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IISc THESES ABSTRACTS

Thesis Abstract (Ph.D.)

Study of vibration, buckling and flutter problems of composite laminates

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1. Introduction

Laminated composite plates are used extensively as primary structural components in various engineering applications. They are built-up of a number of layers in such a fashion so as to best match the requirements of the given structural application. This construction actually results in heterogeneous anisotropy which gives rise to rather complex vibration, buckling and flutter characteristics of laminated composite plates. For an efficient design, however, these features must be well understood preferably by making use of an elegant and economic method of analysis. This thesis is a contribution in this direction, to the analysis of vibration, buckling and flutter of composite laminates.

2. Problem formulation

A general formulation of the problems of vibration, buckling and panel flutter of composite laminates is made, using higher-order transverse shear deformation theory. This generalized formulation is concise and helps in a unified treatment of the three problems, for any combination of boundary conditions and with full control on the various design parameters of the laminates. In the panel flutter calculations, the two-dimensional static approximation for aerodynamic loading is employed. The formulation presented here, based on Lagrange equation approach, is for any angle-ply or cross-ply laminate with symmetric, anti-symmetric or unsymmetric lay-ups. For the solution, in-plane displacements (U, V) and rotations of line normal to middle surface of the laminate (β_x, β_y) are expressed in terms of trigonometric sine-cosine series whereas, out-of-plane displacement (W) is expressed in terms of double series of admissible functions as appropriate to the given boundary conditions of the laminate. During this study, algebraic errors in a paper published earlier dealing with a free vibration problem of a clamped rectangular laminate, which vitiate the final results have also been brought out and clarified.

3. Results and discussions

3.1. Free vibration

The free vibration problems of composite laminates of rectangular, skew and trapezoidal geometries are studied in detail. A general quadrilateral geometry is first mapped on to a unit-square domain, employing a standard technique. The assumed modes for the out-of-plane

Table I
Convergence study; Rectangular, clamped C_1–C_1–C_1–C_1 symmetric angle-ply composite laminate

No. of layers = 4 [30°/60°/60°/30°] a/b = 1 ψ_1 = 0°

M	N	Matrix size	k_1	k_2	k_3	k_4	k_5	k_6
2	2	(20 × 20)	36.79	67.47	97.84	130.6	...	—
3	3	(45 × 45)	35.28	58.61	85.65	119.6	128.8	—
4	4	(80 × 80)	35.03	56.67	81.70	85.4	116.9	126.7
5	5	(125 × 125)	35.01	56.57	80.83	85.1	116.3	126.0

E_1/E_2 = 40.0 ν_{12} = 0.25 G_{12}/E_2 = 0.5

displacement (W) are respectively expressed in terms of double series of clamped-clamped beam characteristic functions for clamped laminates and Chebyshev polynomials for simply supported laminates. The effects of the geometrical parameters such as aspect ratio, ply angle, number of layers as also the thickness ratios of plies on the frequencies of the laminates are systematically studied and the lay-ups of laminates which tend to maximise the natural frequencies of vibration, are arrived at. The preferred stacking sequences and the optimum thickness ratios of laminate for achieving a maximum value of the fundamental frequency for a given configuration are then employed to determine the various frequencies and nodal patterns. Numerical results obtained from this analysis, on specialisation to isotropic as well as orthotropic cases, are first compared with the results available in the literature. Convergence is studied (Table I) for frequency-parameter values of laminates by varying the terms in the assumed series for displacements and rotations. Numerical results, for a set of rectangular composite laminates with clamped and

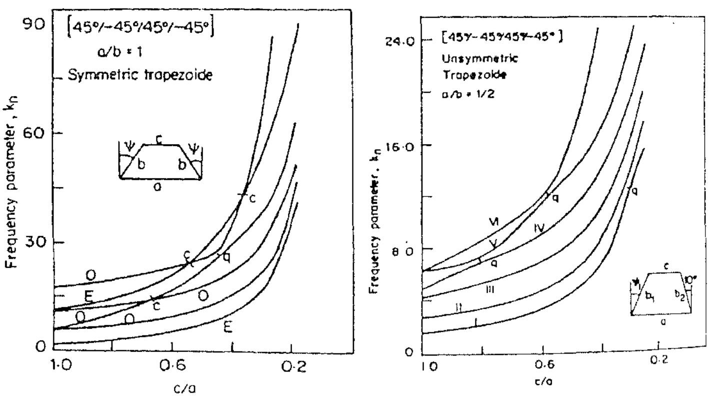

Fig. 1 Variation of frequencies with ratio of two parallel sides of simply supported trapezoidal laminates

simply supported boundary conditions all round respectively, are obtained and compared with the earlier published results. Several of the results obtained for the skew and trapezoidal laminates are believed to be new. The influence of material anisotropy on the occurrence of frequency crossings and quasi-degeneracies of the modes of these laminates is elucidated (fig 1) Results are obtained for laminates made out of various commonly used composite materials such as glass-epoxy (GFRP), boron-epoxy (BFRP), organic fibre-epoxy (OFRP) and graphite-epoxy (GrFRP) These results have provided a good insight into several significant features concerning the influence of geometrical parameters, on the frequencies and nodal patterns of skew and trapezoidal laminates, quite apart from their value and utility to a designer as reliable data hitherto not available

3 2 Buckling

Buckling problem of quadrilateral laminates with different edge conditions is solved for direct, (σ_y, σ_x), shear (σ_{xy}) and combined stresses, using the formulation of chapter 1 In the presence of symmetry in geometry, the resulting matrix equation is divided into two groups corresponding to buckling modes which are skew-symmetric and skew-antisymmetric, respectively. The lower of the two lowest eigenvalues so obtained from these two sets, corresponds to the critical buckling load Convergence has been examined in a few typical cases Critical buckling values of the laminate configurations are obtained for the laminates with clamped and simply supported boundaries all round, as example cases of the general formulation Several significant features concerning the influence of boundary conditions, geometrical parameters such as skew angle, side ratio and fibre orientations in the laminate on the critical buckling coefficient under direct and shear loadings, acting individually or in combination, are studied in detail Numerical results obtained here are also useful in the vibration analysis of such laminates with in-plane load conditions

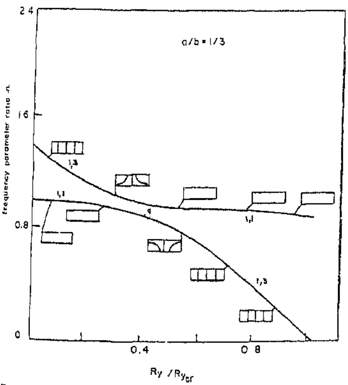

FIG 2 Metamorphosis of nodal patterns with increasing value in-plane uniform compression (σ_r) on A cross-ply quardrilateral laminate ($\psi_1 = \psi_2 = 0$ and $a/b = 1/3$).

3 3 Dynamics of stressed laminates

The influence of applied in-plane stresses on the dynamic behaviour of the laminates is al examined (fig. 2) Free lateral vibration of clamped and simply supported laminates subjected both direct and shear in-plane forces (positive and negative) acting individually and in combinati are considered Numerical results are computed for a wide range of laminate configurations a for various combinations of in-plane forces The effect of in-plane forces on the crossings ai quasi-degeneracies of frequency curves of the laminate are discussed in detail With tl increasing level of applied in-plane stresses, a reduction of the frequency parameter values observed, leading finally to a zero value at the critical buckling load These observations confir the results obtained by direct buckling analysis The extensive data obtained is presented in tl form of curves, which should be of considerable value to the designer

3.4 Panel flutter

The supersonic panel flutter problem of aerodynamic surfaces made of composite laminates also investigated Panel flutter boundaries of unstressed and stressed quadrilateral laminates ai obtained The solution of the flutter problem is obtained for clamped panels by using appropria assumed displacement modes Two-dimensional static approximation is used to represent th aerodynamic loading The assumed mode flutter analysis finally reduces to an algebra eigenvalue problem The critical dynamic pressure parameter is obtained by the frequenc coalescence criterion The effects of fibre orientation, skew angle and the material of the laminat on the critical dynamic pressure are carefully brought out in this study

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Thesis Abstract (Ph.D.)

Variations in boundary shear stress in sand-bed channels subjected to seepage

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1. Introduction

Field channels are invariably subjected to seepage across the perimeter of their cross section It is necessary that the effect of seepage on channel flow be understood clearly to consider this aspect in the design of stable channels Earlier experimental investigations show that the boundary resistance of permeable boundaries is higher than that of nonpermeable boundaries, of the same rugosity[1], and suction always decreases the rate of sand transport whereas blowing increases this rate[2] Recent studies[3] conducted with (0 335 mm sand) near uniform flow conditions showed that, under no transport condition, the boundary shear stress (bed shear) decreases with suction and increases with injection compared to the no seepage condition. When bed material concentration was maintained constant under transporting conditions, suction was found to decrease the bed shear stress and the relative effect of seepage found to be a function of the initial flow condition in the channel and the applied suction.

The present study is an extension to enlarge the available data base under different flow conditions and to determine qualitatively and quantitatively relationships describing the effect of seepage on channel beds (non-transporting as well as transporting) under controlled conditions in the laboratory

2. Experiments

Uniform crushed quartz of 0.80 and 0.53 mm sizes were used to form sand beds in the present experimental investigation. The experimental set-up has facilities to apply seepage out of the channel (suction) as well as into the channel (injection) perpendicular to the sand bed in a rigid walled flume

3. Analysis

The flow in the open channel with seepage applied perpendicular to the bed is a spatially varied flow Accordingly, spatially varied flow equations were used to analyse the experimental data collected in the study for both the sand sizes. Also results are available from a previous study[3] on 0.335 mm sand based on uniform flow analysis To compare the results of this study with the present investigation, the experimental data were analysed using uniform flow equations also The effect of seepage was analysed with reference to the initial condition in the channel and the rate of seepage applied on the bed.

A comparison of the average of the ratios of shear stresses with and without seepage, computed from spatially varied flow analysis for the 34 sections along the main channel and from uniform flow analysis treating the entire channel as a single reach, showed that there is no significant change between the two types of analyses When the bed was below the condition for incipient motion of bed particles, the difference was within 5 per cent of the mean value of the ratio of shear stresses with and without seepage, obtained from the spatially varied flow analysis The ratios of the bed shear stresses with and without seepage computed from spatially varied flow and uniform flow analyses agreed with each other within 8 per cent (of the value computed by spatially varied flow analysis) when the bed was under transporting condition

4. Results

4.1. No transport condition

It was found from the present study that when the bed was below the condition for incipient motion of bed particle, seepage out of the channel (suction) decreases the bed shear stress; whereas seepage into the channel (injection) increases the bed shear stress compared to the bed shear stress for the no seepage condition. The relative change in the bed shear stress due to seepage depends on the initial flow condition in the channel and the rate of seepage applied. The initial flow condition in the channel is expressed as the ratio of the bed shear stress under no seepage condition to the critical shear stress corresponding to the bed material used, (τ_0/τ_c).

The ratio of the bed shear stress with and without seepage, (τ_s/τ_0), is expressed as a function of the ratio of the bed shear stress under no seepage condition to the critical shear stress corresponding to the bed material size, (τ_0/τ_c), and the non-dimensional seepage velocity, $v_0/\sqrt{(g\bar{y}_0)}$, where v_0 is the seepage velocity applied and $\bar{y}_0$ the average value of the initial depth of flow in the channel. The size of the bed material is thus accounted for implicitly in the critical bed shear stress, τ_c. The functional relationship was defined, based on the experimental data for the sand sizes tested. The results show that the relative change in bed shear stress decreases as the flow condition approaches the incipient condition for the movement of bed particles in suction. In the case of injection, the relative bed shear stress increases at a decreasing rate as the flow condition approaches the incipient condition for the movement of bed particles. When the initial flow condition is very close to and below the critical condition for particle movement, the effect of seepage in changing the bed shear stress is found to be insignificant.

4.2. Transporting condition

When the bed was under transporting condition, it is found that suction causes an increase in the bed shear stress when compared to the no seepage condition, as long as the bed material concentration is less than a characteristic value termed as the 'critical concentration' in the present study. In this range, the relative change in bed shear stress due to suction decreases with increase in the concentration and as the concentration approaches the critical value, the effect of suction becomes negligible.

The boundary shear stress is found to decrease with suction at concentrations higher than the critical concentration. The rate of change in the boundary shear stress due to suction is low at relatively lower values of bed material concentration in this range. The relative change in boundary shear stress with suction is found to be a function of initial flow condition and the rate of seepage applied. The initial condition is defined by the inverse ratio of the bed material concentration to critical concentration, (X_c/X). The rate of seepage applied is defined by $v_0/\sqrt{(g\bar{y}_0)}$, where v_0 is the seepage velocity perpendicular to the bed and $\bar{y}_0$ the average value of the initial depth of flow in the channel.

The ratio of the bed shear stress with and without seepage (τ_s/τ_0) is expressed as a function of X_c/X and $v_0/\sqrt{(g\bar{y}_0)}$. The functional relationships thus developed give a quantitative estimate of the bed shear stress due to applied rate of suction.

The critical concentration is characteristic of the sediment and found to be predominantly a function of the particle size and therefore of the critical shear stress associated with it. In the present analysis for the three sizes of sand studied, two functional relationships were developed to estimate the critical concentration: one, relating to the mean grain size and the other to the critical shear stress.

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Thesis Abstract (M.Sc. Engng)

Decision-making styles of executives—a study in Indian manufacturing organization by Prince D. Vijay Kumar.

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1. Introduction

Powerful management science techniques based on rational procedures are being developed and are on the increase, being more interesting to the practising managers. However, the utility of these techniques depends upon their successful implementation in practice. There is growing evidence to show that the style of decision-making of executives involved in implementation determines to a considerable extent the success or failure of implementation of these techniques.

Based on the mental approach of individuals to decision-making, two kinds of decision styles, namely 'analytic' or 'heuristic', were extracted from the many proposed in the literature[1–3]. A decision-maker who perceives through sensation and evaluates through thinking is considered analytic and a decision-maker who perceives through intuition and evaluates through feeling is considered heuristic. Production decision-makers in organizations employ a variety of methods of perception and evaluation and therefore, the problem lies in classifying them either as analytic decision-makers or heuristic decision-makers. Managers tend to possess a mix of the analytic and heuristic approaches depending upon the decision situation.

The tendency to be analytic or heuristic decision-makers will depend on the following four factors: (i) The environment that triggers the decision-making process, (ii) The autonomy of the decision-maker, (iii) The impact of the decision, and (iv) The personality of the decision-maker.

2. Experimental study and discussion

The objective of the study is to develop an instrument to classify executives as analytic and heuristic and to test a few hypotheses relating to decision styles in a given situation.

The instrument was designed using a pilot study involving (i) formulation of a comprehensive definition for each category, (ii) selection of elements involved in analytic and heuristic decision-making styles, (iii) design of a preliminary questionnaire consisting of 56 selected elements Based on the responses in the pilot study and using simple statistical procedures these preliminary questions were condensed into a final inventory of 20—ten each relating to heuristic and analytic which were statistically significant (Table I).

Table I
List of vital elements in analytic and heuristic definitions

	Analytic		Heuristic	
1	Sequential approach	87 39	Moods & feelings	91 69
2	Numerical value	86.69	Hunches	90 06
3.	Organised approach	86.15	Precedents	87.25
4	Critical examination	85.72	Verbal/Scenario	86 69
5	Quantitative methods	83 90	Rule of thumb	86 40
6	Data	82.95	Trial and error	85 10
7	Alternatives	82 81	Central issue	84 85
8	Checking & rechecking	82.09	Judgement	81 84
9	Root of the cause	81 73	Common sense	80 96
10	Criteria	81 42	Value & tradition	80 13

The instrument was validated using a sample of 50 qualified executives as respondents and standard statistical procedure of correlation analysis of predicted results with external indicators The reliability was established using the split half-method

In the final study data collected from 150 manufacturing executives in 25 organizations through the developed instrument was analysed using inter-correlations and tests of significance The results showed that it is possible to classify the production executives into analytic and heuristic types. This is the central theme of this study

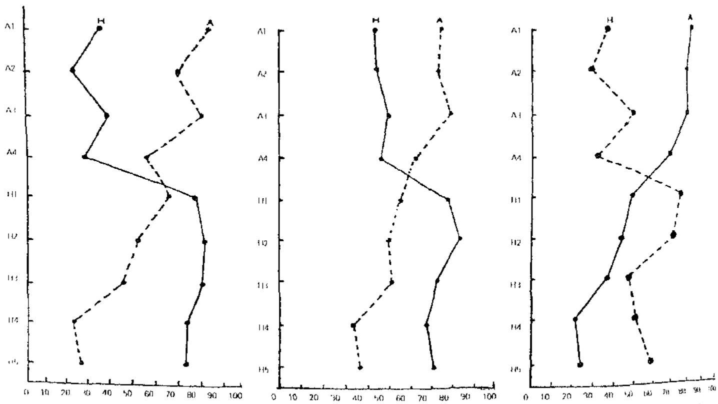

FIG. 1a Profile graph for one's self, A = 60, H = 90

b. Profile graph for subordinates. A = 98, H = 52.

c. Profile graph for superiors. A = 126, H = 24

-- ------ Analytic; —— Heuristic

Group profiles of decision-making styles for analytic and heuristic decision-makers were developed for three situations *i.e.* decision for (i) one's self, (ii) subordinates, and (iii) superiors These profiles were drawn for 150 executives using normalized scores of clubbed questions which indicated major dimensions of decision-making (four for Analytic and five for Heuristic as shown in fig. 1) These profiles indicate the fact that the two major decision-making styles exist and gave additional useful information.

3. Conclusions

Findings from these analyses show that it is (i) possible to classify production executives into analytic and heuristic categories of decision styles, in a given situation, (ii) situations do influence the style, *e.g.* decision for one's self, tends to be more heuristic than decision for others. Profiles of decision-makers presented may help in comparing the styles of different groups of executives. This study has, it is believed, for the first time, attempted to undertake a field study of the decision-making of production executives in Indian manufacturing organization.

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