Electro contact discharge dressing of wire sawing tools

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Keywords: cut off grinding, wire sawing, electro contact discharge dressing, dismantling

Abstract. The wire sawing process is being used increasingly in the deconstruction of nuclear facilities due to its flexibility regarding workpiece geometry and composition. The use on metallic structures represents the latest field of application of this cutting technology. Currently, single-layered abrasive beads are utilized in the wire sawing of metals since no self-sharpening of the beads takes place during the machining of this material. In contrast to the multilayer abrasive beads, only one layer of abrasive grains is present in the bond. If the grains are worn, the entire tool must be replaced, resulting in high costs. The goal of this work is to qualify multi-layered abrasive beads for the cutting of pure metal structures and thereby increase the productivity of the dismantling process. In order to compensate for the lack of self-sharpening effect, the multi-layered abrasive beads have to be sharpened in an adapted dressing process. Electro contact discharge dressing is used due to the metal bond of the beads. Using this method, the bond can be reset in order to bring new sharp grains into engagement. The service life and thus the efficiency of the wire sawing technology for metallic structures is increased in this way.

Introduction

Germany will shut down its nuclear facilities for commercial power generation by 2022. Thus, in addition to the 15 nuclear power plants already in decommissioning or in safe containment, another 17 plants will have to be dismantled in the near future in a most safe, quick and efficient way. The goal is the complete dismantling of all structures belonging to the nuclear power plant. The materials to be separated are mainly structural and stainless steels from systems, components and structural elements as well as concrete from the biological shield and other building structures. Depending on size and type of the reactor, there are between 200,000 t and 400,000 t concrete and some 10,000 t of steel and reinforcement structures [1]. Although not all components are radioactive or contaminated, the work in the control area of a nuclear power plant has special demands regarding the dismantling processes. As mentioned in the beginning, only single-layered wire sawing tools are used for the cutting of all-metal structures according to the state of the art [2, 3]. The resulting metal surface is not abrasive enough to effectively reset the tool bond of multi-layer tools and expose further grain layers. With an adapted sharpening process, however, the bond of these multi-layer wire sawing tools can be reset to bring new diamond grain layers into engagement. An approach to compensate for the lack of the self-sharpening effect of metal cutting is electro discharge dressing. Due to the metallic bond of the wire sawing tools available on the market, this process is suitable for resetting the abrasive segment bond without damaging the diamonds [4, 5].

Composition of wire sawing tools

Wire sawing tools consist of the components carrier rope, steel springs and the abrasive segments. The carrier rope consists of corrosion-resistant steel strands, on which the cylindrical grinding segments are lined up at defined intervals. To prevent axial movements of the grinding beads, which cause a hooking of the tool on the workpiece and thus result in early failure, spacer springs are used. Plastic or vulcanised rubber is injected between the abrasive segments in order to protect the springs and the carrier rope (Fig. 1, bottom). The bond of the abrasive segments has a significant influence on the operational behavior of the wire sawing tool. Diamond tools are divided into (multilayered) sintered, electroplated and (actively) brazed tools (both single-layered) based on their bond structure (Fig. 1, top) [6].

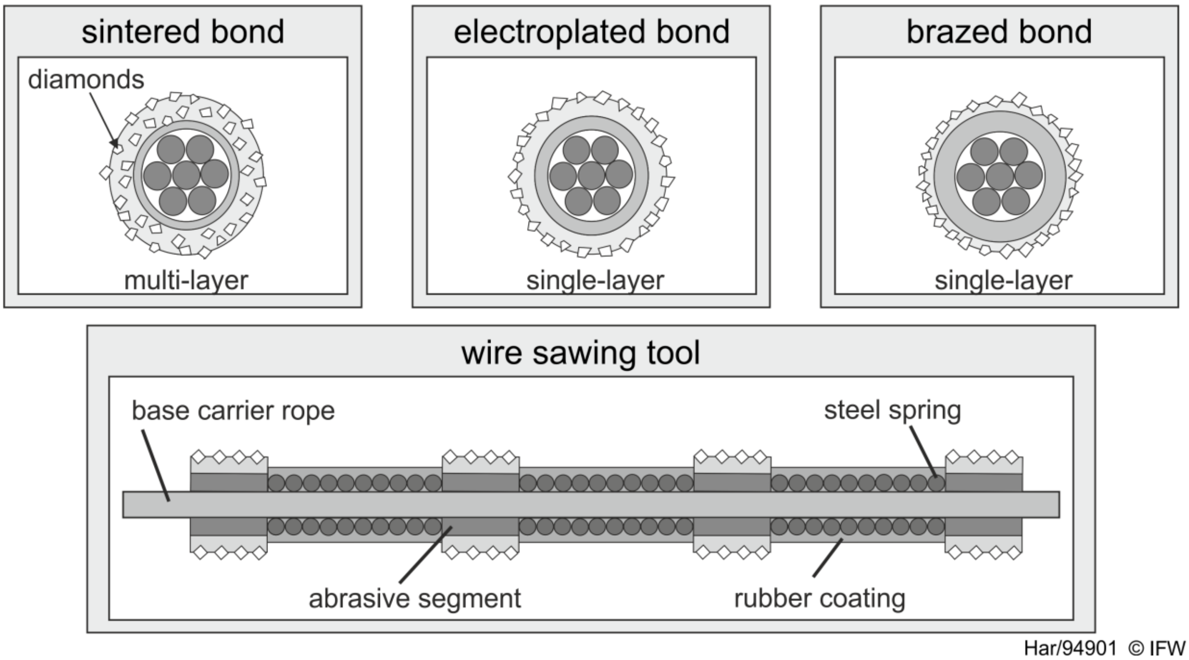

Fig. 1 Composition of wire sawing tools

The essential features of single-layered tools like galvanic or brazed wire grinding tools are high grain retention forces, a larger chip space and a larger grain protrusion. However, the flattening or loss of individual cutting grains causes an irreversible loss of cutting ability as well as an increase in the frictional force. These wear phenomena finally result in a failure of the tool [6, 7]. In contrast, the multilayer sintered abrasive segments utilize the principle of self-sharpening when cutting abrasive materials such as concrete. The topography of the abrasive bead is dependent on the material properties and the process parameters. In addition, the self-sharpening effect of multi-layered tools ensures that depending on the state of wear of the cutting segments grain layers from lower levels are exposed continuously and brought into engagement. This is caused by the abrasive effect of the material to be cut (e.g. marble, granite or concrete) on the bond material [8]. Due to the lack of abrasive effects, only single-layer, galvanic or brazed tools are used for cut-off grinding of metallic structures today [9].

Electro contact discharge dressing

Electro contact discharge dressing (ECDD) is used for the sharpening of metallic bonded grinding tools. By feeding a graphite electrode to the rotating tool, the electrode is machined. An applied voltage creates an electric field, which causes a discharge after exceeding the dielectric strength. During discharge, the chips of the electrode evaporate and the bond is locally melted. After the collapsing of the plasma channel, the molten bond particles are removed from the working space due to the rotation of the tool. This creates a material removal and the bond of the tool is re-set. The process parameters for the sharpening process are sharpening voltage U_{ds}, sharpening current I_{ds} and feed rate of the electrode $v_{f,e}$. The average chip length depends on the cutting speed v_c and the electrode feed speed v_{fds}. The dielectric strength is constant assuming a constant chip formation. In this case, the sharpening voltage directly determines the minimal possible gap between graphite chip and bond surface because the dielectric strength is defined as the quotient of the voltage and the gap width. This minimal possible gap limits the discharge and thus the reachable grain protrusion. If the average chip length increases, the end of the chip is shifted closer to the bond surface. This phenomena also increases the reachable grain protrusion [10]. The material removal takes place both at the anode and the cathode. A distinction is made between negative and positive polarization. Higher temperatures occur at the positive electrode for short-term discharging. The reason for this is the accumulation of mostly negative particles in the formation of the plasma channel. These negative particles are accelerated toward the positive electrode and thus cause a higher material removal. Therefore, it is advantageous to polarize the tool positively and the graphite electrode negatively (negative polarity). Long-term pulses produce equally positive and negative particles in the plasma channel. Since the positive ions have a larger mass, the impact on the negative electrode results in a higher temperature and thus a greater removal of material. In this case, the graphite electrode is positively polarized and the tool is negatively polarized (positive polarity) [11]. When sharpening wire sawing tools, the cutting speed and the separation of small chips from the electrode cause only brief discharges, which is why the negative polarity is used in this application. The technology of ECDD is currently not being used on wire sawing tools. For the dressing process of these tools entirely different framework conditions apply. The dimension of the grinding beads is very small and they must be dressed rotationally symmetrical. In addition, it is complicated to ensure an uninterrupted power supply due to the segmented design of wire grinding tools. For sharpening of these tools, the parameter range to realize an efficient bond reset is not known yet. The material removal of the workpiece can be maximized while minimizing wear on the supplied electrode by optimizing the process parameters. The experimental setup shown below is realized in order to demonstrate the fundamental feasibility and to investigate a wide range of different process parameter combinations (Fig. 2).

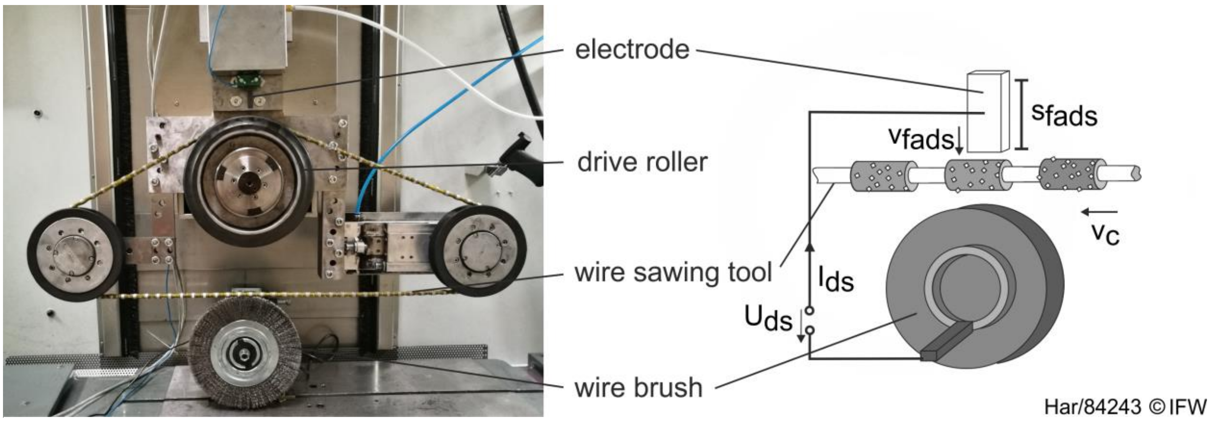

Fig 2 Experimental setup for the sharpening of wire sawing tools

A positive voltage is applied on the wire sawing tool by using a rotating wire brush. A linear motor generates a feed rate to feed the graphite electrode which is poled negatively to the wire sawing tool running at cutting speed. The sharpening voltage and the sharpness current I_{ds} are provided by the power supply. In addition, the total infeed of the graphite electrode $s_{f,e}$ and the sharpening time is decisive for the process result.

Results

For the first series of investigations, multi-layer sintered sawing tools are used to prove the basic feasibility and to narrow down the process parameter range of the sharpening parameters. These sintered segments in new condition have a mean grain protrusion of at least 90 µm. For the sharpening tests, the first step is to ensure a consistent state of wear of the tools by cutting off structural steel S235JR. The result is an average grain protrusion of 50 µm. Based on the results of Denkena for contactless sharpening of cut-off wheels the sharpening current I_{ds} and the electrode feedrate $v_{f,e}$ are initially set to I_{ds} = 10 A and $v_{f,e}$ = 1 mm/min [12]. For each test, a total infeed of $s_{f,e}$ = 40 mm is tested with ISEM-2 electrodes. The electrode cross-section is 8 mm x 11 mm. Using a cutting speed of v_c = 20 m/s, the sharpening voltage is varied in steps of 20 V in a range of 20 V to 100 V (Fig. 3). The resulting grain protrusion is measured by using an optical laser profilometer from NanoFocus.

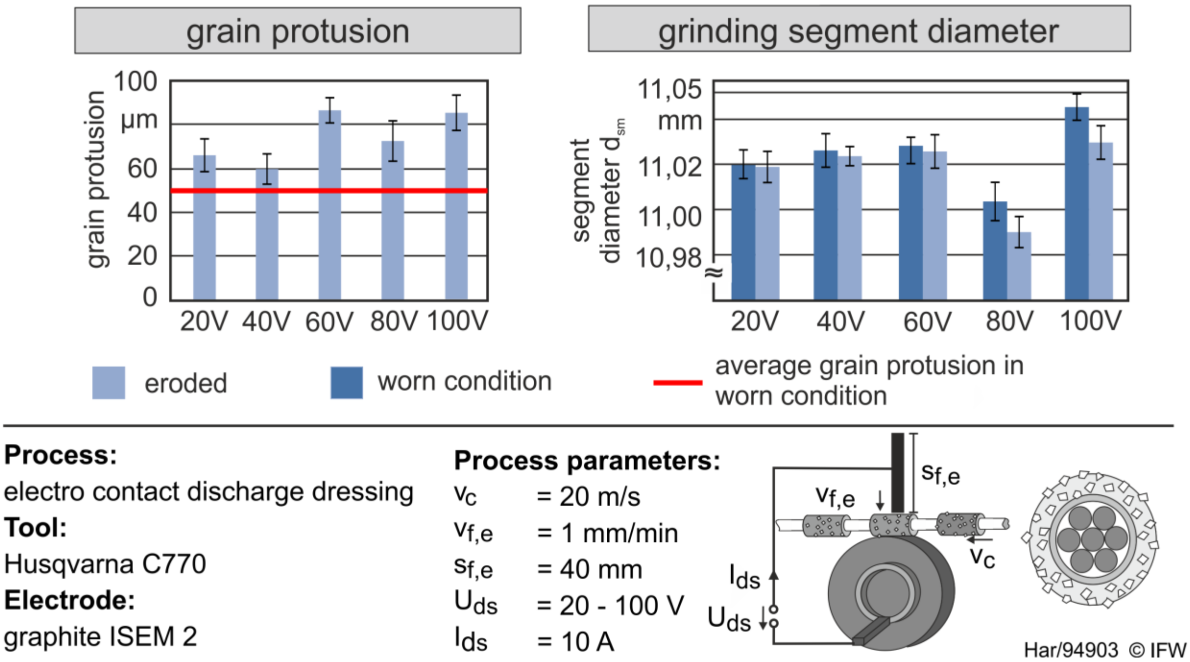

Fig 3 Achieved grain protrusion and reduction of segment diameter

With an applied voltage above 60 V, grain protrusions of up to 90 µm are achieved in these sharpening tests, which correspond to an increase of 80% grain protrusion compared to the worn condition. Thus, in combination with the resulting chip lengths, the applied voltage creates an electric field strong enough to exceed the dielectric strength. If the sharpening voltage is below 60 V the minimal gap width between the graphite chip and the bond surface is too small to ensure discharge and the graphite electrode is machined without resetting the bond. A further increase in the sharpening voltage above 60 V leads to no further increase in the grain protrusion because the maximum number of discharges is achieved. The limiting dressing factor in this case is the total volume of graphite electrode machined. Furthermore, the thermal load for the wire grinding tool is further increased due to an increased electric power input into the process. Therefore, the use of cooling is required in order to prevent damage to the rubber coating of the wire sawing tool. The resetting of the bond and the release of the diamond grains can be observed with the optical measurement device InfiniteFocus G5 by Alicona. All investigated abrasive segments are completely free from reweldings (Fig. 4, left) after sharpening with the lowest sharpening voltage U_{ds} = 20 V and new diamonds are exposed to the surface (Fig 4, right).

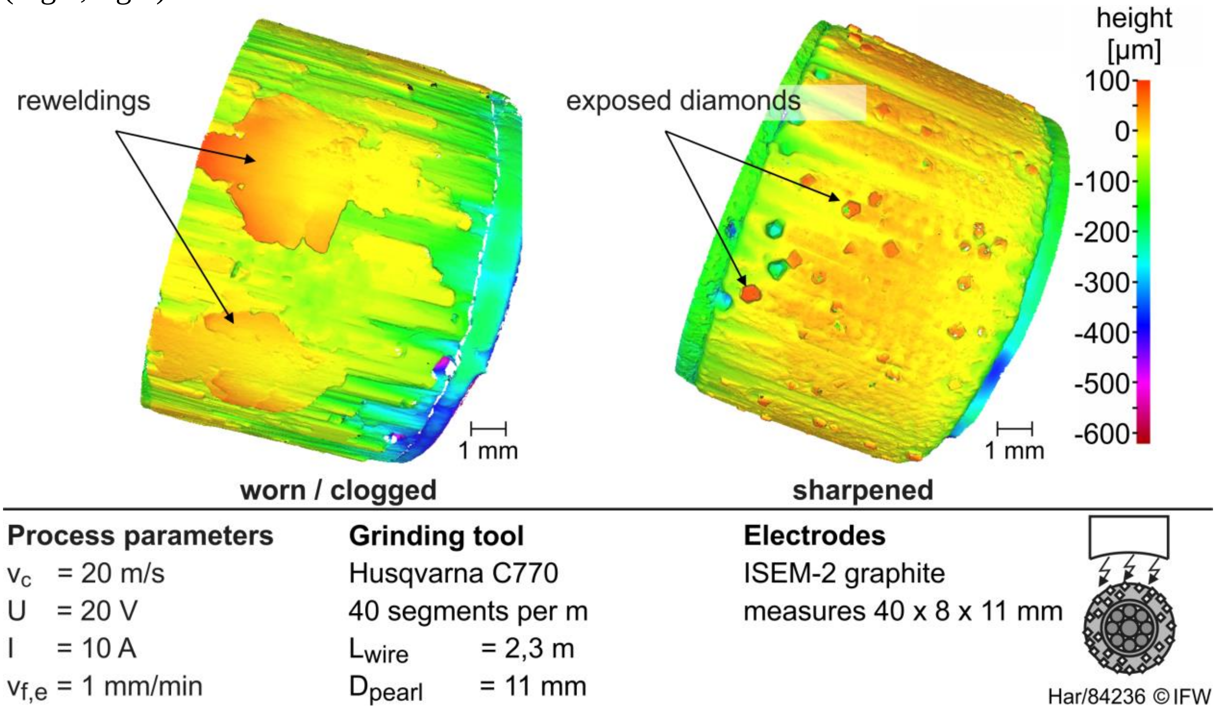

Fig 4 Abrasive segment topography before and after the sharpening process

A closer look at the segment surfaces with the scanning electron microscope confirms these results. In the worn state, the bond of the abrasive segments is mostly leveled which confirms the lack of abrasive effects of the machined steel. The diamonds are flattened and show a small grain protrusion. This would reduce the chip formation during cutting and the process temperatures increase due to increased friction components (Figure 5, left). After using the newly developed sharpening process with a sharpening voltage of U_{ds} = 80 V, new, sharp diamonds can be seen on the surface. The bond has been reset sufficiently to expose the diamonds of the next grain layer. The metallic bond of these grinding segments also shows effects of the discharge processing. The bond has melted locally and the topography no longer shows any grinding marks in the direction of feed (Figure 5, right).

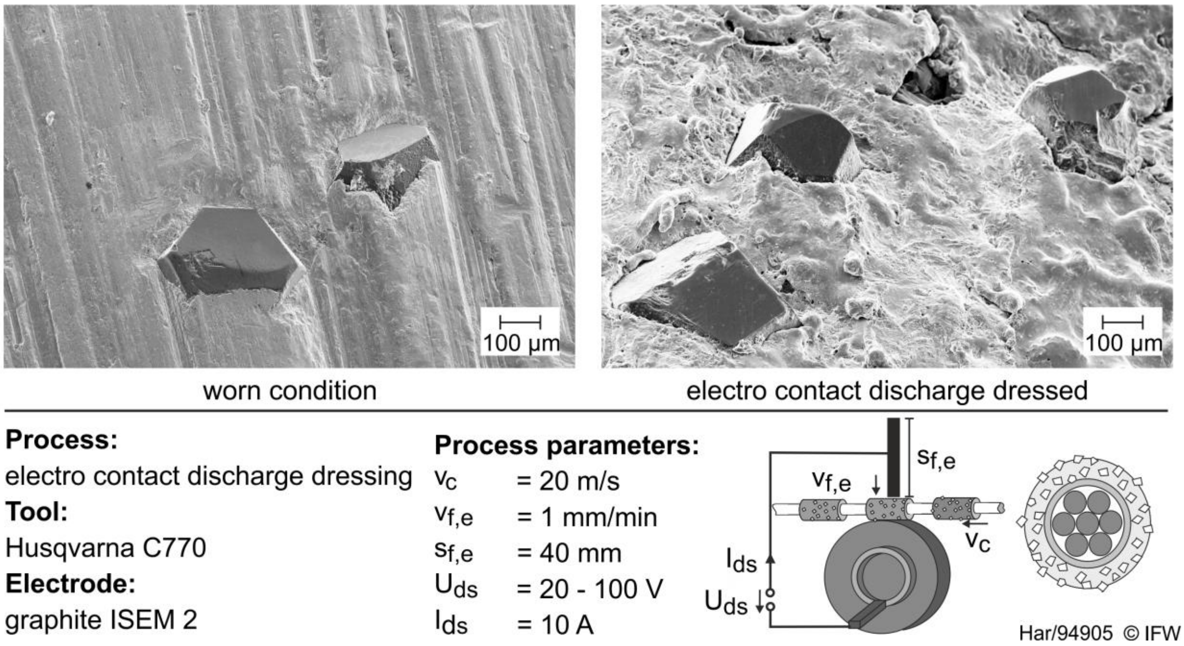

Fig 5 SEM image of the segment surfaces

Summary and outlook

Electro contact discharge dressing is very well suited for resetting the metallic bond of multi-layered wire sawing tools. Even with the use of low sharpening voltages, reweldings are removed and diamonds from lower layers are exposed to the surface. The grain protrusions of the diamonds are effectively increased with an applied voltage above U_{ds} = 60 V, which results in a more efficient cut-off grinding process. The minimal possible gap does not allow a sufficient grain protrusion because the minimal possible gap is too small. Prospectively investigations on the influence of the sharpening current, the electrode feed and the used electrode material will be carried out in this research project. Sintered wire grinding tools have disadvantages in terms of grain retention forces compared to the vacuum brazed variants. This is intended if the self-sharpening effect is taken into account. For a particularly long tool life, however, a combination of high grain retention forces and multiple layers of diamonds is necessary. For this reason, the sharpening of adapted prototype tools with multi-layer vacuum brazed segments will be investigated.

Acknowledgement

The studies presented were funded by the German Federal Ministry of Education and Research (BMBF) within the research project "Electro Contact Discharge Dressing of Multilayer Wire Sawing Tools for Reinforced Concrete and Steel Processing (KESS)" in the Framework Program "Decommissioning of Nuclear Facilities".

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