Success Story
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K-Projekt Network of Excellence for Metal JOINing
Programme: COMET – Competence Centers for Excellent Technologies
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M1 – Advanced Welding Technologies for Molybdenum and its Alloys (MOLY), Sep. '14 – Aug. '18, multi-firm

Electron Beam Welding of TZM Sheets

In the course of this project, the basic weldability by electron beam welding (EBW) of molybdenum alloy TZM was investigated. 2 mm sheet metal parts were butt-welded and a series of welding parameters were chosen and systematically varied with the aid of Design of Experiments (DoE). It was shown, that with careful selection of the parameters welding speed, beam power, pre-heating and post-weld heat treatment, the quality, grain growth, size of weld bead and heat affected zone can be optimized as well as the mechanical properties of the joint.

State of the art
Welding of molybdenum parts

Refractory metals, amongst molybdenum, in general are difficult to weld, due to their high melting temperature and mainly due to grain coarsening caused by the lack of lattice transformation. Solid solution alloys, for instance molybdenum-rhenium sustain their ductility during welding, but carbide strengthening alloys like TZM (titanium-zirconium-molybdenum) are prone to severe embrittlement.

Trials with tungsten inert gas welding (TIG), EBW, and laser beam welding showed some success, but with considerable embrittlement of the weld and heat affected zone. EBW facilitates a very high energy density which enables welding with less total energy input compared to other welding techniques, thus accomplishing a smaller weld and heat affected zone.

The question arose, how much the welding of TZM sheets without filler material could be influenced by varying the EBW process parameters. In the scope of the Master's thesis "Electron Beam Welding of Molybdenum Alloy TZM," this issue was investigated.

Identifying parameter windows for EBW of TZM sheets

First, the basic weldability of TZM was investigated, also to obtain an idea of the required input energy and start point for the parameter variation. After setting the start point, a systematic parameter variation according to a full factorial design (FFD) of Design of Experiment (DoE) was conducted. The varied parameters were: Weld speed, weld power (here beam current), pre-heating of the samples, and post-weld heat treatment. Figure 1 shows cross sections of a high power, low speed (a) and a low power, high speed weld (b).

bmwfw
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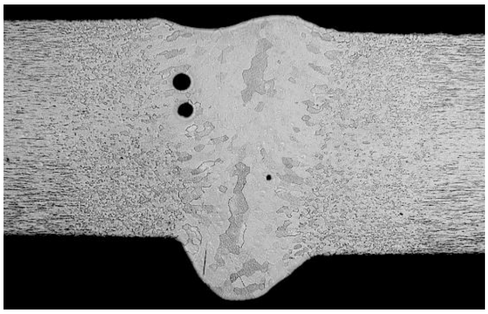
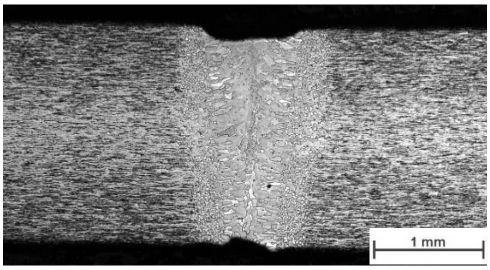


(a)



(b)

Figure 1: Cross sections of (a) high power, low velocity and (b) low power, high velocity welds

Impact and effects

It was quickly revealed, that EBW is quite suitable for welding TZM. Compared to results from literature, grain size and of the heat affected zone were significantly reduced, only by carefully choosing the welding parameters. Exemplary illustrations of the results are shown in figures 2 and 3. A distinct trend was observable, where a higher weld speed and a lower power input, thus a lower input energy per length unit resulted in a smaller grain size and also in a smaller heat affected zone. This tends to yield better mechanical properties.

Pre-heating and post-weld heat treatment influenced the absolute values of the evaluated parameters, but the general correlation to the total energy input prevailed.

These results will be valuable information for the further investigations of the project MOLY.

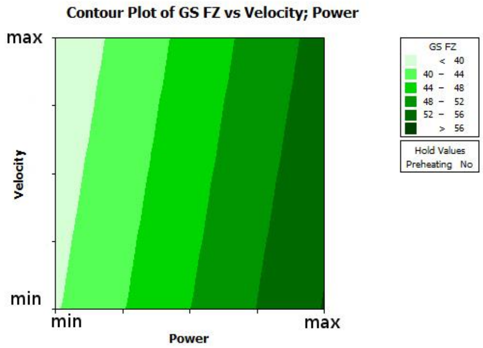


Figure 2: Interaction of velocity and power effecting the grain size of the fusion zone

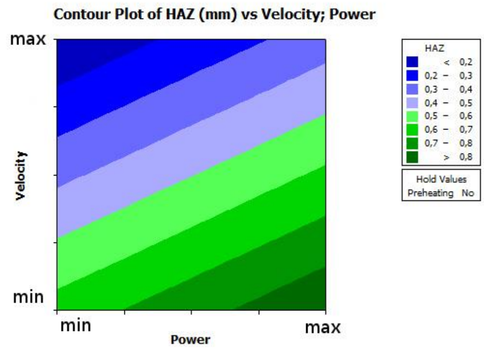


Figure 3: Interaction of velocity and power effecting the size of the heat affected zone

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