Mass-Production Issues of Micro-structured Fuel Processors for Distributed Energy Generation

G. Kolb, H. Pennemann, D. Tiemann

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Mass-Production Issues of Micro-structured Fuel Processors for Distributed Energy Generation

Gunther Kolb, Helmut Pennemann, David Tiemann, Institut für Mikrotechnik Mainz GmbH, Mainz, Germany

1 Introduction

Future sustainable and distributed energy generation will rely in many cases on fuel cell technology. To address the critical issue of hydrogen supply fuel processing of fossil and renewable fuels is a viable option [1].

Because fuel processor/ fuel cell systems for mobile applications are going to be a future mass product, production techniques are required, which allow high volume production at competitive pricing. Development of complete fuel processors for alcohol and hydrocarbon fuels is on its way at IMM applying micro-structured plate heat-exchanger technology. The power range of these systems reaches from 100 W_{el} [2] to 5 kW_{el} [3-5], while larger systems are under development [6]. All production steps required to build a fuel processor are currently addressed at IMM to meet the demands of future mass production and will be discussed below.

2 Microchannel Fabrication

The first step is the introduction of micro-channels into the metal foils, which are made from stainless steels or aluminum. Rapid prototyping techniques such as wet chemical etching of stainless steel or aluminium foils are established for the fabrication of micro-channels. Etching techniques might be suited for mass production already, depending on the number of units produced and on the size of the components. Cheaper techniques such as rolling or embossing are alternatives. One advantage of the embossing procedure compared to etching is, that the thickness of the metal sheets can be reduced significantly, because no material is removed during the shaping process and hence the thickness of the plate remains the same. Fig.1 shows an example of embossed plates and of a small-scale heat-exchanger fabricated by embossing and laser welding. In this first trial the plates were still embossed individually and then stacked manually together with other plates, which were cut by laser-cutting.

However, the embossing procedure alone is not sufficient to fabricate a heat-exchanger out of metal sheets in a fully automated manner. Actually such a shaping procedure is composed of 8-10 individual shaping steps, which could be realized in a follow-on composite tool. Such a tool would combine embossing, punching and folding steps. An endless coil of the metal sheet would then be transported through that tool.

A simpler version of such a tool, which integrates only the punching and embossing steps has been designed but not fabricated to-date (see Fig.2).

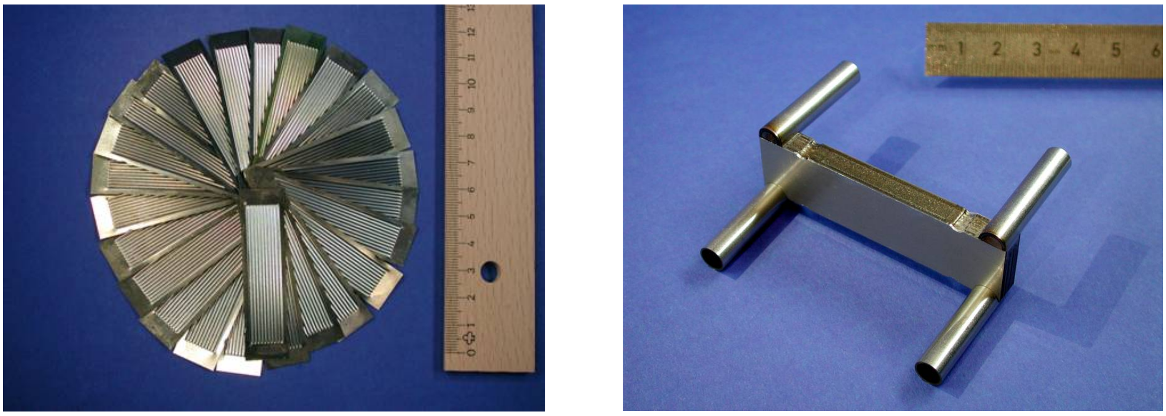

Figure 1: Micro-structured steel foils fabricated by embossing (left); embossed and laser-welded heat-exchanger (right).

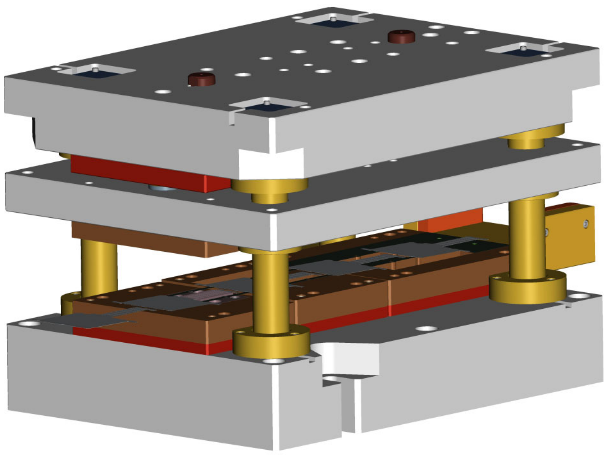

Figure 2: Follow-on composite tool for punching and embossing.

3 Catalyst Coating

The next step is the coating of catalysts into the micro-channels, which turns the plate heat-exchangers into chemical reactors. For the prototype reactors, a manual wash-coating procedure is applied [7]. However, this method includes the masking of the areas not to be coated by tape material, coating of the plate with the catalyst or catalyst carrier slurry (excess slurry is removed) and in some cases even the impregnation of the active species onto the alumina wash-coat in the micro-channels. In the latter case, two temperature treatment (calcination) steps are required to get the finished catalyst.

Different automated coating techniques have been investigated at IMM in the past, among them a coating machine, which more or less mimicked the manual procedure of filling the channels with a surplus of slurry and mechanical removal of the excess. More promising techniques under investigation were spray coating and screen printing. The former procedure, however, still requires masking of the areas not to be coated and generates substantial losses of catalyst material. Therefore screen printing of the catalysts onto the plates was finally chosen as optimum method.

The development of the screen-printing procedure required a careful choice and combination of ingredients added to the catalyst slurry to achieve amongst others features such as the thixotropic behavior required for screen printing. The preservation of the catalytic activity and stability despite the changes of the slurry formulation is of course mandatory and requires experimental verification, which could be achieved in the current case by 1,000 hours activity tests for the catalyst formulations under development. Fig.2 shows examples of micro-channels coated by screen printing.

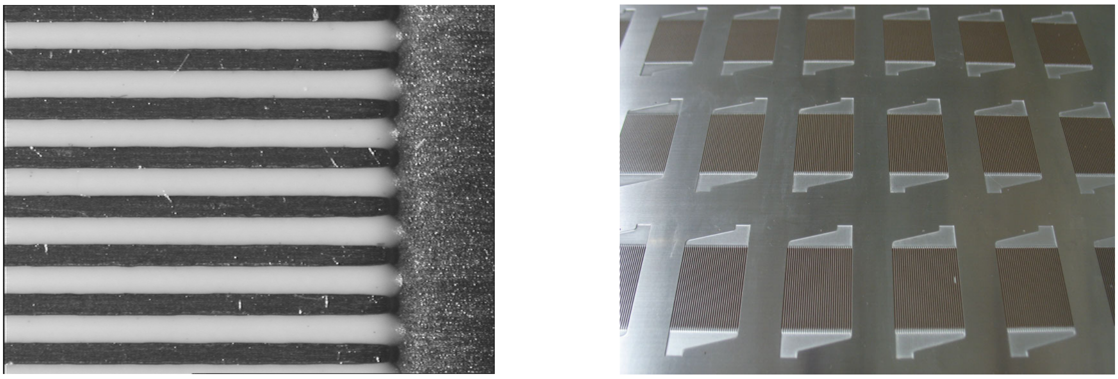

Figure 3: Microchannels coated with catalyst by screen-printing; single plate coated with catalyst slurry (left); sheet with multiple coated plates (right).

4 Joining Techniques

Finally the reactors and heat-exchangers need to be sealed by automated procedures such as laser welding or brazing. The reactors produced by these means are one-way products.

While brazing especially of aluminium is an established technique for plate heat-exchangers in the field of automotive and other mobile applications, it might well impair the performance of the catalyst coatings owing to the elevated temperatures required. Another issue is the release of organic material during the brazing procedure which might well impair catalyst durability.

Therefore a local input of heat, which does not increase the temperature of the catalytic coating significantly such as laser welding is the preferred option. Recently continuous wave (CW) disk and fiber lasers have entered the market, which had been dominated by CO_2-lasers before, as powerful tools for welding of metals. The continuous impact of a high amount of energy on a very small spot of e.g. 25 µm diameter even allows dynamic beam shaping by applying scanner technology. This results in superior quality of the welding seams at sufficient welding depth and high welding speed in the range of several m/min (see Fig.1). Long term welding trials performed with a 1 kW disc laser at IMM revealed superior quality of the welding seams at a length of one thousand meters without any defects. These trials are currently ongoing.

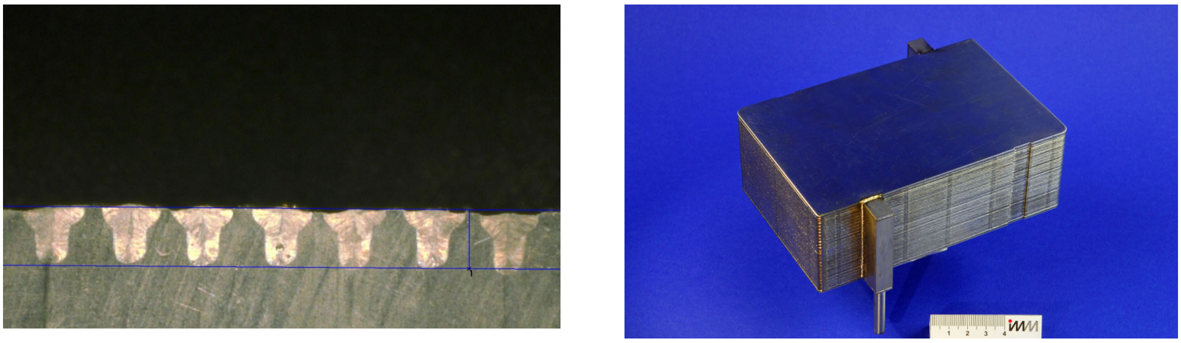

Figure 4: **Welding seams of 1 mm thickness achieved at high temperature stainless steel 1.4841 (AISI 314)(left); plate stack joined by laser welding (right).**

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