## Details concerning the PhD program

**Title:** Modelling of physically base mico-mechanisms of distortional hardening and its effect on sheet metal forming

**Research period**: 3-4 years

**Advisors:**


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**Topic description**: During the past years, Finite Element Method (FEM) simulations based on the commercial software has significantly contributed to designing feasible processes more easily. Material modeling constitutes a key issue in the simulation of metal forming processes. Nowadays, the demand for more accurate industrial problem solutions and the application of numerical simulation with respect to newly developed high strength materials requires the improvement of the accurate material models. Due to the complex micro-structure exhibit by these newly developed high strength materials, enhanced initial and induced anisotropies takes place making it very difficult the modelling of the material behaviour. Texture evolution in metals can be regarded as the rotation of the atomic lattice, which results in the complex macroscopic mechanical behaviour. This induces significant difficulties to well describe the evolution rule of the yield surface, including its expansion, movement and distortion, which can be helpful for the prediction of deformation behaviour of sheet metal under complex and mainly non-proportional loading paths.

In this project, based on the physical understanding of the micro-texture orientations induced by the plastic deformation, some original material micro-macro models accounting for the distortional hardening based on different physical mechanisms will be developed and discussed. From the macroscopic scale, some linear transformation of stress tensor to describe the induced plastic anisotropy can be used (Barlat et al., 2014), and some high rank tensors can be introduce into the equation to control the yield surface distortion and represent the directional hardening effect. From the macroscopic scale, the micro-texture evolution can be introduced through polycrystalline plasticity theory, which can better explain the physical mechanism, meanwhile this method can help to improve the macroscopic models, which are more convenient to use in industry. Besides the modelling of distortional hardening, its effect on the subsequent forming behaviour of sheet metal, like hardening flow, ductile damage, forming limit strain and springback will be studied.

The main objective of this project The project aims to propose a new theory for directional distortional hardening based on different micro-physical mechanisms understanding. One original models will be developed based on the micro-macro approach accounting for texture evolution form mesoscopic scales, and this understanding should be adapted to macroscopic model, which will be easily to use in industrial application.

The research plan can be decomposed nto 2 work packages for the whole project, and also their intermediate results.

1. **WP1: macroscopic, microscopic and multiscale modelling of directional hardening**

   The macroscopic modelling of directional hardening has been proposed by many researchers, like Francois model, Levkovitch and Svendsen model, and Barlat model. Each model has its own advantage in different aspects. Like the flexible geometrical controlling of Barlat model, the decomposition of stress vector based on loading paths for Francois model. Therefore, the comparison of different macroscopic directional distortional hardening models is very valuable for the coming steps. Through comparing these proposed models, the existing methodology for the subsequent anisotropy can be summarized. Furthermore, the new general question will be raised; how to evaluate these model developed based on different mechanisms?

   The CP FEM methodology has been used widely for the investigation of the texture evolution and initial yield surface. Most existing model like Taylor-type and self-consistent polycrystalline models. All these models should also be reviewed and compared at the beginning. For the subsequent hardening evolution, the slip hardening law existing in the CP model is one of the key issues. To account for the non-proportional strain path the formation of the evolution of dislocation density and distribution on the active slip systems should be give more attentions. There are many different formula have been proposed. Meanwhile how to choose and compare these different formulas of above state variables is very important.

2. **WP2: Experimental investigation**

   Although the project will be conducted for the modelling of directional distortional hardening, experimentally investigation of the subsequent yield surface evolution, especially after the loading paths changed, will highly affect the modelling processes described in WP1. How to define the yield point, how to plot the initial and the subsequent yield surface are another key issues in this project. Through reviewing the literatures, it can be found that the experimental investigation about the directional distortional hardening is more about bar materials, and there are only few results given based on the sheet metals. Therefore, there is a need to design some new tests in this project. In addition, the efficiency and accuracy of the experimental results based on the new test design and devices will highly influence the conclusion of this project.