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Employing Finite Element Software for Buckling Analysis of Laminated Composite Plate

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ABSTRACT
The parametric study on buckling analysis of laminated composite plates using ANSYS the finite element software. The results obtained are validated withthe analytical solution from the standard journal papers. The study is focused on obtaining the critical buckling load of cross-ply laminated composite plate subjected touniaxial and biaxial compressive loading, varying plate parameters a/b (aspect ratio) = 0.5 to 1.5 with 0.5 increment, a/h (length to thicknessratio) = 10 and 100, and E_1/E_2 (orthotropic ratio) = 10 to 40 with 10 increment. The effectof change in combination of support condition on edges of plateis carried out for the variables as mentioned above. The effect of fiber angle orientation on size of mesh for cross-ply and angle-ply with symmetric and antisy mmetric stacking sequence to be determined by carrying out convergence test on plate by changing the size of mesh from coarser to finer until the converged mesh size is obtained. The effect of increasing number of lamina for constant length to thickness ratio, aspect ratio, orthotropic ratio and boundary condition; for biaxial compressive loading is carried out to determine the variation in critical bucklingloads.
Keywords: Angle-ply, ANSYS 19.0 APDL, Aspect ratio, Cross-ply, Critical buckling and orthotropic ratio.

I. INTRODUCTION

In structural engineering, there are many types of failures like creep, fatigue, alternate stresses, bending, buckling etc. Buckling takes place in columns, plates, shells, and other structures of regular or irregular geometry. This paper deals with analysis of laminated composite plates for critical buckling in uniaxial and biaxial loading. The minimumloadatwhichtheequilibriumisdisturbedkno wnasthecriticalbucklingload. The laminated composite plates are thin shell elements composed of fibre lamination and epoxy resin is used to bond the lamina. The strength of these composite plates depended on type and properties of fibre material used along with epoxy resin. In structural designing field ANSYS, ABAQUS, FEMAP, COSMOS, Nastran and so on are the most used finite element analysis software's. ANSYS is most trusted finite element software as it provides ease of work to analyse the laminated compositeplates under buckling in uniaxial loading and biaxial loading. Whereas in experimental study the biaxial loading is complicate to perform and requires energy andresources.

It is observed that the aspect ratio, orthotropic ratio and fiber angle orientation lay-up sequences significantly effects the buckling behaviour of the laminated composite plates [1]. The buckling analysis for cross-ply and orthotropic laminated composite platesubjectedtomechanical(uniaxialandbiaxial)and thermalloadingarecarriedout by meshless collocations using Gaussian and Multiquadric radial based functions [2]. The procedure based on the generalized Levy type solution considered in conjunction with the state space concept applicable to rectangular plates subjected to various combination of support conditions applying the first two oppositeparalleledgessimply supported and other edges be clamped, free and simply supported [3]. The buckling analysis of 3-layered cross-ply laminated Composite Square and cylindrical plate with circular cutouts done using ANSYS 14.5 APDL. The effect of varying aspectratio, a/h ratio and changing cutout place in plate are observed [4]. The anisotropic laminated clamped-clamped composite plates are analysed using developed Rayleigh-Ritz generalized analytical buckling formula. The analytical buckling values are validated with FEA software ABAQUS [5]. Carried out the parametric study on symmetrically laminated composite elliptical plates under buckling and vibration varing aspect ratio, fiber orientation and plate edge support conditions [6]. The buckling analysis of rectangular laminated composite plate with and without cutouts for the effects of fiber angle orientation and cutout shapes on critical buckling load are determined [7]. The obtained experimental buckling results are validated with FEA tool MSC.Patran and MSC.Nastran package [8]. The effect of varying plate parameters aspect ratio, orthotropic ratio and fiber orientation for antisymmetric laminated composite plates subjected to in plane loading are discussed to obtain critical buckling load[9].

II. CONVERGENCESTUDY

In this, the convergence behaviour of laminated plates obtained using the material, geometry and support conditions same as the reference.Itisclearthatthepresentresults are converging well with the mesh refinement.

Table-1: Convergence test for cross-ply and angle-ply.

[0/90/0] cross-ply		[45/-45]2 angle ply		[30/-30]2 angle-ply	
Number of mesh (MxN)	Critical buckling load	Number of mesh (MxN)	Critical buckling load	Number of mesh (MxN)	Critical buckling load
10×10	14.519	25×25	10.945	40×40	14.423
15×15	14.516	30×30	10.636	45×45	14.184
20×20	14.514	35×35	10.390	50×50	14.062
25×25	14.513	40×40	10.192	55×55	13.984
30×30	14.513	45×45	10.027	60×60	13.920
35×35	14.513	50×50	9.8854	65×65	13.920
40×40	14.513	60×60	9.8854	70×70	13.920
45×45	14.513	65×65	9.8854	75×75	13.920

The Table-1 shows that the laminated composite [0/90/0] symmetric cross-ply plate critical buckling value gets converge on number of mesh 25×25 on fining number of mesh from 10×10 to 45×45. The laminated composite [45/-45/45/-45] antisymmetric angle-ply plate critical buckling value gets converge on number of mesh 50×50 on fining number of mesh from 25×25to65×65. The laminated composite [30/-30/30/-30] antisymmetric angle-ply platecritical buckling value getsconverge on number of mesh 60×60 on fining number of mesh from 40×40 to75×75.From this study, weget to know that in any laminated composite plate the change in ply angle simultaneously affects the size of mesh on platesurface.

III. RESULTS ANDDISCUSSION

Before start with the new illustration study, the study is to be validated by comparing the results obtained in ANSYS 19.0 with the related standard reference [1, 2].

1.1 Validation

The present ANSYS model is being validate by comparing the results with references [1, 2] bytaking the same material properties and geometrical parameters, the boundary conditions are as stated in references [1, 2]. The present ANSYS model validation has been obtained for two different laminated composite plates and are presented in tables below.

In Table-2 the present ANSYS results are showing good agreement and the values are higher side with max 3.76% error compared to the reference [1] for uniaxial compressive loading in X-axis. And the values are lower side with max 15.98% error for uniaxial compressive loading in Y-axis compared to the reference [1]. It is because of the fact that the present model is developed in the finite element analysis software ANSYS whereas in the reference the model is developed based on analytical solution. In Table-3 validation of buckling analysis carried out in ANSYS 19.0 APDL results compared with the standard research journal [1, 2]. For uniaxial and biaxial compressive loading the values are obtained for all edges simply supported (SSSS) boundary condition.

Table-2: Validate the ANSYS results with reference [1] for 5-layer cross-ply square plate a/h ratio=10 and E_1/E_2 ratio=40.

Boundary condition	Uniaxial $(\lambda_x)_{cr}$			Uniaxial $(\lambda_y)_{cr}$			Biaxial $(\lambda_b)_{cr}$		
	Present	Ref [1]	% error	Present	Ref [1]	% error	Present	Ref [1]	% error
SSSS	24.866	24.400	1.91	20.211	22.500	10.17	12.528	12.100	3.54
CCCC	42.851	41.300	3.76	27.140	32.300	15.98	23.490	24.600	4.51
CCSS	38.315	37.200	3.00	24.508	27.300	10.23	19.861	20.300	2.16
CSCS	34.220	34.400	0.52	23.041	26.000	11.38	17.277	17.100	1.04

Table-3: Validate the ANSYS results with reference [1, 2] for 3-layer cross- ply square plate.

Buckling direction	**a/b**	**a/h**	**E1/E2**							
			10		20		30		40	
			Present ANSYS	Ref [1, 2]	Present ANSYS	Ref [1, 2]	Present ANSYS	Ref [1, 2]	Present ANSYS	Ref [1, 2]
Uniaxial-X	0.5	10	7.434	7.120	12.418	12.210	16.260	16.340	19.317	19.400
		100	8.720	---	16.659	---	24.549	---	32.403	---
	1	10	10.761	9.998	15.583	15.000	19.409	19.320	22.514	22.600
		100	12.579	11.488	20.635	19.650	28.735	27.799	36.828	35.915
Uniaxial-Y	0.5	10	9.494	6.940	10.920	8.720	12.069	10.740	13.092	11.980
		100	11.287	---	14.262	---	17.127	---	20.085	---
	1	10	8.106	7.340	9.680	9.560	11.064	11.370	12.256	12.780
		100	9.627	---	12.556	---	15.618	---	18.718	---
Biaxial	0.5	10	6.068	5.100	7.890	5.980	9.085	6.960	10.108	8.680
		100	7.105	---	10.242	---	12.979	---	15.757	---
	1	10	5.628	5.120	7.972	7.810	9.030	9.000	9.955	10.000
		100	6.581	5.761	10.341	9.579	12.746	12.106	15.204	14.583

Table-4: [0/90/0] symmetric cross-ply for clamped supported (CCCC) on plate edges.

Buckling direction	a/b	a/h	Orthotropic ratio E_1/E_2			
			10	20	30	40
Uniaxial-X	0.5	10	19.943	27.524	31.758	34.468
		100	33.531	64.484	95.115	125.364
	1.0	10	28.967	34.816	38.134	40.226
		100	48.142	78.904	109.720	140.370
	1.5	10	42.991	44.747	45.500	45.807
		100	96.527	126.553	158.827	191.980
Uniaxial-Y	0.5	10	18.605	19.335	19.689	19.901
		100	29.753	37.909	45.419	52.583
	1.0	10	16.991	17.527	18.014	18.397
		100	26.847	34.600	42.009	49.190
	1.5	10	17.473	18.537	18.958	19.215
		100	29.123	37.947	46.254	54.702
Biaxial	0.5	10	14.808	15.963	16.497	16.849

		100	23.427	31.524	38.524	45.090
	1.0	10	14.643	15.151	15.636	16.064
		100	22.676	29.295	36.323	43.410
	1.5	10	15.085	16.159	16.879	17.365
		100	23.861	33.223	42.620	50.771

Table-5: [0/90/0] symmetric cross-ply for clamped and simply supported (CCSS) on plate edges.

Buckling direction	a/b	a/h	Orthotropic ratio E_1/E_2			
			10	20	30	40
Uniaxial-X	0.5	10	19.307	27.090	31.362	34.064
		100	32.560	63.765	94.462	124.712
	1.0	10	22.809	29.894	33.885	36.468
		100	38.140	69.222	99.926	130.250
	1.5	10	31.404	36.463	39.534	41.344
		100	52.577	82.747	113.613	144.400
Uniaxial-Y	0.5	10	13.089	14.396	15.305	16.032
		100	20.456	27.869	34.489	41.061
	1.0	10	11.591	13.630	14.711	15.540
		100	18.398	25.120	31.966	38.803
	1.5	10	11.655	13.343	14.519	15.398
		100	17.644	24.675	31.654	38.565
Biaxial	0.5	10	10.943	12.166	13.008	13.671
		100	17.260	23.990	30.302	36.579
	1.0	10	9.698	11.195	12.242	13.048
		100	15.409	23.004	28.919	34.879
	1.5	10	10.243	12.408	13.423	14.147
		100	16.819	22.713	28.738	34.757

Table-6: Buckling analysis of 3-layer symmetric cross-ply plate for clamped and simply supported (CSCS) on plate edges.

Buckling direction	a/b	a/h	Orthotropic ratio E_1/E_2			
			10	20	30	40
Uniaxial-X	0.5	10	12.433	18.979	23.194	26.150
		100	17.189	33.329	49.303	65.136
	1.0	10	16.998	23.384	27.670	30.787
		100	23.112	39.587	56.011	72.336
	1.5	10	28.186	33.895	37.722	40.384
		100	41.612	58.931	77.093	95.440
Uniaxial-Y	0.5	10	11.470	12.903	13.951	14.793
		100	15.768	20.785	25.605	30.340
	1.0	10	10.402	12.130	13.416	14.418
		100	14.190	19.537	24.831	30.043
	1.5	10	10.817	12.888	14.221	15.172
		100	15.038	21.526	27.455	33.120
Biaxial	0.5	10	8.737	10.301	11.312	12.094
		100	11.897	16.733	21.056	25.259
	1.0	10	8.433	10.105	11.213	12.078
		100	11.498	16.199	20.636	25.045
	1.5	10	10.243	12.408	13.423	14.147
		100	16.819	22.713	28.738	34.757

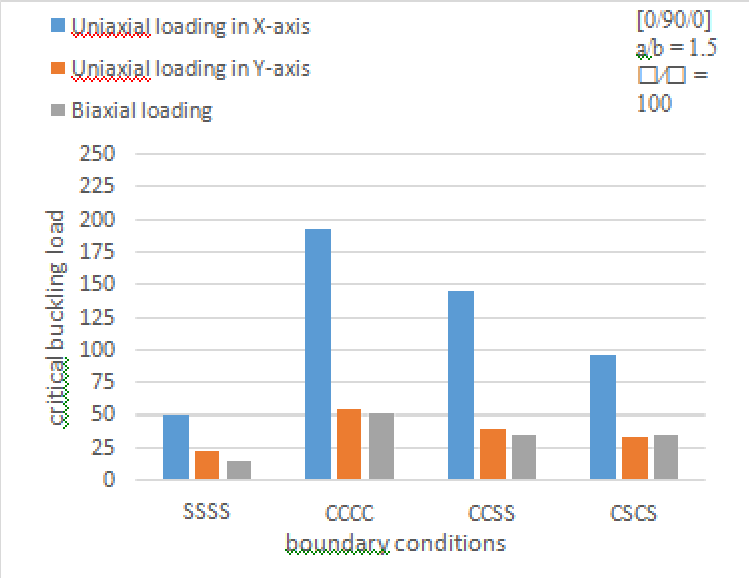

Chart-1: 3-layer cross-ply laminated compositeplate.

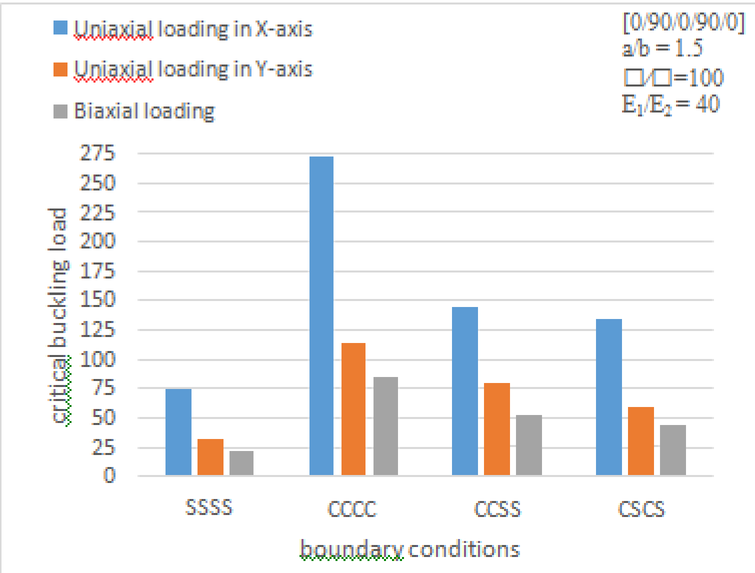

Chart-2: 5-layer cross-ply laminated compositeplate.

In Chart-1 and Chart-2 variation of critical buckling load for different combination of boundary conditions and change in loading pattern on 3-layer and 5-layer symmetric cross-ply composite plates. For a clamped boundary condition on all edges [CCCC], aspect ratio=1.5 and length to thickness ratio=100. The critical buckling load of 3- layered and 5-layered symmetric cross-ply plate is 191.980 and 271.927 respectively for uniaxial loading in X-axis are greater than the other loading patterns.

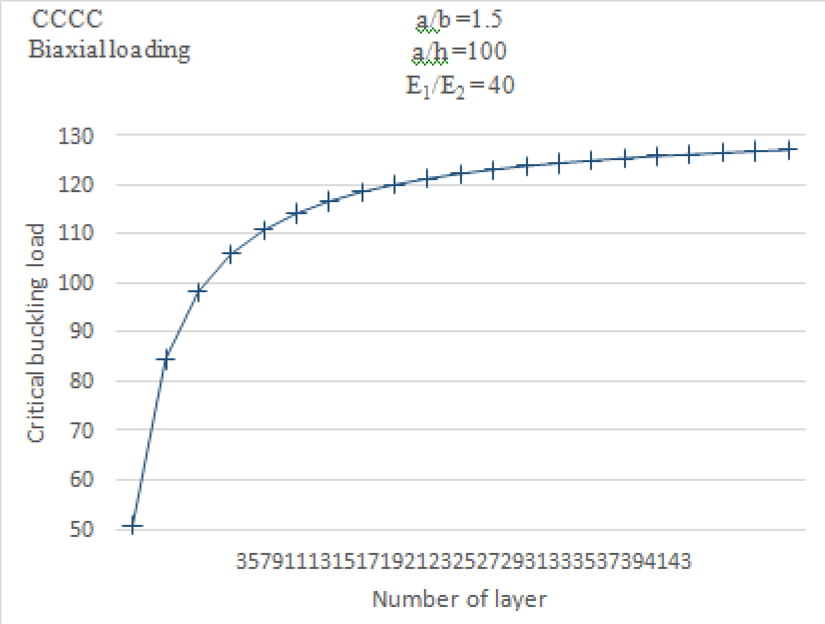

Chart-3: The change in buckling load of symmetric cross-ply plate for number of layers.

The laminated composite plate with same thickness and keeping all other parameters same, the increase in number of layers increases the critical buckling load is shown in Chart-3. From number of layer 33 to 45 there is no more difference in buckling value.

IV. CONCLUSION

In the present study, buckling analysis of laminated composite plate is done using finite elementanalysis software ANSYS19.0APDL.Theobtainedresultsarevalidated with standard results from literature journal papers. The above results for critical buckling loads of symmetric cross-ply laminated composite plates varying aspect ratio i.e. a/b = 0.5,1and1.5,lengthtothicknessratioi.e.a/h=10,100andorthotropicratioi.e.E_1/E_2 = 10, 20, 30 and 40 for different combination of boundary conditions [SSSS, CCCC, CCSS and CSCS].

- In convergence study, it is seen that finer the mesh size in plate element is used, then it will give converged (good) results. For number of mesh 25X25 is used for analysis of cross-ply. It was also observed that when the fiber orientation angle in lamina decreases in antisymmetric angle-ply the convergent mesh size keeps on decreasing.
- From above study, the critical buckling loads keeps on increasingas the orthotropic ratio increased for all combinations of boundary conditions and varying as pectratio.
- It is observed that the critical buckling load of 5-layer symmetric cross-ply plate edges with CCCC boundary condition, a/b=1.5 and a/h=100 for uniaxial loadingin X-axis is higher than the other i.e. $[\lambda_x]_{cr}$=271.927 N/mm and the critical buckling load of 3-layer symmetric cross-ply plate edges with SSSS boundary condition, a/b=1 and a/h=10 for uniaxial loading in Y-axis is least i.e. $[\lambda_y]_{cr}$=8.106 N/mm.
- In results, it was noticed that the plate with same thickness and keeping all other parameters same, the increase in number of layers increases the critical buckling load.

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