References

Running projects:

[1] COCOMAT (Co-ordinator, Improved Material Exploitation of Safe Design of Composite Airframe Structures by Accurate Simulation of Collapse, www.cocomat.de, EC 6th FP)
[2] ALCAS (Advanced low cost Airframe Structures, EC 6th FP)
[3] MUSCA (Nonlinear static MUltiSCAle analysis of large aero-structures, EC 6th FP)
[4] Design of optimal CFRP panels for fuselage structures (DLR – China)
[5] Advanced Aerospace Structures (Fortschrittliche Flugzeugstrukturen, DLR – EADS)
[6] Composite fuselage demonstrator (DLR – Airbus)
[7] Probabilistic aspects of buckling knock down factors, Tests and analysis (ESA)
[8] Buckling Handbook (ESA, ECSS-E-30-24)

Some finished projects:

[9] IBUCK – a fast semi-analytical design tool for stiffened panels (DLR – Airbus Germany)
[10] POSICOSS (Co-ordinator, Improved Post-buckling Simulation for Design of Fibre Composite Stiffened Fuselage Structures, www.posicoss.de, EC 5th FP)
[11] Robust Design (DLR – Airbus Germany)
[12] GARTEUR SM AG 25 (WP leader, Postbuckling and Collapse Analysis, established recommendations for buckling, postbuckling and collapse analysis of CFRP shells)
[13] Globales Tragverhalten (Virtual testing of stringer and frame stiffened shells, Airbus Germany)
[14] Multiobjective optimisation of fibre composite structures endangered by buckling (DLR – China)
[15] Identification of the Stiffnesses of Stringer Stiffened Laminated Materials (DLR – China)
[16] Schwarzer Rumpf (Black fuselage, DLR – Airbus Germany)
[17] Buckling under dynamic loading (German-Israeli-Foundation)
[18] FESTIP (Refinement of Buckling Prediction Techniques for Large Thin Shells Under Mechanical and Thermal Load Conditions, ESA)
[19] Fracture Mechanics of Composites (Damage tolerance of CFRP panels and cylinders prone to buckling, ESA)
[20] EDAVCOS (Efficient Design and Verification of Composite Structures, EC 5th FP)
[21] DEVILS (Design and Validation of Imperfection-Tolerant Laminated Shell Structures, EC 4th FP)
[22] GARTEUR SM AG05 (Chairman, Buckling and Postbuckling Behaviour of Composite Panels)
[23] Composite Bulkhead (Stability investigation of an Airbus CFRP bulkhead, A340-500 and A340-600)

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Institute of Composite Structures
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Stability of thin-walled composite structures

Competences and activities

Stability of thin-walled composite structures

Slender light weight structures are predestined to carry high membrane loads. Under compressionand shear load, however, they are susceptible to buckling. Stiffening by ribs and stringers increases the buckling loads and provides large load carrying capacities in the postbuckling region. Because of its outstanding specific strength and stiffness the application of Carbon-Fibre Reinforced Plastics (CFRP) is increasingly used for highly loaded thin-walled structures. Design and analysis of composite structures must account for the anisotropy and inhomogeneity of the material boosting the need for a joint effort in numerical simulations and experiments.

One main competence of the Institute of Composite Structures and Adaptive Systems is the field of *Stability of thin-walled composite structures*, where activities and competences are focussed on

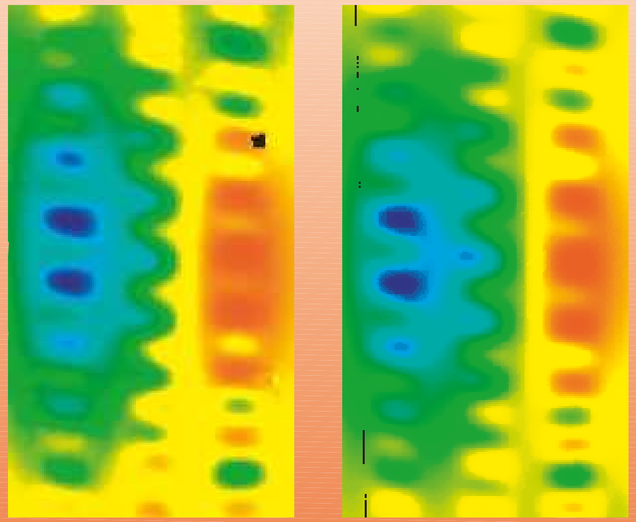
- Postbuckling behaviour
- Imperfection tolerance
- Buckling due to dynamic loading
- Thermo-mechanical buckling.

The objective is to investigate the buckling and post-buckling behaviour up to collapse by nonlinear numerical simulations and experiments. To that end fast design tools are developed, commercial certification tools are improved and experiments are performed. The software tools can either be directly incorporated into the design process or be used to deduce simple design rules. The experiments provide a better understanding of the physical behaviour of the structure and therewith allow for a more realistic modelling. Furthermore they are needed for validating the developed software tools.

Figure 1 illustrates the buckling test facility which is mainly designed for high precision buckling tests of thin-walled shells like cylinders or panels under axial loading, torsion or internal pressure. The load history of axial compression ranges from static loading to shock loading. The hydraulic cylinder is equipped with a small servo-valve for static tests additionally with a second valve for high dynamics. The deformations are measured using high-speed cameras of the ARAMIS system which is based on photogrammetry. Figure 2 illustrates exemplarily the comparison of an experiment and simulation of a buckled, stringer-stiffened CFRP panel.

The Institute of Composite Structures and Adaptive Systems has a leading role in Europe in that area which is demonstrated by the co-ordination of the two EU projects POSICOSS [10] and COCOMAT [1], as well as the participation in numerous research and industrial projects [2–23].

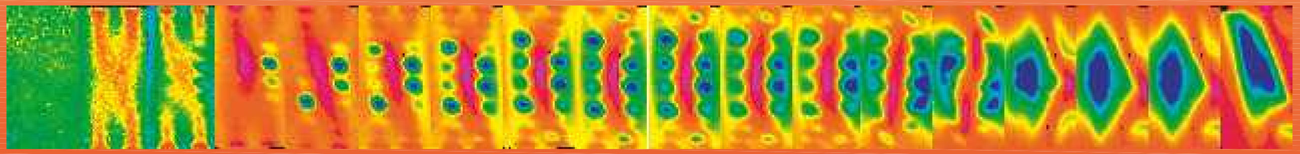
Figure 1 · **Buckling test facility with high-speed cameras of the ARAMIS measurement system**



Experiment

Simulation

Figure 2 · **Out-of-plane deformations of one tested CFRP panel**



Highlights achieved in previous projects

1) IBUCK – A fast semi-analytical design tool for stiffened panels

IBUCK, is a fast, semi-analytical buckling and post-buckling tool for stiffened panels under axial, transverse or in-plane shear load. The panels are assumed to be representative for an aircraft fuselage section and are comprised of a skin and stiffeners in both longitudinal and circumferential direction (stringers and frames, respectively). In addition, aircraft-specific components such as doublers and clips are included in the model. Figure 3 shows a deformed panel in the postbuckling region.

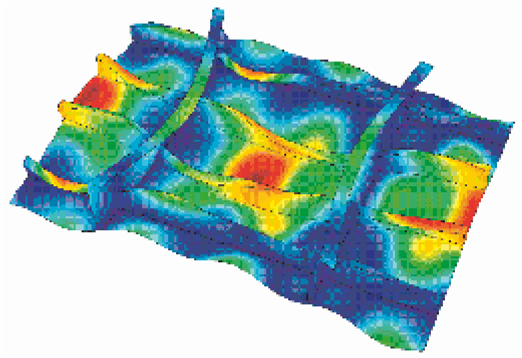


Figure 3 · **Out-of-plane deformations of a tested CFRP panel (obtained by IBUCK)**

2) New robust design concept for imperfection sensitive structures

An innovative robust design concept for imperfection sensitive structures was developed and is currently extended. This concept allows reducing structural weight by extending the rather conservative guideline limits and accounting for composite structure specifics. Figure 4 shows a result of a 360° measurement on a CFRP cylinder using highspeed ARAMIS cameras which allow obtaining precise results on the dynamics of buckling deformations.

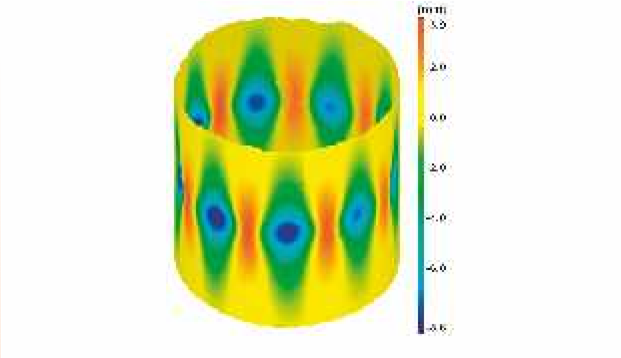


Figure 4 · **Results of a 360° measurement on a CFRP cylinder using ARAMIS**

3) BEOS – A fast tool for the simulation of the stability behaviour of sandwich structures

BEOS is a simulation tool for the fast calculation of buckling loads and eigenfrequencies of unstiffened and stiffened sandwich structures which are assumed to be composed of two eccentric-isotropic face shells and an anisotropic intermediate core (cf. Figure 5). The structure can be doubly curved. The main advantage of BEOS in comparison with commercial tools is the significantly faster prediction of the stability limit.

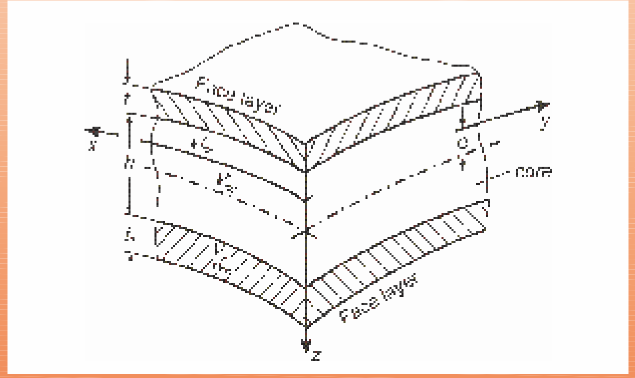


Figure 5 · **Sandwich structure – fast simulation of buckling loads using BEOS**