Public summary of PhD-thesis of Franz Bormann
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One step closer to a new generation of steels

In the past decades, the performance of steels has undergone an enormous progress. A constant challenge was, and still is, to breach existing limitations to stay a top competitor in the material industry, where applications increasingly often demand grades that are strong as well as deformable—two properties that conventionally contradict. One of the current steel classes that fulfills this requirement is the so-called high-strength steels. They consist of multiple phases of different composition and combine therewith soft and easily deformable with hard and little deformable material properties. The result is a material which requires, as compared to conventional steels, a strongly increased deformation energy (per volume) to reach the critical point of material failure. Owing to this advanced material performance, high-strength steels pose for instance in the automotive industry a rather attractive material choice. With the increased deformation energy, which is equivalent to the absorbed energy upon impact and thus a measure for the safety, the volume of the design can be reduced while maintaining the total amount of absorbed energy. Thus, without compromising safety, lightweight and fuel-efficient designs can be facilitated. However, as a natural consequence of their complex composition, involved failure mechanisms occur at high deformations which are not fully understood yet. One potential source of material failure origins from the interfaces where two or more different phases meet.

It is widely known that the deformation process in steels is governed by the motion of line defects in the atomic structure, the so-called dislocations. During the deformation the dislocations propagate towards the interfaces where they, due to the difference in material properties, get obstructed from further motion. As a result, dislocations accumulate, leading to high internal forces and thus to a potential crack nucleation at these interfaces. Nevertheless, it is observed that under certain configurations no crack is nucleated but dislocations are instead being transmitted into the next phase.

To advance towards the next generation of steels, a profound understanding is required of the relation between the dislocation accumulation at interfaces and the competition between dislocation transmission and crack nucleation. In this PhD thesis, I developed a computational model for such a fundamental study. The results show a strong influence of the interface configuration on the outcome of the competition. Based on the present research, a further development of the methodology allows for a deeper insight into the highly complex mechanisms. The acquired insight can then be used to manufacture steels with ideal interface properties, allowing for a high deformation without early crack nucleation.

Title of PhD-thesis: Towards understanding of interface decohesion in metallic multiphase alloys.