Mesoscopic modelling of fatigue damage and crack initiation in aluminium alloys
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Objective
The aim of the project is to model high-cycle fatigue of structural elements taking into account the underlying processes at the mesolevel.

Motivation
Materials used in modern aircraft structures have to sustain repetitive loading conditions. The main task of engineers and designers is to find a compromise between resistance against these cyclic loads and weight. There is great interest in more precise and less conservative methods based on modelling of the fatigue process. As aluminium alloys, in particular 2024 alloys, are used for coating wings and fuselages on civil airplanes (Figure 1), they are in the area of our research.

Vein structure
The first thing to occur in constant strain amplitude fatigue is dipole formation and dislocation loops generation with increasing stress. In this process dislocations glide in channels between loop patches.

Persistent Slip Bands
The increase in the stress leads to the formation of persistent slip bands. As stress increases, the characteristic loop diameter of the patches becomes smaller. This triggers the formation of dipolar walls in the matrix through the widening of the channels and the mutual blocking of the screw dislocation segments movement.

Cell structure
The last transformation which occurs during constant strain amplitude fatigue is the generation of a cell structure. All three types of structure, veins, persistent slip bands and cell structure, follow each other with increasing fatigue stress so as to reduce the dislocation content and stored energy.

Conclusions
Fatigue crack initiation strongly depends on the formation and evolution of dislocation structures. In order to understand these processes, dislocation interactions must be properly modelled.

Future work
The future work is to build a mathematical model of the dislocation interactions in which the energy minimization would be a driving mechanism of all processes. The finite element implementation of the model should allow us to describe the formation of dislocation structures.

References: