

Project no. 314739

HEPHESTOS

Hard Material Small-Batch Industrial Machining Robot

Collaborative Project



WP 7

Deliverables D7.2

Final Workshop Report

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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	X

Document information

Abstract: This deliverable provides information about the Hephestos Final Workshop. It corresponds to deliverable 7.2: Workshop II (actually the Final Workshop corresponds with Workshop III). The Final Workshop was organized by the Hephestos project participants at MAG facilities in Oulu (Finland) on 16th of October 2015.

This deliverable contains restricted information and it has been classified as confidential.

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Introduction

Workshops have been considered a very appropriate way to disseminate the project results not only to the scientific community but also to the industrial community, allowing to receive feedbacks from a large spectrum of potential industrial users.

Initially the project “Description of Work” foresaw the celebration of two workshops (months 6 and 36), but finally the project partners organized three workshops, including and new one in the European Robotics Forum (ERF) 2014. For this reason, the Final Project Workshops is actually Workshop III.

The main objective of Workshop I (Figure 1) was to present the current situation of the use of robots in the Machining World and to present the Hephestos Project objectives to the scientific and industrial community. It was held at IPK facilities in Berlin on 5th of April 2013 (Project month 8). It included ten presentations from different industrial companies and research institutions, a panel/roundtable discussion and scientific encounters.

Participation fee
Die participation fee for the workshop is 50,- €.

Registration
The maximum number of participants is limited. Seats are allocated upon confirmed registration on a first come first serve basis. It is, therefore, advised that the participants be registered on or before the 28th March 2013.


Organisation Committee
Dr. D. Surdžović, Prof. E. Gambaio,
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Accommodation
To your convenience we have reserved a number of rooms in the neighborhood hotels. For more information please contact Mr. Just.
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<http://www.ipk.fraunhofer.com/address-and-map/anfahrt>




5th of April 2013, Berlin, Germany

Robots in the Machining World
Towards Reliable Flexible Manufacturing



Workshop within HEPHESTOS FP7 Project



Event at a glance	Programme
<p>Robotic machining is characterized by considerable gap between the rapidly growing interest of end-users and the potential benefits of robot technology on the one hand, and the practical applications and utilization on the other. Although robotic machining products and services constitute less than 5% of existing robotic sales, nevertheless there had been a clear trend of growth in the last years and this trend is expected to persist into the future.</p> <p>Numerous developments and researches, however, have recently addressed globally the main technical barriers to a wider adoption of robots for material removal in the industry. Recent developments deal with critical robot machining problems such as efficient planning and programming, increasing robot accuracy, suppression of vibrations, advanced control and tooling techniques etc.</p> <p>The aim of this workshop is to present the latest developments of robot machining in the industry and research including, among the others, the development of novel industrial robotic systems for machining, the results of EU FP7 project COMET as well as various recent theoretical and experimental results etc. The workshop will initiate an open discussion among potential end-users from numerous industry sectors, industrial robot developers and integrators, as well as researchers concerning actual requirements, transfer of novel techniques and the future developments.</p> <p>The workshop is organized within the new FP7 project HEPHESTOS: "Hard material small-batch industrial machining robot", focusing on machining of highly customized products by means of industrial robots, which also will be shortly presented.</p> <p>At the end of the Workshop, participants are cordially invited for a vernissage "Science encounters Art - Part I" that will be the first time of which the interaction of robotic and human sculpturing is presented.</p>	<div style="display: flex;"> <div style="flex: 1;"> <p>9:30 – 10:00 Registration</p> <p>10:00 – 10:10 Welcome, Workshop objectives D. Surdžović, Fraunhofer-IPK, Berlin</p> <p>Session I:</p> <p>10:10 – 10:35 Milling Robot Staubli RX170HSM - Between Robots and CNC Machines H. Göllnitz, Staubli GmbH, Bayreuth</p> <p>10:35 – 11:00 Can Industrial Robots be Used in the Manufacturing Industry for Machining Operations? C. Lehmann, BTU, Cottbus</p> <p>11:00 – 11:25 Open Industrial Robot Control Platform and Algorithms A. Bortone, COMAU SpA, Torino</p> <p>11:25 – 11:50 Approach for Combining Flexibility and Adaptation in Robot Based Machining M. Drust, Fraunhofer-IPA, Stuttgart</p> <p>11:50 – 12:15 Additive Manufacturing of Large Parts with Industrial Robots T. Felch, Fraunhofer-IFT, Magdeburg</p> <p>12:15 – 13:30 Lunch Individual tour to the exhibition/experimental field</p> </div> <div style="flex: 1;"> <p>Session II:</p> <p>13:30 – 13:55 Robot-Based Machining R. Krappinger, ABB, Wiener Neudorf</p> <p>13:55 – 14:20 Advanced Robot Multi-Axis Machining on Metals C. Doukas, LMS, Patras</p> <p>14:20 – 14:45 Robot Machining of Stone G. D'Urso, QDESIGN S4, Bientina</p> <p>14:45 – 15:10 Edge Machining of Turbine Parts Using Industrial Robots M. Manthey, Fraunhofer-IPK, Berlin</p> <p>15:10 – 15:35 Development of Robotic Machining Centers B. Lukas, A* GmbH, Seligenstadt</p> <p>15:35-16:00 Coffee break</p> <p>16:00-17:00 Panel/Roundtable Discussions: How the Industrial Robots Meet the Machining Requirements G. Holland, UJA, Agder 3 Panelists</p> <p>17:30-19:00 Science encounters Art - Part I Vernissage of human-robot interactive sculpturing</p> </div> </div>

Figure 1: Hephestos Workshop I flyer.

Workshop II was held at the 5th European Robotics Forum 2014 in Rovereto (Italy). Under the title “Advances in robot machining”, the project partners presented the research achievements in a two hours session. The session had 29 attendants (from 22 different institutions).

1 Final Workshop Objectives

The main objective of the Final Workshop was to show an integrated demonstration of the most important technical results obtained in the project. The project includes two different demonstrators denominated Demonstrator 1 and Demonstrator 2 (see Deliverable 6.1). Demonstrator 1 was selected as a demonstrator for the Final Workshop since it includes the possibility of integration of most of the work developed in the technical Workpackages for several representative operation scenarios:

- WP2: Sensory system
- WP3: Programming and simulation
- WP4: Advanced control
- WP5: Human-machine interfaces and interaction



Figure 2: Hephestos use case 1 Demonstration Cell.

Demonstrator 1 consists of a complete flexible robotic machining cell and it has been installed at MAG facilities in Oulu (Finland) (see Figure 2). This demonstration includes four different demonstrations: two milling cases (Aluminum and Inconel milling), drilling and polishing. These four demonstrations were designed to show the different technological capabilities developed in the project:

1. Localization of parts for programming and simulation:
Laser profilers are used to acquire 3D profiles data from objects allowing to get a user coordinate frame.
2. Programming and simulation with path compensation:
A prototype wireless sensor module is used for teaching machine paths for the industrial 6-axis robot using an impedance robot controller. Alternatively, the HRI application (Hammer) can be used to build robot trajectory points and paths.
Easy-Rob robot simulation is used for robot programming including off-line path corrections based on robot elasticity and process material cutting models.
Hammer application can be used to build robot programs in a very simple way and for a first simulation of robot paths.
3. Compliance control for robot machining:
Improvement of the robot position controller for better machining performances based on model based control system. An external RT controller implements a position based compliance control.
4. Monitor program execution in real robot using augmented reality techniques:
Hammer application provides augmented reality algorithms to show useful information about the task the robot is executing.

The consecutive execution of the four demonstrations in the Final Workshops allowed to see the different capabilities of the systems developed in the project.

2 Workshop organization

2.1 Previous work

After the selection of Demonstrator 1 to show the project technological results, the Final Workshop had to be organized at MAG (integration leader) premises in Oulu since the Flexible Robotic Cell was difficult to translate due to its size and weight.

NH3 Comau robot and the main parts of the robotic machining cell were installed in Oulu at the beginning of project year 3. The technological developments (WP2 to WP5) were developed by the project partners during years 1 and 2 in collaboration, but it was necessary to integrate them in the Demonstrator 1 single robotic cell. For this reason, an “integration week” was organized from 22 to 26 of June. All the project participants worked in cooperation to develop the different scenario demonstrations. All the partners thoroughly prepared this integration work, however, several unexpected technical problems appear during the integration mainly due to the incompatibility of the different necessary equipment. Additionally, since there were only one available robot it was necessary to organize its shared use. After the integration week, most of the systems were ready for the final demonstration but some refinements were still needed.

2.2 Workshop technical preparation

To do a final integration of all the systems and to prepare the presentations and demonstrations, the project partners worked again together on the Workshop site during the four days before the Final Workshop. The last versions of the different systems were tested and integrated in the four demonstration cases.



Figure 3: Hephestos Final Workshop preparation at Oulu.

2.3 Workshop Schedule

The Workshop flyer including the agenda is shown in Figure 4.

Event at a glance

The robotic machining represents an emerging, promising and rapidly growing field with considerable interest of the industry, especially SMEs. The aim of the HEPHESTOS project was to develop a better understanding of hard material robot machining application systems by shifting the focus away from how robots can replace CNC machines to the issue how robots can complement traditional CNC machining and human in high variant low-volume production.

After three years of RTD work we are pleased to invite you to our demonstration and critical evaluation of achieved results in declaring novel and sophisticated practical methods (for planning, programming, sensing technology and real time control) that follow efficient deploy of industrial robot in application which are of considerable commercial potential and in pertinent to the large scale flexible robotic machining technology (e.g. milling, finishing, drilling, polishing).



HEPHESTOS Workshop

09:30	On-site registration
10:00	Welcome P. Kosonen, JOT Automation Ltd.
10:10	HEPHESTOS at one glance G. Schreck, Fraunhofer IPK (Project Coordinator)
10:30	Sensory systems for robot machining T. Heikkilä, VTT Technical Research Centre of Finland H. Kabelitz, ME Messsysteme GmbH
11:00	Robot task planning and programming S. Anton, Easy-Rob G. Hovland, Universitetet i Agder
11:30	Advanced robot control techniques for machining operations D. Surdilovic, Fraunhofer IPK A. Bottero, Comau SPA.
12:00	Lunch
13:00	Human-Robot interaction in industrial applications E. Gambao, Universidad Politecnica de Madrid (UPM)

13:30 **Introduction to system demonstrators**
P. Kosonen, JOT Automation Ltd.
L. Toth, G-Robots Kft.

13:40 **Field demonstrations**
Individual

14:50 **Coffee Break**

15:05 **Round table discussion**
P. Kosonen, JOT Automation Ltd.

15:50 **Concluding remarks and closing**
G. Schreck, Fraunhofer IPK

16:00 **Farewell**

Address of the workshop site:
JOT Automation Ltd.
Vihkari 10
90440 Kempele, Finland (near Oulu)



Map-Link, HERE Maps, Google Maps

Participation fee
There will be no participation fee.

Registration
The maximum number of participants is limited. Seats are allocated upon confirmed registration on a first come first serve basis. It is, therefore advice, that the participants be registered on or before 08th of October 2015.

Accommodation
To your convenience we have reserved a number of rooms at [Sokos Hotel Arina](#) close to the workshop site. For reservations by mail (sales.oulu@sokoshotels.fi) or phone (+358 8 3123 255) use booking code "HEPHESTOS". For more information please contact Mr. Gall.

Add. hotels near the workshop site:
[Radisson Blu Hotel Oulu](#)
[Scandic Hotel Oulu](#)

Transportation
Please share your interest in transportation from Oulu city center to the workshop site during registration. We will arrange the transportation. The distance from the airport to the workshop site is about 5km, approx. 10 min by taxi.

Social Event
Farewell after the official end of the workshop.

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Position/Division _____

Address _____

Phone _____ FAX _____

E-Mail _____

Date, Signature _____

16th of October 2015
JOT Automation Ltd., Oulu, Finland



Hard Material Small-Batch Industrial Machining Robot

Final Project Workshop




Figure 4: Hephestos Final Workshop flyer.

Fraunhofer IPK distributed the invitation flyer to possible interested technology users and developers. Due to the long travel to Oulu for non-Scandinavian participants, the Workshop had not participant fee and transport between selected hotels at the city of Oulu and MAG facilities (10 km) where arranged.

The final Workshop receives 17 attendants from 10 different institutions.

After the participants welcome by MAG, the Hephestos project was presented at a glance. Following, four technical presentations (Figure 5) presented the main technological work.



Figure 5: Technical presentation.

After a short introduction to the system demonstrator, the attendants moved to shop floor to see the field demonstrations (Figures 6 and 7). The four use cases were consecutively presented and after the demonstrations the attendants where free to see every system closer and to ask questions. Some attendants test several systems by their own like the programming system, virtual robot teach pendant or augmented reality glasses (Figures 8 and 9).

A final roundtable discussion allowed common questions and definition of possible future work and the Workshop was concluded with the final remarks and farewell.

The Final Workshop was filmed and a short video was prepared and distributed.



Figure 6: Field demonstration.

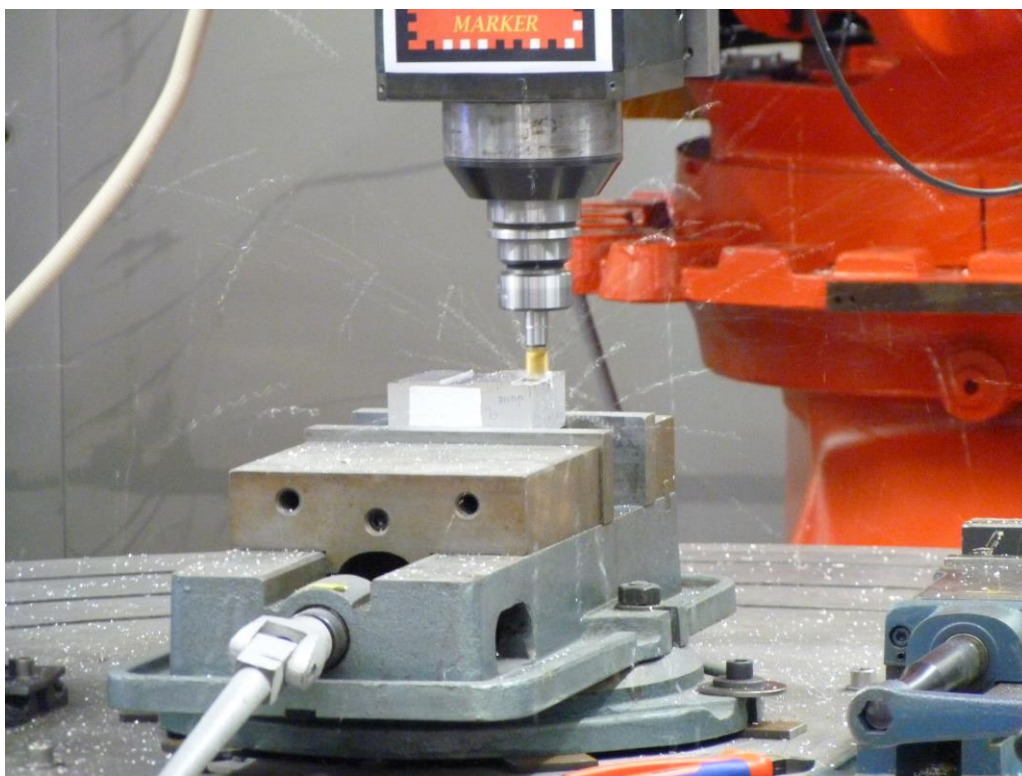


Figure 7: Robot machining during the Final Workshop.

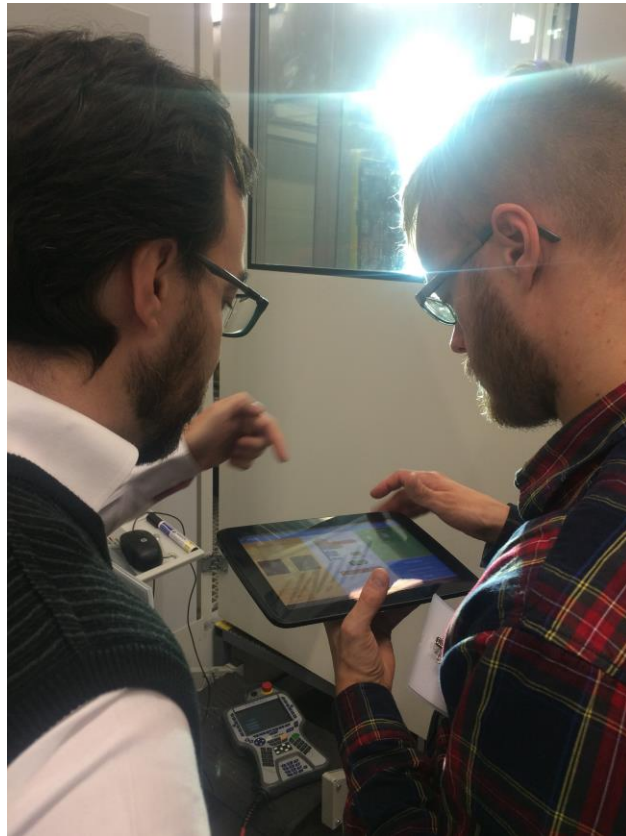


Figure 8: Robot programming demonstration.



Figure 9: Augmented reality.

3 Workshop Results and Obtained Feedback

3.1 Results

Spite the several mentioned difficulties, it was possible to show the four different demonstrator and the different sub-systems performance to the attendants with no significant errors. The robotic system demonstrates its machining capabilities with both, no hard and hard materials. Although it was not foreseen during the Workshop preparation, several attendants had the opportunity to personally test several sub-systems and it was very interesting to get their comments.

The Workshop agenda was maintained with no important delays. The general roundtable discussion was reduced since most of the comments were directly done during the field demonstrations.

3.2 Obtained feedback

The technical presentations and the filed demonstrations opened several questions and comments from the attendants allowing to receive a feedback of the system performance in general and the different developed subsystems. Not all this feedback was directly received during the Final Workshop day; the project partners have also received interesting feedback after the Workshop and during direct contacts with possible customers or end-users in fairs and private conversations. It has been considered interesting to include this feedback in this deliverable.

1. Complete robot machining cell feedback:

Since the project beginning, as it was confirmed in Workshop I, many possible customers and the technical community showed a big interest in the project objective of using a robot for machining hard materials for small-batch production and even in general to use machining robots. The machining industry expressed its interest in this possibility, not only for machining of industrial pieces but also for machining of artistic sculptures with robots, reducing the costs and augmenting ease of use. The robot manufacturers also showed their interest in the Hephestos technological way of solving the inherent difficulties.

After the project finalization we conclude that this initial interest is still alive. We consider that the selected procedure is still valid (several attendants presented other methodologies). However, it is still necessary to increase the reliability of the software and hardware of the robot control system. Comau will use the project experience to improve the capabilities of the G5G Open Robot Controller.

Some attendants also express their interest to collaborate in future projects.

One of the attendant pointed that the field demonstration did not cover all the topics presented in the technical presentations.

In general, the attendants were happy about the demonstrations, we receive only some remarks about typical small demo errors. The technical presentations received very good comments.

Many of the attendants also expressed that it was nice to know the project in detail and the project partners.

2. Sub-systems feedback:

Of course, not all the participants were interested in the robot machining system as a whole. Some of them were interested in robot machining, but not necessarily including all the sub-systems presented in the demonstrations. We received several questions about the possibility of applying some of the technological achievements to other systems or applications.

Some customers were only interested in specific developments of the project that could have their particular application to the market.

3D vision based localization received a great interest from one of the participants in the Final Workshop since it matches very good with their current interest. VTT is in direct contact for near future collaborations.

The Hammer application received also big interest from several participants, specially the monitoring capabilities. Internally, there are conversations between Easy-Rob and UPM for possible commercialization of this application. Additionally, Comau is also interested in this technology for HRI and there will be a common meeting to share the technology.

MEM force sensor received also great interest in the market. A workshop to check the possibility of its use in medical robots was organized on 9 of October 2015 and MEM has received some comments about possible improvements of the sensor increasing modularization and offering electronic component with ProfiNet Industrial bus.

4 Conclusions

The Final Workshop required a big effort of all the project participants. Field demonstrations are always complex but after the work developed in WP2-WP5, the workshop preparation effort was underestimated and one work of on-site collaboration was not enough to have everything completely ready. This forced the consortium to spend four more collaboration days in Oulu before the demonstrations. However, the acquired experience and collaborative work was one of the best and satisfactory experiences in Hephastos projects and after the Final Review Meeting in Berlin some of the partners expressed it.

Since MAG was the leader of the integration WP and Demonstrator 1 was installed in MAG facilities in Oulu, the Final Workshop had to be organized there. Due to the difficulties of travelling to Oulu this fact increases the efforts of the Workshop organization and also reduced the number of attendants. For this reason, the project partners decided to participate in the Deburring Expo 2015, to continue their common participation in future fairs, their participation in Robo Business 2016 at Odense (Denmark) and a new workshop organization has been proposed for the 7th European Robotics Forum at Ljubljana (Slovenia) under the title “How interactive robots may support small-batch machining in industry”.