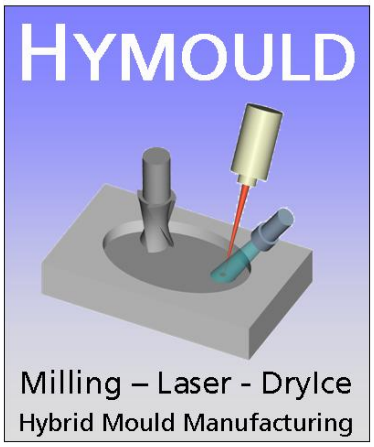


Sixth Framework Programme

HORIZONTAL ACTIVITIES INVOLVING SMES

COOP-CT-2006-032931

HYMOULD

Development of a Hybrid Machine Tool Concept
for Manufacturing of Free-form Surface Moulds

Instrument Cooperative Research Project

Publishable Final Activity Report

Due date of deliverable: M24
Actual submission date: 18.12.2008
Dissemination Level: PU

Start date of project: 01. October 2006 Duration: 24 Month

Organisation name of lead contractor for this deliverable: Fraunhofer IPK
Revision: delivered to EC

1 Publishable Final Activity Report

1.1 Introduction

The overall objective of the project was the development of a hybrid machine tool concept for the manufacturing of free form moulds and dies. Difficult-to-cut materials such as high-alloy metals have recently gained importance in this field of application because they have excellent material properties combined with ecological and economic benefits. The wide variety of materials proves to be the main problem with respect to the production of complex precision parts as a wide range of manufacturing technologies is necessary to achieve the required quality. The industrial end-users are interested in a flexible all-in-one machine tool and a significant decrease of the time-to-market in the rapidly changing consumer goods market. Thus, the HYMOULD project focuses on meeting both customer demands and production requirements by combining high-speed cutting, laser ablation and dry-ice blasting in one machine tool.

1.2 Project objectives

The detailed ***HYMOULD project objectives*** are:

- ***Hybrid machining technology*** for production of high-quality moulds on basis of
  - precise HSC-milling
  - laser ablation
  - dry-ice blasting
- ***Suitable machining technologies and strategies*** by means of:
  - successful combination of these processes in subsequent machining steps (suitable process chain) in the first step
  - successful combination of these processes to hybrid machining operations in the second step
  - technology data bases for single process technologies as well as for hybrid combined process technologies
- Successful ***application of the hybrid machining technology*** for the manufacturing of demonstrator moulds with the following characteristics:
  - obtainable minimum surface roughness of Ra = 0,1 µm
  - maximum structure dimensions of 100 mm x 100 mm x 100 mm
  - precise and fine structures without burr or deformations
  - made of difficult-to-cut materials like high-alloyed steel with > 64 HRC
- ***Concept for a hybrid machine system*** with integrated process modules consisting of:

  - two basic manufacturing cells – HSC-manufacturing cell (demonstrator I) and laser ablation/ dry-ice blasting manufacturing (demonstrator II)
  - process modules and components which can be implemented in the manufacturing cells
  - suitable interfaces and control
  - useable handling-, monitoring-, and guidance systems
  - CAD data model of hybrid machine systems on basis of existing process modules and components
- ***Concept for a closed loop CAD-/CAM strategy*** considering the hybrid technologies:
  - technology database of all processes for implementation into the CAM-system
  - technology-dependent strategies for generation of tool path
  - post processors for the manufacturing cells or demonstrators respectively
- ***Exploitation and dissemination plan*** for the technologies and the machine tool concept:
  - transfer of single processing modules and components into stand-alone machining units for integration in other machine tools within the next one year
  - exploitation of hybrid machining technologies and databases
  - transfer of the hybrid machine tool concept into a final product within the next two years

1.3 Contractors involved

Table 1: involved contractors

Partic. Role*	Partic. Type**	Partic. no.	Participant name	Country	Date enter project	Date exit project
CO	RTD	1	Fraunhofer Gesellschaft, Institute for Production Systems and Design Technology (IPK)	Germany	month 1	month 24
CR	RTD	2	IDEKO Sociedad Cooperativa	Spain	month 1	month 24
CR	RTD	3	Brandenburgische Technische Universität	Germany	month 1	month 24
CR	SME	4	GFH GmbH	Germany	month 1	month 24
CR	SME	5	KLASEN & PARTNER GbR	Germany	month 1	month 24
CR	SME	6	MEC s.r.l.	Italy	month 1	month 24
CR	SME	7	Soraluce	Spain	month 1	month 24
CR	SME	8	Nisaform s.r.o.	Czech. R.	month 1	month 24
CR	SME	9	Walter Pack S. L.	Spain	month 1	month 24

1.4 Work performed

The work started in the ***first phase*** with an analysis and specification of the system architecture, combined with the conceptualization of selected manufacturing processes including cell specification. The knowledge of the process behavior and process parameters was very important for the implementation and control of milling components, laser ablation unit and dry-ice blasting system.

During the ***second phase***, CAD/CAM modeling has been performed in parallel RTD work with respect to the envisaged demonstrator units. The development and set-up of the experimental demonstrator unit concluded the second phase of the project. During the HYMOULD project, a hybrid machine tool concept for the manufacturing of high-quality moulds and dies for small batch series has be developed that combines abrasive machining as ***roughing process and polishing in a single set-up***. The combination of HSC milling, laser ablation and dry-ice blasting is shown in **Figure 1**. Up to now, finishing operations are carried out manually by the use of lubricants taking approx. 30 % to 50 % of the machining time. There is no satisfactory, automated method for this task yet. Due to the concept of HYMOULD, the required ***machining time*** for moulds and dies can be considerably ***reduced***. The interaction of the three modules will be ensured by an integrated CAD/CAM system. This will enable a fast and easy ***usage of design data for mould and die*** machining.

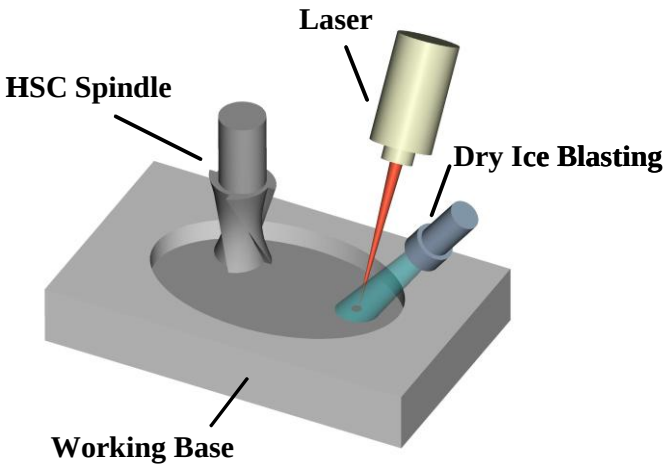


Figure 1: Hybrid technology concept of the HYMOULD-project

The machine tool concept was ***developed on different levels in parallel***. Firstly, there have been basic experimental investigations, which showed the potential of the combination of the three technologies for different applications on the one hand. On the other hand, the demands on the hybrid machine tool became apparent. The hybrid machine tool concept was therefore developed as a ***virtual machine tool*** as well as a ***technology catalogue / semantic net*** and as ***physical machining environment.*** Here, components for hybrid machining have been integrated into existing machine tools. ***Experimental investigations*** have been carried out on these newly created machining environments. The results are presented in the next paragraph, according to the levels mentioned before.

Dissemination activities as presentations on trade fairs, scientific meetings, publications in scientific and popular journals have been performed. Advertising activities as regional, national and international promotions promoted the Hymould hybrid machine tool concept.
The public project website can be found at www.hymould.eu.

1.5 Results

1.5.1 The virtual Machine tool concept

In the following figure, one can see the comparison of the traditional design and the new design using a virtual prototype, which leads to time saving.

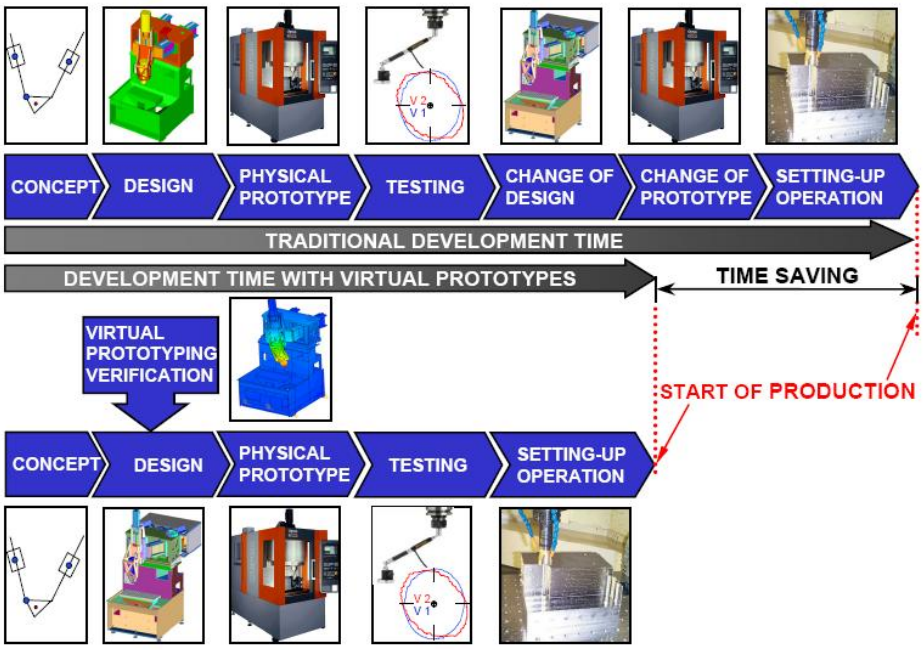


Figure 2: Development of Virtual Demonstrator

The virtual prototype developed inside this project is illustrated in the following figures:

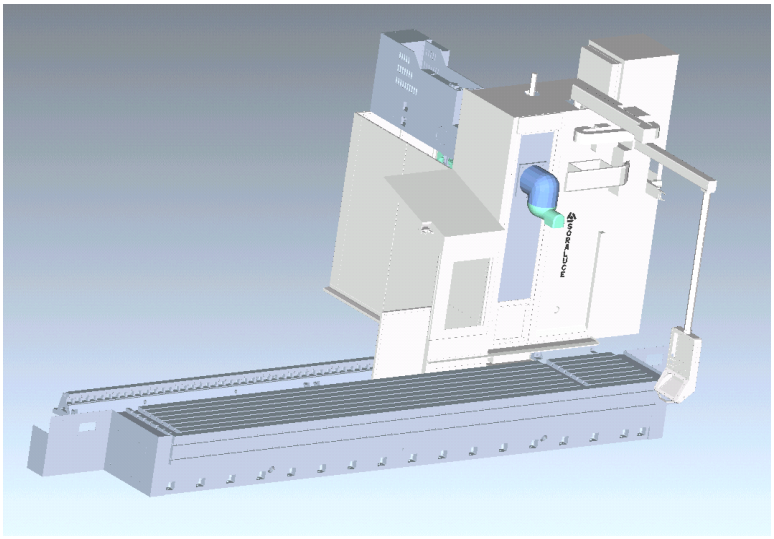


Figure 3: Virtual Demonstrator (laser head green)

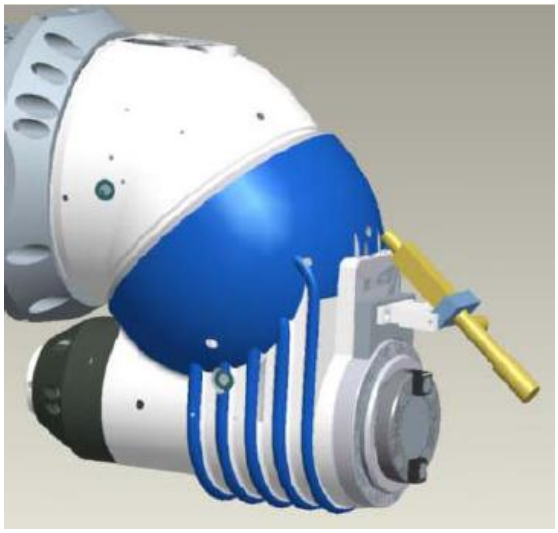


Figure 4: Virtual Demonstrator-Integration of Components: CO2 Nozzle

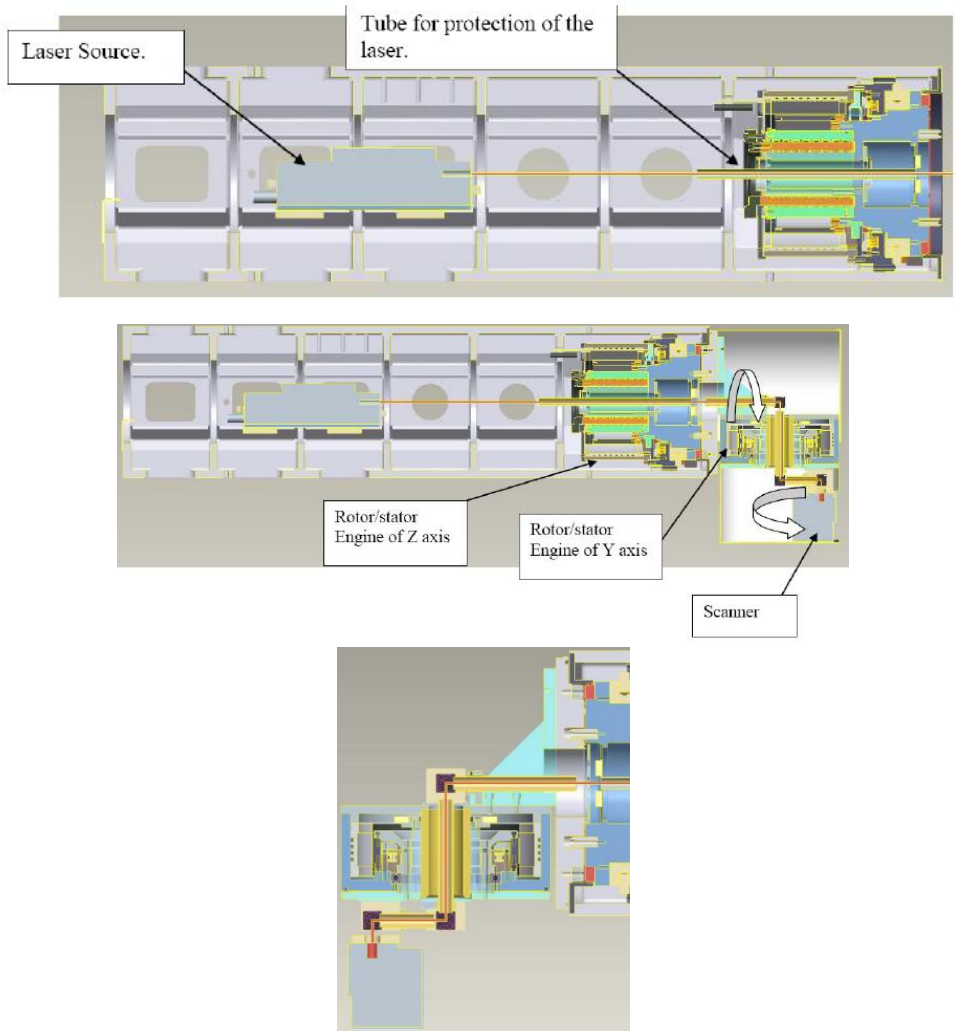


Figure 5: Virtual Demonstrator-Integration of Components: Laser Components

The virtual machine tool was used for

1) Mechanical integration and design
2) Assortment of components
3) Work space studies
4) Vibration FEM analysis
5) Collision detection
6) Proof of NC paths
7) Thermal FEM analysis

Accordingly to figure 2, the virtual machine tool is the basis for the physical design of the hyprid machine tool, which is planned to be realized at Soraluce. The profound modeling of the virtual prototype inside the project hymould is expected to result in a significant overall time saving.

1.5.2 The Technology Data Catalogue / Semantic Net

The main aims of the Technology Data Catalogue (TDC) have been gathering, retrieving, structuring, processing and sharing relevant engineering data/information in an intelligent way. The TDC will also provide structured information about the "best-practice" settings of the manufacturing system. Data sources have to be defined and a suitable knowledge representation structure has to be created in order to store the relevant implicit and explicit knowledge generated at the different levels of companies.

The TDC uses product data standards to overcome data format heterogeneity of explicit knowledge sources. Standards will provide an unambiguous and computer interpretable representation of product data. The product data had been taken from different sources like for instance experiments achieved during the project (compare fact sheets) and implicit knowledge from the experts (compare fact sheeds): fundamentals of product description and support, geometric and topological representation, product structure configuration, materials, shape variation, tolerances, and process structure and properties.

An ontological system has been suggested to work out problems of semantics in knowledge representation. The Software K-infinity was used for this porpose. The Figure below shows the screenshot of the Environment set up as Hymould demonstrator.

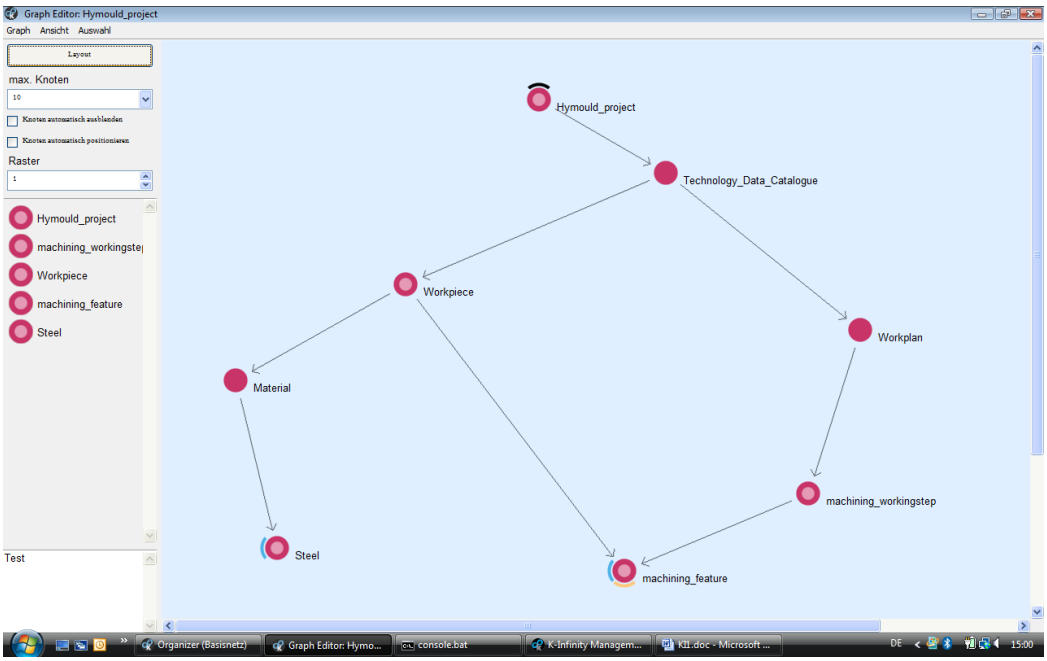


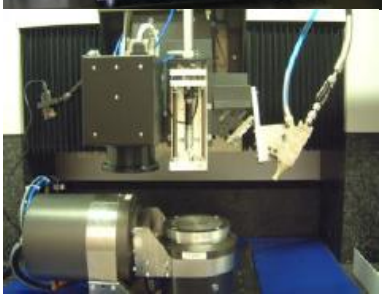
Figure 6: Developed semantic net in hymould, program environment (K-infinity)

1.5.3 The Physical Machining Environment

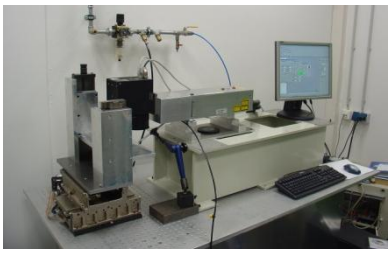
The components for hybrid machining have been integrated in machine tools and into test setups. The following environments for hybrid machining have been set up inside the hymould project.

1. CO2-machining environment integrated Soraluce milling machine head

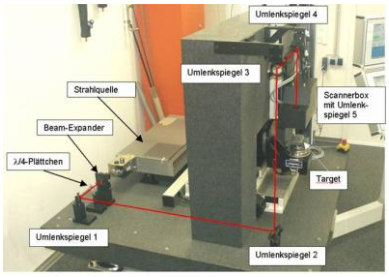
2. 5-Axis Precision machine Tool for hybrid ps-Laser-machining and CO2-machining (The CO2-Nozzle, shown in the lower picture, on the right, was developed, tested and integrated inside hymould)



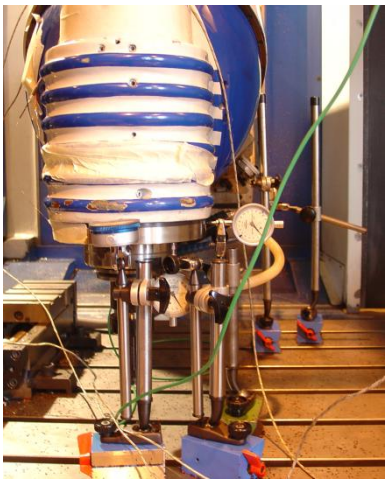
3. Laser Machining Test Stand for ns-Laser-Machining



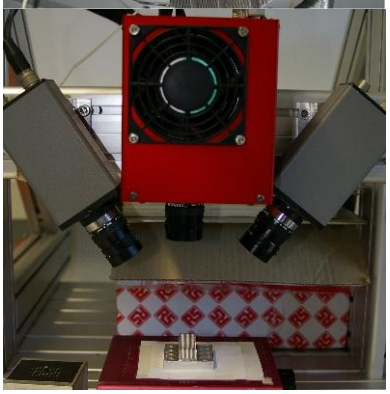
4. Laser Machining Test Stand for ps-Laser-Machining – Environment for development of 3D-Laser-Cam-System.



5. Temperature measurement and thermal elongation measurement environment for CO2-machining



6. Machine Tool Integration of measurement systems for evaluation on part accuracy



1.5.4 The Results of the experimental investigations

Inside the project, different benchmark parts have been selected respectively designed. These parts have been machined with different technologies in different materials by different partners. Round robin tests have been organized for this purpose. This enabled the consortium to overcome the fact that no complete machine tool for complex hybrid machining was available due to the short duration of the project.

The detailed results are for exclusive use of the consortium, but the following general results can be concluded.

- The main application for dry ice in this context is cleaning of moulds rather than surface structuring and polishing (Fact Sheets 2,14)

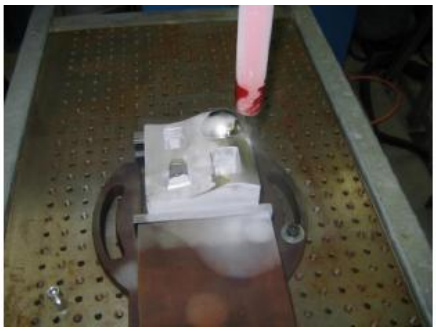


Figure 7: CO2-treatment of milled mould

- CO2 blasting is of minor influence during laser machining regarding laser parameters and surface roughness. (Fact Sheet 3)
- The selected dry ice blasting machine and the selected nozzle has huge influence on the results regarding cleaning of moulds and dies. (Fact Sheet 4)
- The material removal using a ps-Laser can be adjusted over a wide range with the laser parameters. (Fact Sheet 5)
- A ps-laser can be used for “polishing” purposes when a low laser power and puls overlap is applied (Fact Sheet 6)
- A ns-laser can be used for micro structuring of dies and moulds as well as a ps Laser, compare following illustrations (Fact Sheet 7)

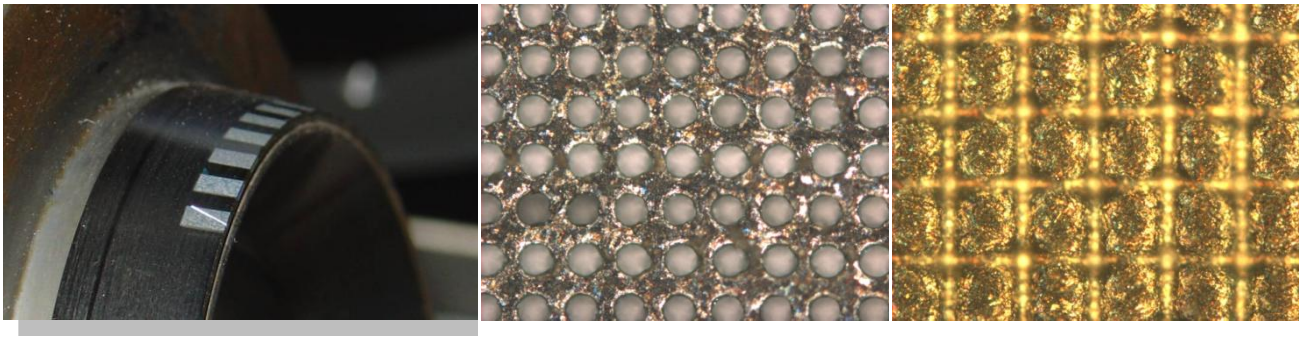


Figure 8: Micro structured mould (left), Microscope picture of hemispheres in steel (middle), Microscope picture of machined steel surface (right)

- 3D-geometries can be ablated with the laser to high precision. The parameters have to be defined for each material due to their different properties.

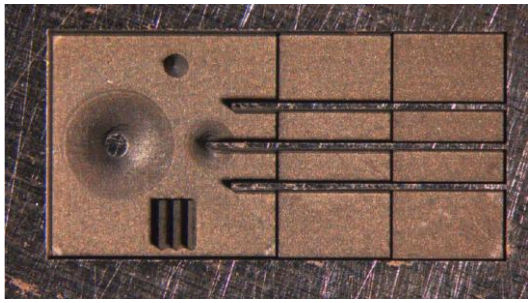


Figure 9: Micro structured mould in mould steel (dimension 4x8 mm²)

1.6 Exploitation

1.6.1 Method of Exploitation for overall use of hybrid machine tool

The machine tool manufacturer Soraluce will set up a hybrid machine tool on the basis of the Developments in the Hymould Project. The virtual demonstrator documents these investigations. The processes have been approved at the machining centres at each of the partners. Several benchmark-processes and benchmark parts have been defined and treated by different processes at different partners. The measures and test series will be put together in a data basis in a unitary design. This design is a standard fact sheet design which was developed by the RTD-partners according to existing hybrid-machining concepts and according to established knowledge system structures.

This structure enables each partner to use, upgrade and strengthen the generated knowledge.

1.6.2 Exploitation in Detail

SME Partner MEC:
will exploit a dry ice pellet system in order to gain a new market segment: Integration of dry ice pellet systems into machine tools, in close cooperation with SOR.

SME Partner SOR:
gets the opportunity to setup a multi functional machine tool and gains information of process- and machine tool "behaviour" and enhances its business portfolio.

SME Partner KLA:
does further development of a "closed loop" CAD/CAM software system.

SME Partner NIS:
obtains a new hybrid process, and expands its shop floor functionalities regarding working on macro- as well as on micro parts and –structures.

SME Partner WAP:
obtains a new hybrid process, and expands its shop floor functionalities regarding working on macro- as well as on micro parts and –structures.

SME Partner GFH:
Supplies technology-knowledge in the fast growing sector of hybrid machining processes and laser ablation in mould making processes.

RTD Performers BTU, IPK, IDE:
are disseminating their knowledge by integrating it into lectures, seminars and workshops, on fairs, EU-platforms etc.
Dissemination activities as presentations on trade fairs, scientific meetings, publications in scientific and popular journals have been performed as well. Advertising activities as regional, national and international promotions promoted the Hymould hybrid machine tool concept.

The public project website can be found at www.hymould.eu.
Coordinator contact details:

Fraunhofer Institute Production Systems and Design Technology (IPK)
Pascalstr. 8-9
10587 Berlin, Germany
Phone: +49 (0) 30 / 6392 – 3960
Fax: +49 (0) 30 / 6392 – 3962
mailto: joerg.essmann@ipk.fraunhofer.de