Research Topic for AGS overseas - A*STAR and University of Oxford Partnership (AOP)

“Solid state recycling of machining chips through novel severe plastic extrusion process”

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Background
Currently, most metal scrap undergoes remelting in furnaces in order to recycle into ingots. However, this conventional recycling method has many disadvantages, including low material yield (~55%), reduction in the purity and large energy input, etc. These limitations drive the development for more efficient recycling technologies. Recently, a potential alternative has emerged, which is solid-state recycling [1]. Such route directly converts metal scrap into bulk material without heating the material to the liquid state, not only reduces the energy consumption but also improves the recycling efficiency (up to 95% yield). On the other hand, among all the Severe Plastic Deformation (SPD) methods, Severe Plastic Extrusion (SPE) [2] has recently been introduced (two years ago) as the latest technique that offers excellent microstructural refinement. It is the authors’ belief that this SPE approach can be applied to the solid state recycling area thanks to the steep deformation gradients and massive mechanical heat generated in the process.

Objective and Approach
In this study, a new apparatus for SPE will be designed and constructed in SIMTech. Extrusion of billets of various profiles using Al, Mg and Cu alloy machining chips will be carried out (Fig.1). Processing conditions for each material type will be identified, which lead to discovery of the most effective consolidation with optimal internal structure: minimal porosity, equi-axed grain, etc. Different processing parameters will be used, and key mechanical properties of the products will be evaluated. Finite element simulations of the SPE process will be conducted in order to predict the key combinations of the material properties and process parameters that control the final product quality. This will aid process optimization and putting forward a new stress-based chip-bonding criterion.

Building on the platform of experimental and modeling activities conducted in SIMTech, further advancement of the characterization and modeling will be carried out at the University of Oxford. Detailed microstructural characterization of the products will be performed in the Multi-Beam Laboratory for Engineering Microscopy (MBLEM). MBLEM houses a range of analytical instruments, including lab diffractometer with an area detector and Eulerian cradle for texture and stress analysis, as well as a high energy X-ray imaging facility for non-destructive inspection of defects down to a few µm. It also hosts FIB-SEM microscope for nano-scale sample preparation, manipulation and tomography of internal structure and defects. Furthermore, EDX and EBSD detectors are also attached for elemental composition and grain orientation mapping. The full range of these analytical capabilities will be employed to characterize the internal structure of extrudates. The data collected using different microscopes will be subjected to advanced image processing using ImageJ package that incorporates algorithms for feature identification and statistical analysis. A particular aspect of the Oxford-based study will be the use of in situ micropillar compression tests to determine the local mechanical properties and to use the results as input for advanced FE modeling (Fig.2).

The final outcome of the project activities will be the identification of the process windows suitable for consolidation treatment of light alloys. Our aim is to advance the technology sufficiently for future commercial exploitation.

References