МАТЕМАТИЧКИ ИНСТИТУТ САНУ, ОДЕЉЕЊЕ ЗА МЕХАНИКУ

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FAILURE MECHANISMS OF COMPOSITE SANDWICH STRUCTURES

Sandwich panels consist typically of two thin face sheets (or facings, or skins) and a lightweight thicker core. They display various failure modes under general bending, shear and in-plane loading. The failure modes can be predicted by conducting a thorough stress analysis and applying appropriate failure criteria in the critical regions of the beams. The analysis is difficult because of the nonlinear and inelastic behavior of the constituent materials and the complex interactions of failure modes.

A thorough investigation of the failure mechanisms of composite sandwich beams under four- and three-point bending and cantilever beams was undertaken. The beams were made of unidirectional carbon/epoxy (AS4/3501-6) facings and a PVC closed-cell foam (Divinycell) core. Two types of core material H100 and H250 with densities 100 and 250 kg/m^3, respectively, were used. The thickness of the facings and core were 1 mm and 25.4 mm, respectively.

Sandwich beams were loaded under bending moment and shear and failure modes were observed and compared with analytical predictions. The failure modes investigated are face sheet compressive failure, core failure, facing wrinkling and indentation failure. The various modes have been studied separately and both initiation and ultimate failure have been determined. Initiation of a particular failure mode and triggering and interaction with other failure modes was also investigated. A detailed stress and failure analysis was performed taking into account that a biaxial state of stress is developed in both the core and the facings. The stress state was combined with the Tsai-Wu failure criterion for both the core and the facings. A failure map for the entire specimen was constructed. Failure in the core occurs in the form of crack initiation. The crack initiation was predicted and compared with experimental observations

The initiation of the various failure modes depends on the material properties of the constituents (facings, adhesive, core), geometric dimensions and type of loading. The appropriate failure criteria should account for the complete state of stress at a point, including two- and three-dimensional effects. Failure modes were discussed according to the type of loading applied. In sandwich columns under compression, or beams in pure bending, compressive failure of the skins takes place if the core is sufficiently stiff in the through-the-thickness direction. Otherwise, facing wrinkling takes place, which can be predicted by Heath's formula. In the case of beams subjected to bending and shear the type of failure initiation depends on the relative magnitude of the shear component. When the shear component is low (long beams), facing wrinkling occurs first while the core is still in the linear elastic range. The critical stress at wrinkling can be predicted satisfactorily by an expression by Hoff and Mautner and depends only on the facing and core moduli. When the shear component is relatively high (e.g., short beams), core shear failure takes place first and is followed by compression facing wrinkling. Wrinkling failure follows but at a lower than predicted critical stress. The predictive expression must be adjusted to account for the reduced core moduli.

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ЛУДВИГ ПРАНТЛ И ТЕОРИЈА ГРАНИЧНОГ СЛОЈА – ПОВОДОМ 105 ГОДИНА ОД НАСТАНКА ТЕОРИЈЕ - 2. ДЕО

У наставку претходно одржаног саопштења биће говора о методама решавања једначина теорије граничног слоја које је извео Л. Прандтл и о доприносима наших аутора овим методама. Такође, биће показано како је ова теорија довела до развоја једне нове математичке методе – методе сингуларних поремећаја. Примена ове методе у оквиру теорије граничног слоја омогућила је израчунавање апроксимација вишег реда, док је у оквиру теорије таласних кретања течности и хидродинамичке

теорије стабилности њеном применом створена могућност извођења многих типова тзв. еволуционих једначина.

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VIBROIMPACT SYSTEM DYNAMICS: HEAVY MATERIAL PARTICLE OSCILLATIONS ALONG ROUGH CIRCLE WITH TWO SIDE MOVING IMPACT LIMITERS

Paper present analytical results and some visualizations of the nonlinear dynamics of vibro-impact system with one degree of freedom and two side moving impact limits. Mechanical energy of a heavy material particle oscillations along a rough circle in vertical plane, with Coulomb's type friction and with two side moving impact limits of the angle elongation is object/subject of the analytical research. The corresponding ordinary nonlinear differential equations of dynamic equilibrium states are derived accompanying with corresponding initial conditions and corresponding conditions of the ideally elastic or no elastic impact conditions, as well as conditions of the alternation of the friction force of the Coulomb's type for the case large initial conditions. First integrals of the governing nonlinear differential equations of the material particle motion in considered case, earlier published, with corresponding integral constants are used for analytical and graphical analysis of the kinetic, potential and total mechanical energies of the corresponding vibroimpact system, as well as power of the friction force works in characteristic interval of the motions between impacts and of the alternations of the friction force direction. Also, bifurcations of the possible different solutions of the material particle nonlinear dynamics along rough circle with two side limit impacts ate considered. Also, a theorem of the total mechanical energy of the considered vibroimpact system with friction is formulates. Analytical expressions of the phase trajectory branch in the intervals between two impacts, as well as between impacts and positions of the alternations of friction force directions are presented. By use analytical expressions of the phase trajectory by use MathCad a visualization of the vibroimpact oscillations was presented. Conditions for corresponding numbers of impacts and positions of the alternations of the friction force directions, before oscillations with out impacts are analyzed, as well as conditions up to heavy material particle rest state on the rough line with friction of Coulomb's type are pointed out. In the considered cases we conclude that phase trajectories present line of the kinetic energy dependence of the generalized coordinate.

Предавања ће се одржати у сали 2 на првом спрату зграде САНУ, Кнез Михаилова 35, у <u>18:00 часова</u>

Секретар Одељења
Бојан Међо

Управник Одељења
Професор Теодор Атанацковић