At the Division of Applied Mechanics we can offer a number of suitable projects for MSc theses and smaller project courses. Given below is a list of potential topics. For more information, please contact us: applmech@angstrom.uu.se

Fatigue of hybrid composite materials

The basic feature of composite materials is that they draw synergy from the combination of superior properties of several constituents. Carbon fiber/glass fiber hybrid composites combine low cost with high performance, used in e.g. rotor blades in wind turbines. Previous experimental results show that a finer distribution of the different types of fiber results in better mechanical performance. The goal of this project is to analyze the measured behavior and determine relations between stiffness reduction and dissipation during cyclic loading. This would render better understanding of the underlying damage mechanisms, which could potentially be used in design of more fatigue resistant materials. The tasks would include MATLAB programming of micromechanical models for stiffness reduction of angle-ply composites, and hysteresis shapes in stress-strain curves, to be compared with experimental findings. Background in solid mechanics is required.

Sequence effects in variable amplitude cyclic loading

Heterogeneous materials like composites generally show a sequence effect in block amplitude loading, i.e. the material shows a memory effect in the sense that a high-low amplitude sequence leads to a different damage state and residual strength, than the reverse order, i.e. a low-high sequence. Such effects are generally described by phenomenological models in design against fatigue degradation and failure. A mechanism-based physical model would show which microstructural features and properties that are responsible for the observed effects and accelerated fatigue degradation. In this project, existing experimental data for cross-ply carbon-fiber composites will be analyzed and compared to a physical cumulative damage model expressed by coupled differential equations accounting for the active damage mechanisms. Background in solid mechanics is required.

Fracture toughness and cohesive zone modeling of double-cantilever beam tests

Many materials show large scale damage zones during cracking. Linear elastic fracture mechanics is not applicable in such cases. Fracture toughness is then not a material property, but the cohesive law (traction vs. displacement) can in many cases be regarded as a material property independent on specimen geometry and type of loading. If the cohesive law is characterized, the crack-growth and eventual failure could be predicted more accurately for components made from materials exhibiting large-scale damage zones. Two techniques are readily available to measure the cohesive phenomena in crack-opening mode: (i) double-cantilever beams loaded by wedge forces, and (ii) double-cantilever beams loaded by pure moments. The former is easy to perform, although the cohesive law must be determined by solving an integral equation. The latter is experimentally more difficult, but the cohesive law can be identified in a straight forward manner. The purpose of this study is to compare the two methods based on experimental input for the same sheet-molding compound material.

Micromechanical models in intralaminar fracture of composites

Cracking in composite laminates tend to occur along the reinforcing fibers. The fibers or fiber bundles may bridge over such cracks, thus enhancing the resistance to crack growth and increasing the fracture toughness. Recent development of micromechanical models predicts cohesive laws that are relatively close to experimental results in both mode I and mode II loading. The axial stresses and failure of the cross-over beams are however generally not accounted for. The task is to develop finite element models and possibly also analytical models incorporating fiber failure and axial stress in the cross-over fiber beams. The predictions should be compared with the previously reported models to see if a closer similarity to experimental results is achieved. Background in solid mechanics is required.

Beam theory analysis of mixed-mode fracture in beams

The energy release rate or stress intensity factor in mixed-mode end-loaded split tests is available in literature. For centered cracks, the analytic expressions based on beam theory are identical with the corresponding expressions for the stress-intensity factor obtained with orthotropic rescaling and finite element modeling. For eccentric cracks, the two solutions diverge. The reason for this anomaly is not fully understood. The purpose of this project is to try to find the root cause of the divergence, and explain which assumptions in the analytical model that give rise to the divergence, and suggest ways to overcome this error for eccentric. Finite element modeling and MATLAB programming is integrated in the project. Background in solid mechanics is desirable.

Modeling of dynamic fracture in strong heterogeneous materials

Dynamic deformation and fracture in network materials are very complex processes that depend strongly on the volume fraction, the fiber architecture, the mechanical properties, rates of applied loads, and appears in several different circumstances. For example: nearly all fractures in human tissues are results from dynamical loads.

A completely new simulation technique is developed in this project, which is based on discrete particle modeling, that enable us to study dynamic properties and evolution of dynamic deformations and fractures within fiber materials on several scales. The method is meshfree, having extreme computational speed, is simple, inherently include time evolution and captures the material behavior through a description including billions of particles. Micromechanical experiments are presently performed at Grenoble INP and analyses of the 3D evolution of micro deformations are made in the adjacent synchrotron X-ray microtomography facility ESRF to support the model.

The project brings insight in how network materials could be altered to improve certain properties. This is particularly important when e.g. developing functionally shock-absorbing shelters, and cloths or new nanopaper products. The perhaps most significant contribution from the project, from a human perspective, would be the potential to support orthopedic surgeons to design equipment helping people suffering of osteoporosis, or other skeleton diseases, which are inclined to dynamic fracture.

Sustainable design of recycled wood-fiber based packages

Corrugated board is the most common application of recycled wood fiber-based materials. It is a preferred packaging material structure for a number of reasons; it offers a great stiffness and strength to weight ratios and stacking abilities. Due to its shock-absorbing capabilities it also reduces product waste due to rough handling. Additionally, corrugated board is an environmental friendly packaging material since it is made entirely from a renewable resource. The wood fibres can in theory be recycled and reused many times. However, despite the mature nature of corrugated board manufacturing there are serious gaps in the understanding of the coupling between properties of the constituent wood fiber materials and structural performance of the final product. This has become painfully appearent in recent years when lighter materials with higher degree of recycled fibers have been introduced to the market. Downgrading specifications is a trend, as a response to demands on resource optimization, and when lighter recycled wood fiber material grades are used, the structure often encounter premature collapse due to the compressive load and the boxes fail by buckling of the vertical panels.

In this project will a numerical (finite element) full-scale 3d model for optimal geometry of the structure with respect to compression strength, board weight and material usage be developed to enable a sustainable design of recycled wood-fiber based packages. The main objectives of the project are:
• Develop models to predict deformations and fracture in recycled board packages
• Perform sophisticated experiments to judge the models

Numerical modeling of impact fracture

Essentially, the experimental part will be carried out at FOI, and damage/fracture and mechanical response will be quantified at FOI and UU, jointly. State-of-the-art experimental equipment for impact testing, such as flash X-ray equipment, will be used. In addition to the table-top X-ray microtomography at UU, beam time will be allocated at synchrotron facilities for 3D imaging. The experimental results will be used as vital input to and for validation of the numerical models, which constitutes the main part of the project, carried out principally at UU, although in close collaboration with experts in numerical modelling at FOI. The approach is based on multi-scale continuum particle modelling of impact deformation and fracture.

The focus will be on modelling of the complex response of multi-material protective structures that are often used in armours applications, e.g. helmets and body armours. The key elements in these designs are high strength materials like ceramics and fibre composites. The materials are usually arranged in various layered structures in order to take maximum advantage of the combined properties of the system. The impact response of the armour is characterised both by massive cracking and large elastic-plastic deformations. The massive cracking generates an interaction where cracks initially are infiltrated by the penetrating threat. The fracturing will also generate a complex load pattern on adjacent material, which makes a detailed prediction of the total response very challenging.