DEVELOPMENT OF A NOVEL TUNGSTEN PROCESSING TECHNOLOGY FOR ELECTRO-CHEMICAL MACHINING (ECM) OF PLASMA FACING COMPONENTS

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Bulk components fabricated from tungsten-alloys are used in fusion technology as plasma facing components for blanket and divertor applications, whereas in the He-cooled divertor scenario, W-alloys are also considered as structural material. Due to the extreme properties of tungsten and its alloys (e.g. hardness, strength, brittleness) conventional shaping is cost intensive and introduces mostly stresses and micro structural defects like micro cracks into the work pieces. Under high heat loads and introduced thermal stresses, as especially seen in high heat flux testing of first series of He-cooled divertor mock-ups, this can result in failures of components due to massive cracking. Both, economical processing and material aspects initiated the development of advanced soft tungsten machining technology. Electrochemical machining (ECM) is known in steel technology to exhibit such potential also under the aspect of mass production. However, the specific chemical behaviour of tungsten and its alloys prevented ECM processing in industrial technology.
In the first step of the development program - tungsten shaping by ECM - the general requirements for electrolytes were analysed and electrolyte systems were designed which could eliminate the passivation effect – the killing criteria in former industrial testing - during current-assisted dissolution for component shaping. Based on this successful electrolyte development for ECM application, three different branches of ECM processing were developed depending on special component requirements. These processes were named S-ECM, M-ECM and C-ECM. The prefixes S, M and C are standing for special process characteristics. S-ECM is the development line for surface finishing of pre-shaped parts with the technological background of surface polishing and removal of surface scales with introduced defects / micro cracks. In contrast to S-ECM, the processes M and C were developed for 3-dimensional shaping of W-parts. The prefix M indicates that this electro-chemical machining works with a mask technology, protecting areas which should not be dissolved by the ECM current. The C-ECM process works with a non-consumable negatively shaped tool like in a copying process.

Essential for the quality of surfaces and the constancy of machined parts are the mechanical and physical process parameters like e.g. gap distances between work piece and tool or the type of applied DC dissolution current. In the paper, dependencies like current density vs. impact on edge rounding / flank steepness or the improvement of product quality by changing constant current dissolution towards pulsed DC application will be discussed and illustrated.. All the three processes are in an advanced development stage and typical reference component could be successfully machined. For example slotted structures with aspect ratios of 10 and trench depths of 2 mm were fabricated applying DC-pulsed currents with frequencies in to 10 to 100 kHz range. In the outlook of the paper, further process improvement strategies will be presented and discussed in correlation to the electro-chemical characteristics of the ECM process.