METAL LAMINATED TOOLING - A QUICK AND FLEXIBLE TOOLING CONCEPT

Thomas Himmer*, Dr. Anja Techel**, Dr. Steffen Nowotny**,
Prof. Dr. Eckhard Beyer**,***

* Fraunhofer USA, Inc., Center for Coatings and Laser Applications
46025 Port Street, Plymouth, MI 48170-6080
E-Mail: thimmer@fraunhofer.org
http://www.ccl.fraunhofer.org

** Fraunhofer IWS, Winterbergstr. 28, D-01277 Dresden, Germany

*** University of Technology at Dresden,
Chair for Surface Engineering and Thin Film Technology
at the Institute for Production Technology,
Postbox, D-01062 Dresden, Germany

Using the MELATO® (Metal Laminated Tooling) - technology deep drawing-, stamping- and injection molding tools of various sheet metal materials can be manufactured. The different kinds of stress such as pressure or temperature require adapted connecting technologies. Thus, a temperature-steady connection of the sheet metal lamellas is necessary for injection molds, which can resist the injection pressure. This paper describes the integration of tempering systems in injection molding tools or die casting tools. Related topics such as laser beam welding for bonding and laser beam build-up welding are presented as well.

1. Introduction

For the fast manufacturing of complex formed tools Fraunhofer IWS works together with partners from the industry on a constant automation solution for cutting, packaging and adding steel sheet cutouts. With the selection of the most suitable connecting technology, also requirements must be considered to quality, surface quality and the production costs. Deep drawing or stamping tools do not require a complete connection of the single metal sheets. Here, a fast and economical connection is the main objective. Due to simple automation, laser beam welding offers itself as joining process. On the other hand, a temperature-steady connection of the sheet metal lamellas is necessary for injection molds, which can resist the injection pressures.

2. MELATO® process chain

Three-dimensional CAD data of the tool to be manufactured are read into the CAD system, using standard interface formats (IGES, STL), as can be seen in figure 1. Subsequently, the tool is sliced into single cross sections. In addition, the layer thickness that must be determined before is set, considering metal sheet tolerances or shrinkage of the soldering metal. After slicing, the single cross sections are arranged on a metal sheet panel. The cross-sections are cut out by laser beam and are, subsequently, joined by various bonding technologies. Strength and life of tools may be additionally improved, for example, by the finishing of critical edges by laser beam build-up welding. Finally, the tool is finished by milling, EDM, polishing and heat treatment [1].

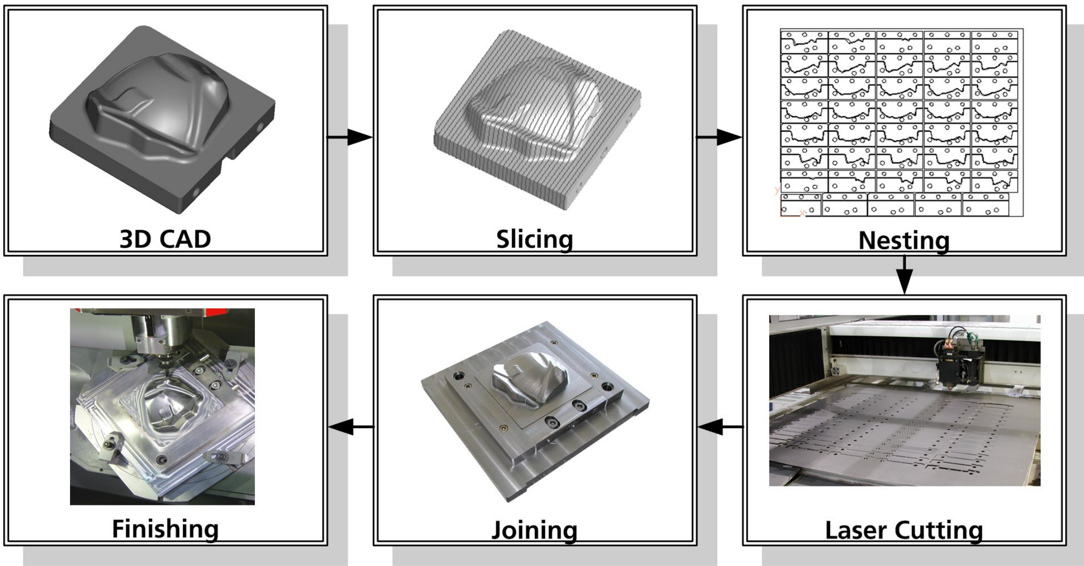

Figure 1: MELATO® - process chain

3. Injection molding tools with conformal Cooling Systems

If a cooling system should to be integrated in the tool, the tightness and heat conductivity of the laminated tool must be very high [2]. Suitable connecting procedures are hard soldering and high temperature brazing. MELATO® - tools, which are manufactured by high temperature brazing, are hermetically sealed and possess a good heat dissipation. After brazing the laminated tool is finished by milling or polishing.

3.1 Bonding technology

With the layer technology it is possible to integrate complex tempering systems in injection molding tools or die-casting tools, as can be seen in the figure 2. An optimization of the tools can be done by FEM-analysis or with a thermal image camera. In this way, the cycle time can be reduced dramatically and distortions of the parts are reduced, because of the homogeneous tool temperature.

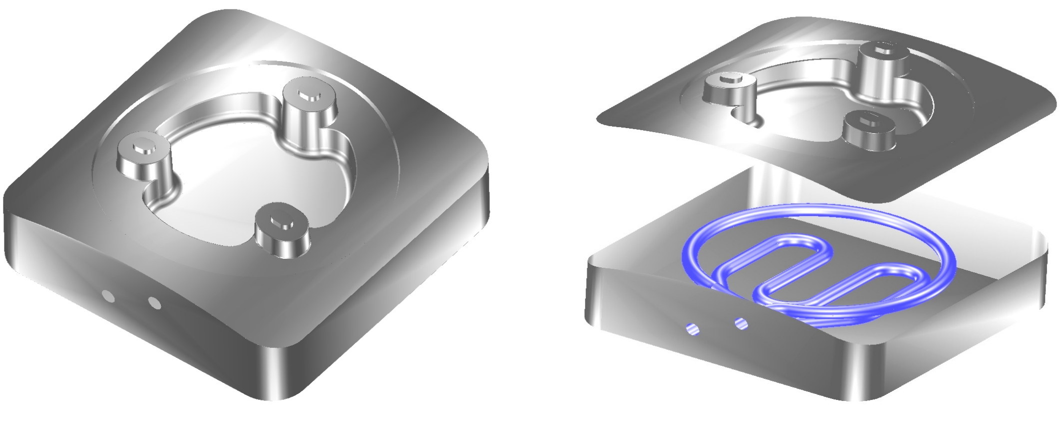

Figure 2: Left: injection molding tool insert, right: view of the internal cooling system

The strength of hard-soldered connections depends primarily on and the applied soldering procedure.

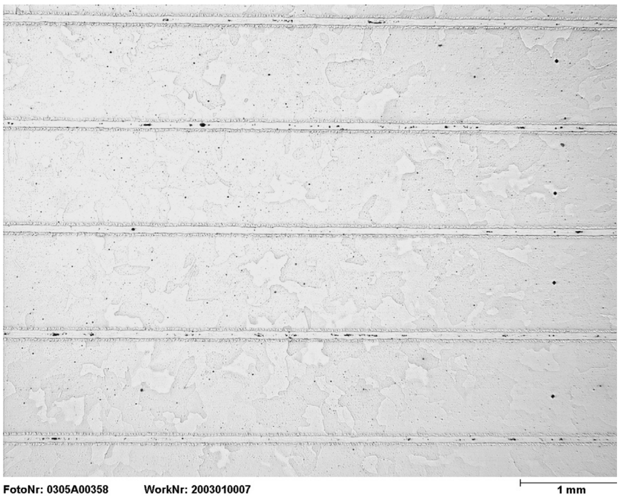

Figure 3: Cross-section of a brazed tool

The high temperature brazing takes place in vacuum or in an inert gas atmosphere. The strength of the connections, from low to highly alloyed steel, reaches the strength of the basic materials. Most used soldering metals are nickel-, silver-, and copper based. For the production of laminated tools for the high temperature range only high temperature soldering metals on nickel basis are applicable due to the enormous thermal load, whose heat resistance is enough to 800°C [3]. They possess even with high operating temperatures firmness sufficient for injection molds or die casting tools.

High temperature brazing has high demands for the preparation of the joints. The samples were therefore manually released from oxide coatings and cleaned afterwards with ethanol and/or acetone. Subsequently, the up-sprayed soldering coating was dried (10min with 120°C) in a furnace. Then, the lamella package was soldered in the furnace under inert gas atmosphere at 1060°C.

3.2 Finishing and testing

After the tool was soldered, the finishing took place by means of milling and polishing (figure 4). Finally the tool was installed in the tool framework and tested with a project partner. In summary, the following statements can be made for testing:

- The laminated tool showed up compactly and the layer interfaces are almost non-porously.
- The integrated cooling system proved as suitable, no leakage occurred.
- In these experiments, the cycle time with a conventionally manufactured and a laminated tool half could be reduced at 35%.

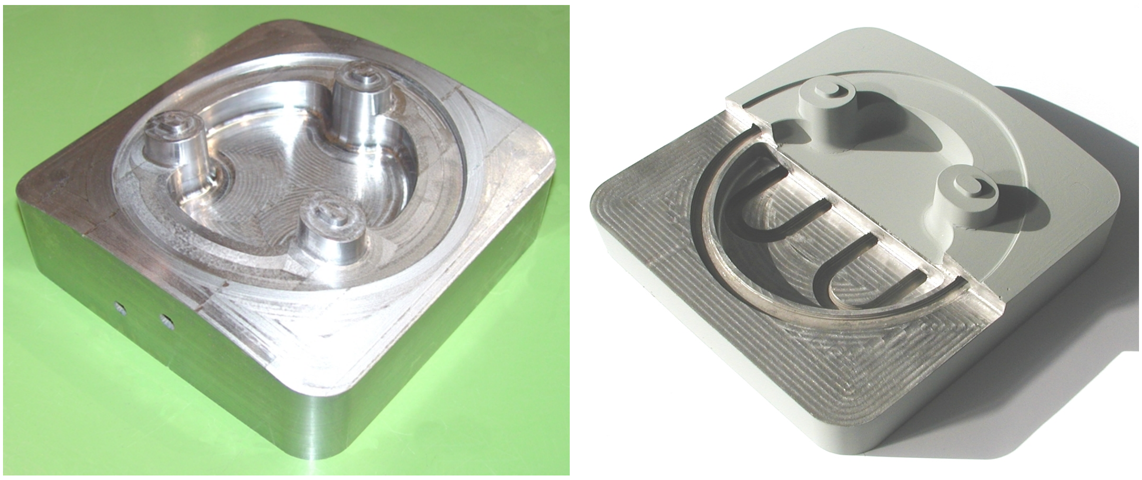

Figure 4: Left finished tool, right: cross sectional view of the cooling system

4. Metal sheet forming tools

4.1 Laser beam welding

The layer structure of MELATO® - tools and the demand to integrate welding operations into the building process (automation) determine the selection of suitable welding methods. The heat entry into the part is relatively low with laser beam welding (small heat influence zone).

The energy entry can be influenced by the parameters laser power and welding time and/or welding speed. The welding operations can be automated and integrated in processing centers by the use of suitable CAD/CAM software. In order to do this, a software was developed, which makes it possible to divide 3D-CAD-models into layers and to prepare the data for cutting. In addition, the position of weld spots is calculated automatically and weld defects, such as increased welding seam height is compensated. This is done by cutting a hole in following layer, at the position of the spots [4].

Figure 5: Deep drawing punch

The spot distribution takes place according to pre-defined boundary conditions via the user. These conditions are distance of the points from the outline and distance of the points to each other. In this way, the total amount of the points and thus the heat input in the part can be influenced. The tool path information for controlling of the laser beam welding machine are generated automatically.

Figure 5 shows a deep drawing tool manufactured by laser beam spot welding. The building and finishing of tools can take place directly in machining centers, if laser beam welding equipment is integrated. For this, a 3axes and 5-axes machining center, where modified. Goal is the complete processing (laser beam welding, milling, laser cladding) of tools and parts in one set-up.

After the stair stepping effect was removed manually, about 25 parts could be manufactured with the laminated punch. As material for the lamellas mild steel was used. The formed high strength steel has a thickness of 1,5 mm, a tensile strength of 700 MPa and a yield strength of about 400 MPa.

4.2 Universal tool frame concept for MELATO®

In the result of initial investigations it was stated, that for the special application "stamping tools" an economic application of the lamella technology can be obtained particularly with exchangeable modules. For these tools a tool frame concept for the part sizes 250 x 250, 500 x 500 and 750 x 750 mm was developed. A module consists of the tool frame, the laminated free form surfaces and a 2-chuck jaw block that can be taken out from the frame. Only this block is removed from the frame for finish machining [5]. The universal tool frame remains in the press.

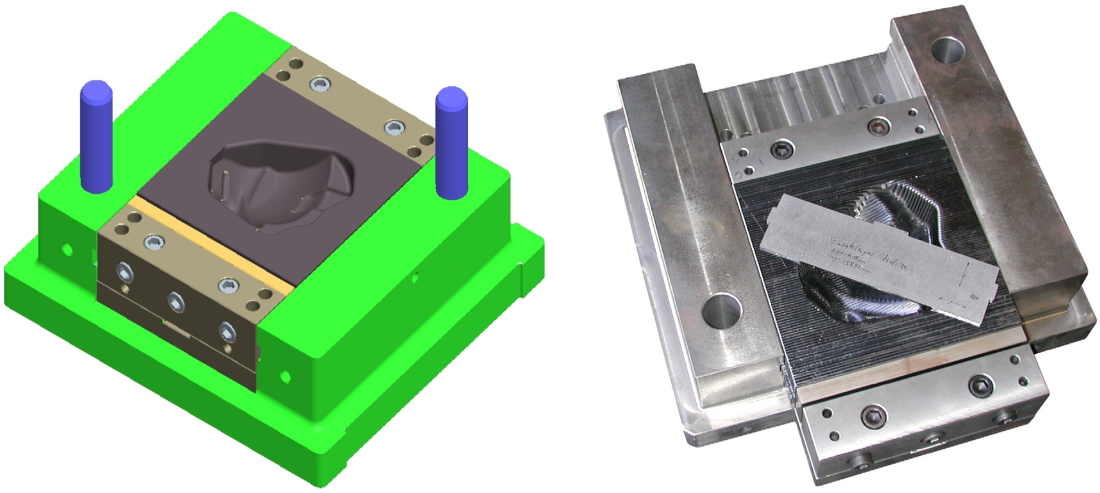

Figure 6: Universal tool frame concept for a stamping die

This concept has the following advantages:

- Fast exchange of the modules either for machining or for manufacturing is possible.
- Individual lamellas can be exchanged.
- Since only the module blocks are milled, the huge tool frames can remain in the press.
- The clearly smaller modules are simpler to handle.
- Rough cutting is avoided.
- The prototype tool block can be finally joined by welding, for the use as a mass production tool.
- After welding, the block containing the laminated structure can be taken out from the 2-chuck jaw for a product change.

As can be seen in figure 6, the tool frame concept for the part sizes 250 x 250 was constructed and manufactured. Finish machining and testing of this concept is now under development.

5. Hybrid Build-up Welding

The laser beam build-up welding has itself established as a precision coating method for surface protection and for reparation of highly stressed and complex formed building parts and tools on industrial scale. The combination of laser technique with other welding and heating methods contributes advantageously to the widening of the application field, offers totally new solutions for layer-techniques and improves the efficiency especially of extensive or voluminous material coatings.

In order to do this, a two-stage laser-/plasma build-up welding technology with additional inductive heating was developed. This combination enables the flawless generating of voluminous bodies out of Stellite materials with hardness bigger than 40 HRC. Moreover, an improvement of the coating and substrate capacities in the coating of casting materials is obtainable.

The industrial engineering implementation is managed by means of a CNC-milling centre, into which a closed CAD/CAM process chain for 3D-CAD-modelling and programming of the tool paths is integrated. It enables the programming of the build-up welding process and the finishing operations. Basis of the computations are usually imported 3D - CAD - models or digitization data. Based on this data and the chosen build-up strategy, the software (DCAMnc of NCSoft Wagner KG, Germany) generates 2D or 3D paths. A special challenge is represented in the path calculation for the procedure combination laser / plasma for the economic production of 3D structures. At this point, geometry and/or process parameters are set, which have been optimized in numerous test series [6]. This software includes the modules for the MELATO®-process as well.

Using this combination of laser-/ plasma build-up welding, a reduction of the building time by 60% for the generation of parts is possible. As can be seen in figure 7, first an outline wall (A) is built and then plasma welding is used to fill the cross section (B). Plasma welding is 10 times more productive then laser -build-up welding. On the other hand, the precision of laser-build-up welding is much better (approx. 0,5 mm), therefore it is used for the contour.

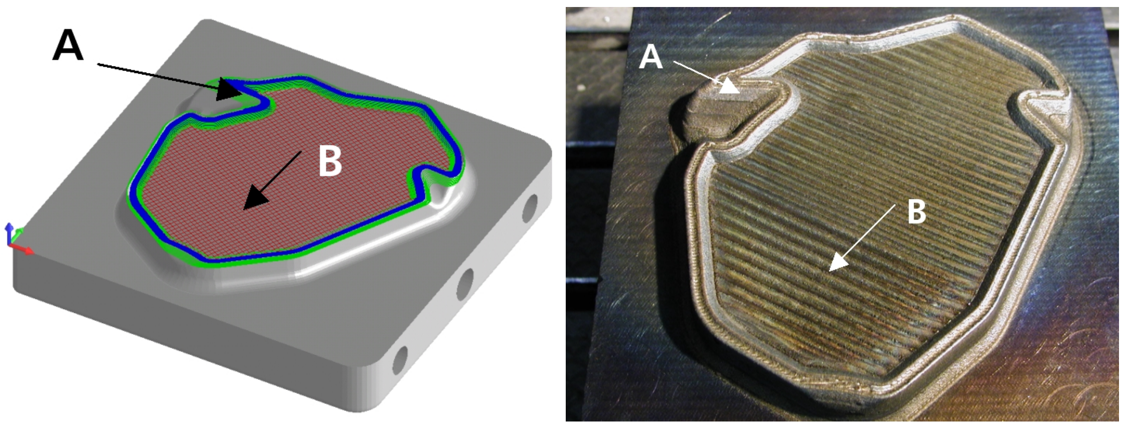

Figure 7: Generation of tools using laser-/ plasma build-up welding

Using this hard- and software, repair and/or generating of parts or tools can be fully automatic accomplished [7].

6. Summary

The investigation on laminated tooling has shown, that this technology has the capability for rapid tooling of deep drawing-, stamping- and injection molding tools. For the different applications, various process chains have been developed.

Injection molds require a perfect bonding, in order to produce a high surface quality and a dense connection of the lamellas. The investigations showed that the developed process chain for high temperature brazing is suitable for the manufacturing of tools with integrated cooling systems.

For the generating of forming tools, laser beam welding has shown a high potential for the quick manufacturing of forming tools. For this application a special software was developed, that is able to generate all necessary data for cutting and laser beam welding.

In addition, a tool frame concept was constructed and manufactured. The presented concept is suitable equally for the application for prototype tools and mass production tools. Thus the sheet metals in the prototype stage are only clamped or welded partially. The exchange of single sheet metals or blocks is thus possible. After the release to the series production, the tool then is complete welded to a block.

Alternatively for the generation of tools, a combination of laser-/ plasma build-up welding was shown. Using special software tools nearly all procedures and the necessary programs for several processing machines can be generated.

Further investigation is focused on the bonding technology for MELATO®, to enter new application areas such as pressure die casting. An automated solution for the generation of tools by laser beam welding is now being developed at Fraunhofer IWS.

Additional information can be found for Metal Laminated Tooling and
Laser Build-Up Welding under: http://www.iws.fhg.de/projekte/051/e_pro051.html

7. Acknowledgements

This research and development project is founded by the German Federal Ministry of Education and Research (BMBF) within the framework concept "research for the production of tomorrow" and cared by the agency “Production and Production Technologies” (PFT) at the Forschungszentrum Karlsruhe.

8. References

[1] Himmer T., Techel A., Nowotny S., Beyer E.,
"Recent Developments in Metal Laminated Tooling by Multiple Laser Processing"
Proc. 13th Solid Freeform Fabrication Symposium,
Austin/Texas, S. 466-473, August 2002

[2] Nakagawa T., Kunieda, M., Liu S.
"Laser Cut Sheet Laminated Forming Dies by Diffusion Bonding"
Proceedings of 25th International MTDR Conference, S. 505-510, 1985

[3] Dorn L.
„Hartlöten: Grundlagen u. Anwendungen"
Expert Verlag Sindelfingen, 1985

[4] Himmer T.
„Verfahren zum verzugsfreien Fügen von Blechen durch Laserstrahlschweißen"
DE-Patent: 102 11 511

[5] Ruess B., Höhe K.
"MELATO - Umformwerkzeuge im Automobilbau"
Workshop Rapid Tooling „Automatisierte Prozesse und neue Prozessketten"
Fraunhofer IWS Dresden, Feb. 2003

[6] Schmidt A.
"DCAMnc zur Programmierung von Robotern und CNC – Maschinen"
Jahresbericht Fraunhofer IWS Dresden, 2003

[7] St. Nowotny, S. Scharek, T. Naumann, R. Gnann, Eckhard Beyer
"Integrated Laser Milling Center for Complete Machining"
The International Congress on Applications of Lasers and Electro-Optics, 2001