTED ON BOTH SIDES RECTANGLAR PLATE – CASE 2

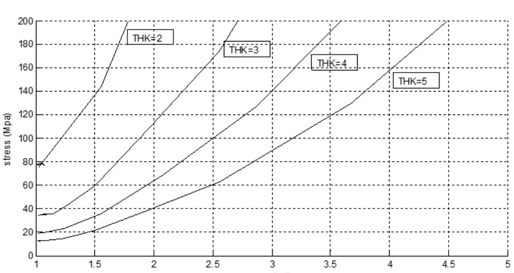

FIGURE (7) ASPECT RATIO VS STRESS FOR SIMPLY SUPPORTED PLATE WITH TRANSVERSE LOAD OF 0.2 MPa

thickness	2	thickness	3	thickness	4	thickness	5
aspect	Stress	aspect	stress	aspect	stress	aspect	stress
1.02	75.73	1.02	33.60	1.02	18.77	1.02	12.06
1.56	143.56	1.25	41.78	1.24	23.14	1.23	14.58
2.09	278.62	1.50	59.21	1.55	35.74	1.50	21.32
		1.99	112.19	2.07	67.76	1.94	38.12
		2.56	174.53	2.88	127.95	2.56	63.04
		3.57	339.52	4.06	248.59	3.67	129.40
						5.18	260.19

TABLE (3) ASPECT RATIO & STRESS VALUES INDICATING STRESS/ASPECT FOR SIMPLY SUPPORTED PLATE WITH TRANSVERSE LOAD OF 0.2 MPa

Note that thickness of 1mm for the aspect ratio of 1 is well above 200 N/mm2

RESULTS OF ISOTROPIC CLAMPED ON BOTH SIDES RECTANGLAR PLATE – CASE 3

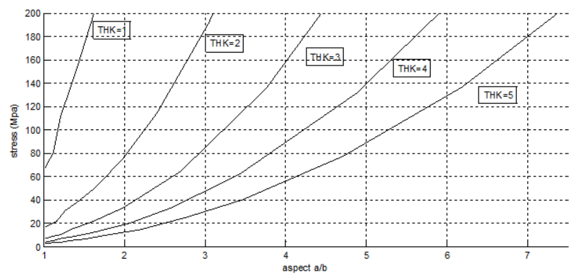

FIGURE (8) ASPECT RATIO VS STRESS FOR CLAMPED PLATE WITH TRANSVERSE LOAD OF 0.1 MPa

thickness	1	thickness	2	thickness	3	thickness	4	thickness	5
aspect	stress	aspect	stress	aspect	stress	aspect	stress	aspect	stress
1.02	67.57	1.02	16.96	1.02	7.529	1.02	4.255	1.02	2.739
1.06	72.7	1.05	17.84	1.06	8.085	1.06	4.571	1.05	2.895
1.12	80.9	1.10	19.41	1.11	8.904	1.12	5.096	1.11	3.179
1.21	111.9	1.16	21.9	1.20	10.32	1.21	6.981	1.19	3.66
1.38	146	1.27	30.63	1.36	15.45	1.39	9.121	1.32	5.271
1.63	200.2	1.42	38.34	1.63	22.13	1.64	12.62	1.50	6.745
		1.64	50.87	1.98	33.46	2.07	20.48	1.80	9.971
		1.98	75.61	2.70	64.52	2.58	33.26	2.19	14.68
		2.40	113.6	3.76	135.7	3.43	62.03	2.77	25.15
		3.05	191.7	5.29	280.3	4.87	131.5	3.47	40.46
		3.96	340.4			6.49	239.6	4.71	77.26
								6.19	137.1
								8.25	246.8

TABLE (4) ASPECT RATIO & STRESS VALUES INDICATING STRESS/ASPECT FOR CLAMPED PLATE WITH TRANSVERSE LOAD OF 0.1 MPa

RESULTS OF ISOTROPIC CLAMPED ON BOTH SIDES RECTANGLAR PLATE – CASE 4

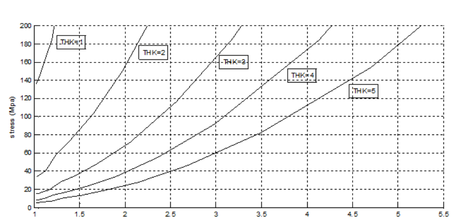

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FIGURE (9) ASPECT RATIO VS STRESS FOR CLAMPED PLATE WITH TRANSVERSE LOAD OF 0.2 MPa

thick-ness	1	thick-ness	2	thick-ness	3	thick-ness	4	thick-ness	5
aspect	stress	aspect	stress	as-pect	stress	as-pect	stress	as-pect	stress
1.02	135.5	1.02	33.96	1.02	15.11	1.02	8.533	1.02	5.466
1.06	144.2	1.06	36.66	1.05	15.99	1.06	9.11	1.06	5.821
1.11	158.9	1.13	41.06	1.10	17.48	1.12	10.12	1.11	6.432
1.20	184.9	1.24	58.41	1.16	19.48	1.21	13.78	1.19	7.303
1.33	270.9	1.38	72.7	1.29	28.07	1.37	17.74	1.33	10.64
		1.65	102.2	1.45	35.33	1.57	23.06	1.51	13.63
		1.97	149.7	1.69	47.38	1.91	34.84	1.79	19.78
		2.49	246.7	2.06	72.07	2.36	55.06	2.14	27.82
				2.56	116	2.98	91.72	2.69	46.18
				3.18	186.1	4.13	183.8	3.50	82.43
				4.10	322.9	5.68	360.9	4.71	154.1
								6.44	298.7

TABLE (5) ASPECT RATIO & STRESS VALUES INDICATING STRESS/ASPECT FOR CLAMPED PLATE WITH TRANSVERSE LOAD OF 0.2 MPa

TYPE	PRES Mpa	THK	a/b	a	MODE-1	DEFL.	R	MODE-2	DEFL	R	MODE-3	DEFL	R	MODE-4	DEFL	R	MODE-5	DEFL	R
SS	0.1	1	1.285	51.4	0	11.117	S	2.96E-05	14.681	S	29.187	11.476	B	58.17	18.401	T	178.12	32.081	T
SS	0.1	2	2.58	103.2	0	7.841	S	14.274	5.76	B	58.544	9.548	T	77.681	9.223	B	198.3	12.206	T
SS	0.1	3	3.81	152.4	2.37E-05	4.123	S	9.6968	3.907	B	41.491	4.337	B	71.863	7.316	T	168.55	9.867	T
SS	0.1	4	5.07	202.8	2.24E-05	2.851	S	7.296	2.925	B	35.524	3.72	B	73.784	5.142	T	149.63	7.122	T
SS	0.1	5	6.35	254	1.22E-05	1.723	S	5.7767	2.271	B	23.708	2.436	B	62.558	3.278	T	89.003	5	T
SS	0.2	2	1.78	71.2	0	5.406	S	3.19E-05	4.883	S	30.006	7.465	B	84.998	11.168	T	329.05	9.973	T
SS	0.2	3	2.72	108.8	2.91E-05	5.947	S	19.38	4.654	B	79.844	7.38	T	120.04	9.601	T	211.53	12.13	T
SS	0.2	4	3.61	144.4	0	4.449	S	14.429	3.384	B	59.38	4.49	B	96.112	6.545	T	204.42	8.1	T
SS	0.2	5	4.55	182	0	2.709	S	11.305	2.722	B	51.347	3.321	B	97.601	4.848	T	203.58	6.802	T
CC	0.1	1	1.6	64	43.583	9.986	B	62.865	17.553	T	136.75	17.691	B	177.47	29.021	T	231.52	38.834	B
CC	0.1	2	3.06	122.4	24.758	6.209	B	56.473	9.919	T	88.813	6.778	B	138.83	12.86	T	194.89	12.837	B
CC	0.1	3	4.47	178.8	18.679	3.942	B	54.605	6.422	T	62.044	5.602	B	144.78	9.014	T	170.4	8.446	T
CC	0.1	4	5.89	235.6	13.392	2.944	B	42.554	3.505	B	59.361	5.727	T	107.61	4.721	B	157.67	5.131	B
CC	0.1	5	7.38	295.2	10.05	2.453	B	32.415	2.602	B	61.588	4.783	T	65.863	2.866	B	154.57	5.916	B
CC	0.2	1	1.19	47.6	82.112	16.276	B	101.12	24.535	T	197.99	30.115	B	347.35	1.62E-12	T	909.37	46.715	T
CC	0.2	2	2.23	89.2	46.314	7.902	B	87.065	13.526	T	197.05	12.38	B	341.46	14.702	T	505.8	31.045	T
CC	0.2	3	3.26	130.4	34.23	5.063	B	78.833	7.69	T	157.98	6.165	B	201.94	9.594	T	382.89	9.864	T
CC	0.2	4	4.25	170	26.072	3.839	B	76.727	6.088	T	116.82	5.963	B	192.57	8.166	T	275.96	7.28	T
CC	0.2	5	5.28	211.2	19.48	2.939	B	60.89	3.259	T	79.674	5.434	T	192.67	4.828	T	263.06	7.36	T

SS : SIMPLY SUPPORTED; CC: CLAMPLED; S : SKEWING; B : BENDING; T : TWISTING

TABLE (6) MODAL ANALYSIS FOR OPTIMUM ASPECT RATIO

REFERENCE [1] Chen Jianqiao, Tang Yuanfu, Ge Rui, An Qunli, Guo Xiwei (2013), Reliability design optimization of composite structures based on PSO together with FEA, Chinese Journal of Aeronautics,343–349 | [2] M Amrita, Sarojini Jajimoggala, (2012), Design Optimiation by using Particle Swarm Optimiation in MATLAB and APDL in ANSYS, International Journal of Engineering Science and Technology (IJEST) |