PROJECT FINAL REPORT
Section 4.1

Grant Agreement number:	**FP-285030**
Project acronym:	**MEGAFIT**
Project title:	**Manufacturing Error-free Goods at First Time**
Funding Scheme:	**Large-scale Integrating Project**

Date of latest version of Annex I against which the assessment will be made:

	21/10/2013
Periodic report:	**Final report**
Period covered:	**from 1 December 2011 to 30 November 2014**

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1 Final publishable summary report

1.1 Executive Summary

This report summarizes the results reached in the FP7 FoF project MEGaFiT. The results were achieved by 17 partners from 6 countries in the period from December 2011 to November 2014. The MEGaFiT project had the primary goal to develop and integrate all necessary technologies which create the basis to reduce the number of defects in manufacturing of complex high-precision metal parts.

Background

The goal of reduction the number of defects is driven by several observed trends. These trends were identified before the project started, but in fact are still applicable. The trends on the manufacturing of complex high-precision metal part can be summarized as follows:

1. The process typically involves many complex multi-step process chains. However, still excessive and expensive finishing processes are needed in order to acquire the final specifications.
2. The defect rates are high, typically between 1-15%, resulting in high cost prices.
3. There is a continuous trend for more demanding specifications (higher quality, smaller features, lower costs), while simultaneously batch sizes decrease and product variety increases. This results in a smaller number of identical products, which in turn hampers the build-up of experience.
4. The current approach to increase process robustness by applying the well-known Six-Sigma methodology to reduce defects is exhausted for these types of manufacturing processes, due to process and part complexity. A next breakthrough is needed for further defect reduction.

The MEGaFiT project aimed to create a breakthrough to face today's global competition. This breakthrough is established by applying adaptive process control. Adaptive control is needed in situations where uncontrolled fluctuations occur which result in defects. It adjusts the process system by a control law in order to cope with these uncertainties. Adaptive process control has been applied successfully in other industries. This report summarizes the development and applications at a different length scale in manufacturing: micro-forming and additive manufacturing, both focussing on the goal of zero-defects manufacturing.

Results

In order to reduce the number of defects by adaptive process control, the relevant process variables and interactions were identified. As this was time-consuming, costly and difficult on the physical manufacturing process, this was performed on numerical models (WP3). However, as the numerical models are too time-consuming for evaluation by the real-time in-line process control, the main interactions identified in WP3 were captured in metamodels that are easy-to-evaluate (WP4). Fast in-line measurements were developed to feed the control system with real-time information (WP5). To make adjustments in the process, actuating mechanisms were developed and the metamodels were implemented into the process control unit (WP6). All above developed knowledge and systems were integrated into the two pilot production lines in industrial settings to prove the approach to fulfil the main goal of reducing defects (WP7).

Depending on the application, these results can be applied on process lines yielding to a reduction of:

- defects from 5-15% to below 1%,
- cost by at least 20%,
- material and energy consumption by at least 20%,
- number of finishing operations by at least 35%,

and, therefore, meet the objectives as defined in the proposal.

By sharing the approach via education, products, equipment, software and implementations, the results become available to other businesses within Europe (WP8) to bend the trends towards a competitive and sustainable European manufacturing industry.

1.2 Summary description of project context and objectives

The MEGaFiT methodology was deployed on 2 process lines. For both process lines, various advances beyond state-of-the-art are listed in the description of work. In the following table, these aspects are listed including the project outcome (Table 1). The tables show many positive results. Two of the items can only be proven on one of the process lines (Microforming). For Additive manufacturing, the state-of-the-art defects were an underestimate of the actual defects (about 30%). An improvement was achieved to below 5%. Due to this, also the proposed finishing improvement could not be shown.

Table 1 – MEGaFiT advances over the State-of-the-Art and the project result (Legend: + met; / partly met; – not met)

Area	Parameter	State-of-the-Art	MEGaFit advances over State-of-the-Art	Met
Defects and quality	Defect rate	5 - 15% for involved manufacturing partners	<1%	/
	Quality	Finishing needed to achieve required accuracies	Less finishing operations needed because of enhanced product quality	/
	Quality methodology	Six-Sigma is exhausted	Adaptive process control	+
In-depth process understanding	Pre-processing prognosis	Numerical models only of part of the process chain and with limited accuracy	Based on knowledge-based 3D numerical models of process chain	+
Model based knowledge systems	Metamodel	Based on numerical models	Continuous improvements based on measurement data	+
Real-time process control	Rejection/ acceptation	Rejection of complete batches	Adjust the process to avoid rejection, based on the actual state	+
	Process control	Process adjustments by hand (open-loop)	Automatic adaptive process control (closed-loop) based on actual sensor data; non-linear control concepts; model-based control	+
	PLC	PLC with fuzzy logic capabilities	Combine PLC and self-improving metamodels	+
In-line measurement	Geometrical measurement	2D, 2.5D	3D features	+
	Geometry completeness	Missing areas due to high gradients	Complete acquisition of 3D features	+
	Measurement concept	Post-process measurements	In-process measurements	+
	Measurement sampling rate	Sampling 1 out of 1000 parts (measurement time ~minutes)	Measure every product (measurement time << 1 second)	+

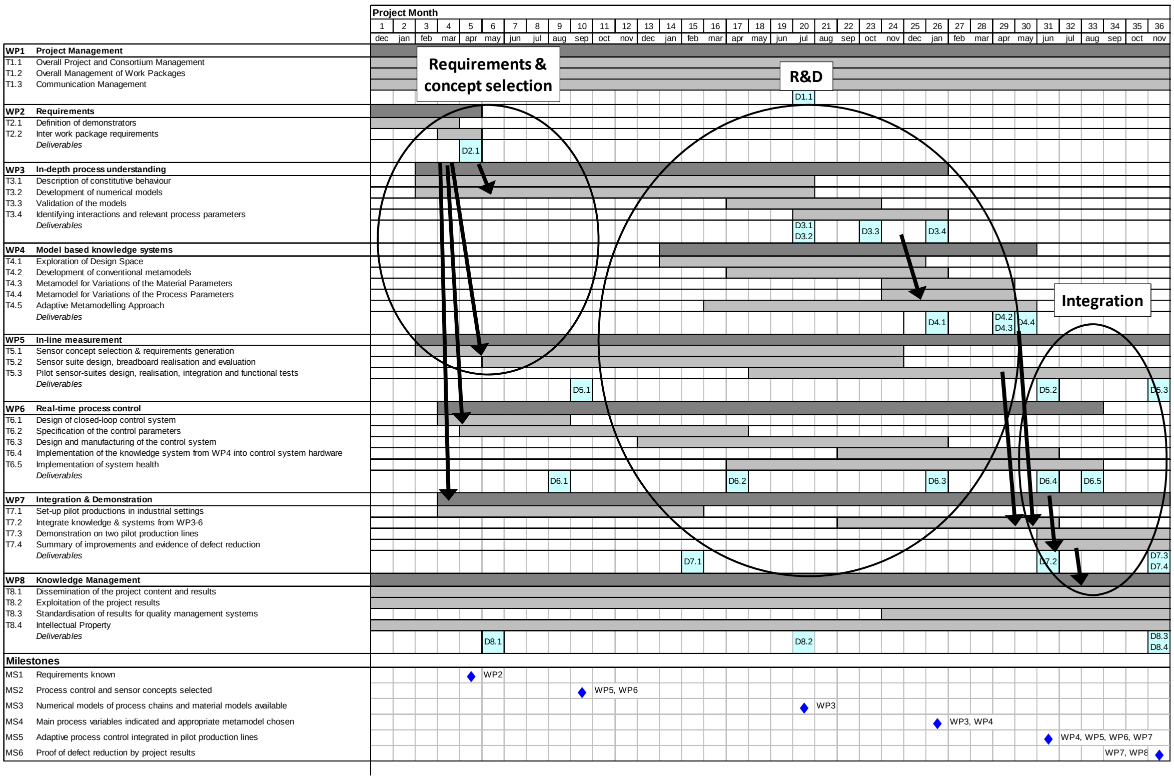
1.3 Description of main S & T results

1.3.1 WP1: Project Management – Overall description

Overview

The project was performed according to plan (see Table 2). The internal review process of all deliverables was scheduled one month before the due date to ensure high quality. In some cases, deliverables were internally preponed to balance the workload among the team.

Table 2 – Project planning



Risk assessment was a key tool in this project. It showed many high impact risks early in the project. Active mediation of the many risk could reduce the delay of D6.4 and D7.2 to only 2 weeks.

Problems which have occurred

The unforeseen exit of CRF left the team with no longer allocated activities that are needed for achieving MEGaFiT's goals. Several partners took the responsibility to fill the gaps. The modification was formalized in Amendment No 1.

Co-operation with other projects

The MEGaFiT team cooperated with the other 3 zero-defect projects which have received funding the Theme FoF.NMP.2011-5 "Towards zero-defect manufacturing". The other projects are: MIDEMMA, IFACOM and MUPROD. The coordinators of the 4 zero-defect projects presented their cluster initative, called 4ZDM, at the FoF Impact Workshop on March 11-12, 2013. A zero-defect manufacturing cluster CSA (FoF7) has been successfully submitted by the 4ZDM coordinators.

Conclusion

Solid results were delivered by a close cooperating team.

The following is a description of the most important results per workpackage:

1.3.2 WP2: Requirements

Objective

The objective of WP2 was to describe the industrial carriers for the involved industrial partners and define 2 demonstrator processes that represent the main challenges in these carriers. For these demonstrators, the quality parameters were determined and possible failure mechanisms were identified. An estimation was given for the 'current' defect rate and a goal established for the target defect rate. Critical parameters for in-line measurements had to be selected and were related to the required accuracy for in-line measurements. The interfaces between different work packages were specified with reference to the required accuracies.

The WP consisted of the following tasks:

- T2.1 Definition of demonstrators
- T2.2 Inter work package requirements

Results/Innovations

In the first 4 months of the project, the industrial carriers were defined by the 4 industrial partners (Philips, Rihs, SIE and CRF). Subsequently, 2 demonstrator products and processes were defined that include the typical properties of the carriers.

1. A demonstrator for Additive Manufacturing (AM), representing a control wheel turbine blade, was defined by SIE and TUHH. The selected process is Selective Laser Melting.
2. A demonstrator for Micro Forming (MF) was defined by Philips, Rihs, CRF and reviewed by UT, ETH and LFT. This demonstrator product is a dummy product, produced by deep drawing, bending and micro forging. It combines the relevant properties of the carriers for Philips, Rihs and CRF. The product is produced both in stainless steel and in a copper-beryllium alloy, in order to represent the carriers of the industrial partners.

For both demonstrators, defects and specifications were defined, drawings were prepared and possible in-process measurements and controls identified.

The dependencies between Work Packages were described. All partners and especially the Work Package Leaders were involved. For every Work Package, the essential input from other Work Packages was described in a dependency matrix.

Conclusion

Work Package 2 was finished in April 2012 with the completion of deliverable D2.1 "Specification of demonstrators and inter work package requirements". In the sequel of the project, the definition of requirements and inter-work package relations proved to be very useful in communication between the partners.

1.3.3 WP3: In-depth process understanding

Objective

In order to realize zero-defects by in-line real-time process control, interactions between critical-to-quality aspects, relevant process variables and noise variables needed to be identified. For this reason, in-depth process understanding and knowledge were indispensable. The objective of this workpackage was to gain this knowledge and make it accessible for other workpackages to enable process control.

The WP consisted of the following tasks:

- T3.1 Description of constitutive behaviour
- T3.2 Development of numerical models
- T3.3 Validation of the models
- T3.4 Identifying interactions and relevant process parameters

Results/Innovations

In T3.1, the constitutive behaviour of the used materials for the two processes was captured. For the Microforming process (MF), novel test methods were deployed by UT and ETH to characterize the kinematic hardening. The role of friction was characterized by LFT and the bulk of the tests were performed by Philips. For the Additive Manufacturing process (AM), Scanning Electron Microscope analysis were made on AM produced samples to characterize the melt pool, voids and phases. The results of the AM and MF analysis were transferred to the other tasks within this workpackage.

In T3.2, The numerical models were developed. These models needed to cover the important aspects of the process. For both demonstrators, 3D numerical models were made. These numerical models included the knowledge of T3.1 (see Figure 1). Next, the numerical models needed to be validated. For both demonstrators, a large set of experiments was made in order to quantify the predictability of the models. This resulted in a modified approach for the Additive Manufacturing process for the identification of interactions and relevant process parameters (T3.4). In this case, samples were made to characterize the process and its interactions. For Microforming, the developed models were used to identify the interaction.

The results were achieved in close cooperation with WP4.

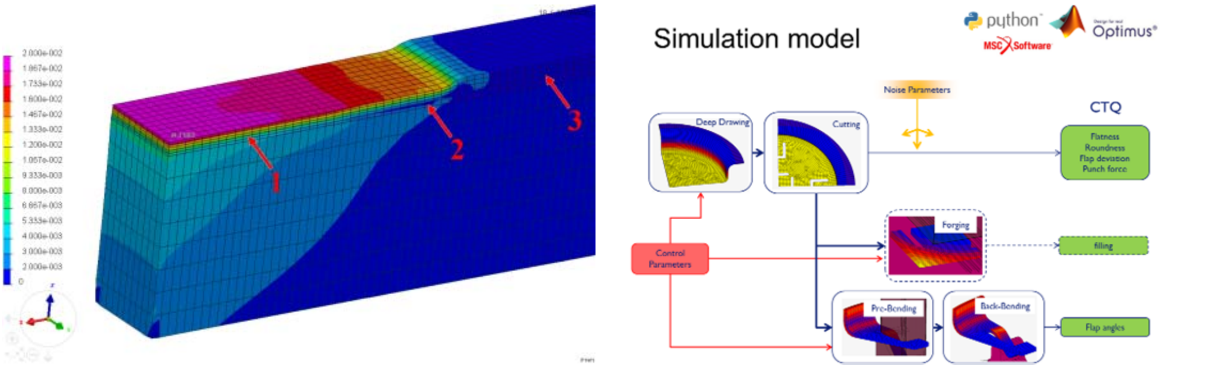


Figure 1 – (left) simulation of the shrinkage behavior during the Selective Laser Melting process; (right) the automated simulation steps for the Microforming demonstrator.

Conclusion

Work Package 3 was executed according to plan. The gained knowledge was captured in 4 reports. The developed automation of the models by UT made them available to other workpackages and enabled a smooth transfer of the results. Several methods were implemented in the commercially available solver MSC.Marc. Support was given till the end of the project.

1.3.4 WP4: Model based knowledge systems

Objective

Within WP4, metamodels had to be developed which capture the interaction between the quality, noise and control parameters, see Figure 2 below. Finally these models had to be integrated into the process controller to realize adaptive process control. Therefore, the WP consisted of the following tasks. In task 4.1 the design space was investigated. Screening studies, using the simulation models from WP3, and several experimental test session helped to investigate the process behaviour and the sensitivity of each input variable on the system response. Task 4.2 contained the generation of the metamodels. This followed a general procedure consisting of DOE, fitting, accuracy quantification and interpretation. The approach, how the models are used for control, was developed in this task too. Task 4.3 / 4.4 handled the identification of the most sensitive parameters regarding material and process. Several experimental test sessions were performed as well to analyse the discrepancies between simulation and experimental results. The last task 4.5 covered the development of adaptive metamodels approaches and their implementation into the control system hardware.

The WP consisted of the following tasks:

- T4.1 Exploration of Design Space
- T4.2 Development of conventional Meta-Models
- T4.3 Meta-Model for Variations of the Material Parameters
- T4.4 Meta-Model for Variations of the Process Parameters
- T4.5 Adaptive Meta-Modelling Approach

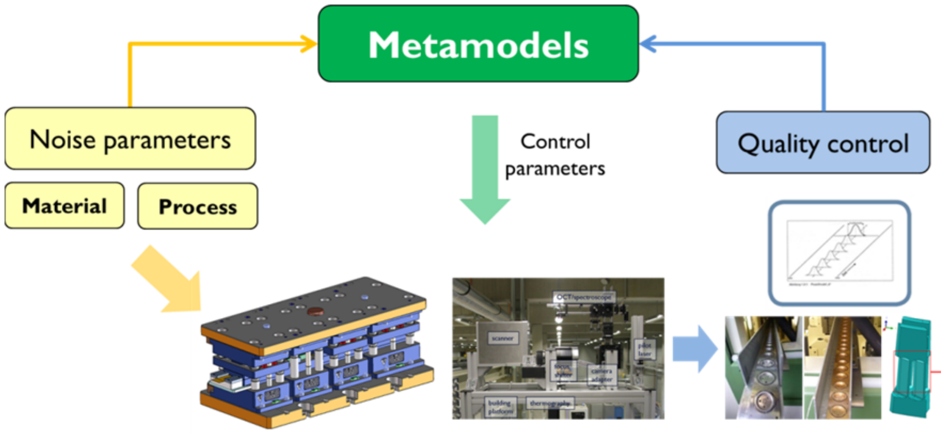


Figure 2 – Control approach for both demonstration lines

Results/Innovations

The process control step particularly benefits from the different measurement systems as well as from the simulation models and the metamodels developed. The control approach in fact adopts feed-forward techniques that significantly improve the process control approach and, based on different strategies, contribute to the achievement of the nearly zero defect manufacturing goal set by the project.

The simulation models from WP3 have been integrated into a single and uniform platform. The platform has been extended to support interfacing with PLC hardware. The new approach has been made interoperable with the control approaches developed, thus allowing a tight and smooth operation of the control algorithm, of the PLC tool and of the metamodels created. This extension has been successfully deployed and tested.

To explore the design space for numerical models in the most interesting and relevant regions, a development of an adaptive exploration technique has been successfully completed. This approach minimizes the number of samples needed with respect to other classical design exploration methods. This technique, using proper sampling and modelling techniques, can build the best possible accurate metamodels based on the available data. The data that can be used may be experimental (e.g. coming from sensors) and/or numerical (e.g. coming from simulations).

Conclusion

Work Package 4 was executed according to plan. The gained knowledge was captured in 4 reports. To gain in depth knowledge about the process behaviour, a screening study with numerical models is important. By using simulations it is possible to change a specific process parameter, while keeping other influencing factors constant. That is a major advantage compared to real tests, where it is nearly impossible to realize such a kind of study.

The developed approach for control is completely general and could be applied on both demonstration lines. Moreover, the use of the metamodels developed in WP4 goes beyond the use for the control approach only. These models were also used for the design of the control algorithms. In this "testing environment", different strategies and noise scenarios were evaluated and refined and finally implemented before testing in reality.

1.3.5 WP5: In-line measurement

Objective

The objective of work package 5 was to develop sensor-suites for both pilot production lines. The sensors should allow 'real-time' production-line control, augmented by overall quality verification on every N-th product. This means that in addition to developing suitable sensors, calibration has to be assessed and near real-time data post-processing needs to be in place.

The WP consisted of the following tasks:

- T5.1 Sensor concept selection & preliminary requirements
- T5.2 Sensor suite design, breadboard realisation and evaluation
- T5.3 Pilot sensor-suites design, realisation, integration and functional tests

Results/Innovations

For the additive manufacturing process line, a thermographic camera and a RGB sensor were obtained and integrated in an existing additive-manufacturing setup. Dynamically adapting the exposure strategy based on workpiece temperature allows for the minimization of internal stresses in the product. The RGB sensor data is used to assess the quality of the meltpool. A separate development is the OCT galvo-scanner system which is capable of measuring e.g. powder bed topology, allowing the early detection of defects.

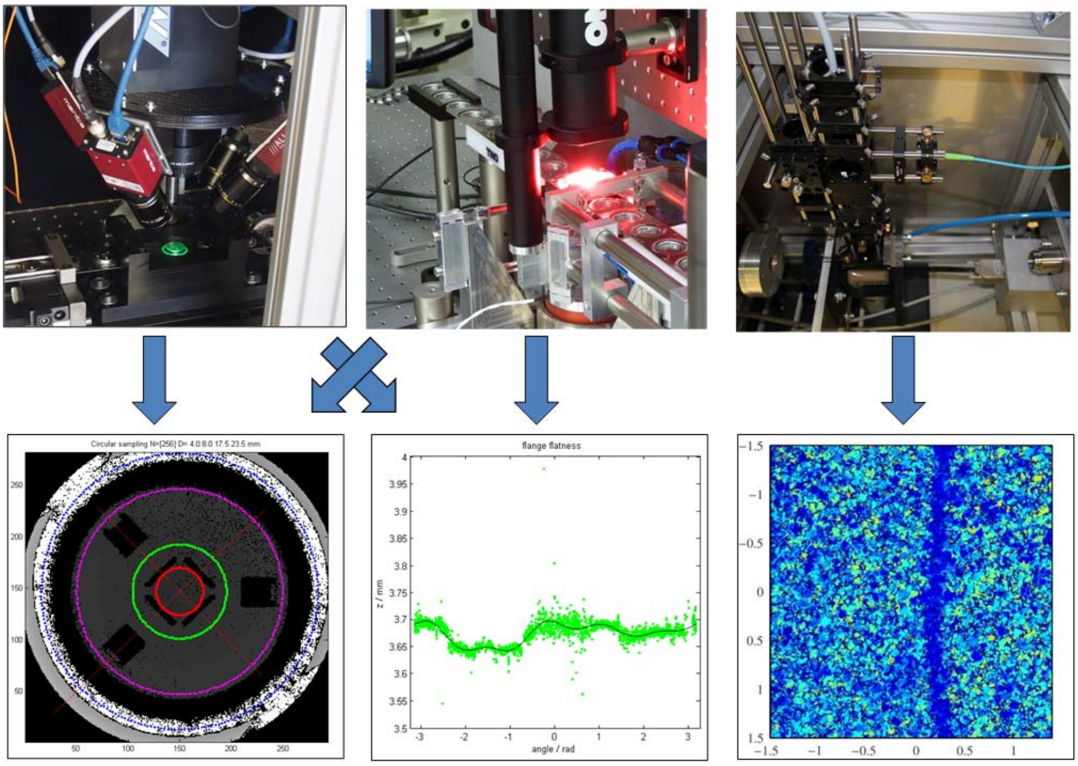


Figure 3 - Major sensor systems and typical results; Fringe projection system (left); video-rate OCT sensor (middle); galvo-scanner OCT (right)

For the microforming pilot line, two separate advanced systems were developed for measuring the geometry of the demonstrator product. The video-rate OCT sensor is capable of 100% product inspection. Almost 2 orders of magnitude faster than existing systems, the sensor is be able to generate a 3D point cloud of the surface of the demonstrator object and extract quality parameters from this data in half a second. The fringe projection system is capable of a more accurate 1-in-n product inspection. Using multiple cameras, the system is able to measure at high lateral resolution and at high surface angles. A custom microscope for measuring the bending angle was also developed. Calibration strategies were devised and executed for both the OCT and fringe projection systems.

Conclusion

Work package 5 was executed according to plan. After assessing the measurement requirements, several novel sensor concepts were defined. Sensors were tested in a breadboard setting and then further developed into pilot sensors. Extraction of critical-to-quality parameters from the raw sensor data was implemented, enabling the control system to steer the manufacturing process. Calibration strategies were defined for each novel sensor system, allowing for measurement values to be traced to standard. Results were captured in 3 deliverable reports. A patent application was filed, with a second under preparation.

1.3.6 WP6: Real-time process control

Objective

The objective of WP6 was to develop and implement real-time process control systems applicable to the two demonstrator production lines that have been defined within WP 2. At first, for the two pilot processes the system architecture with all involved parameters had to be designed (Figure 4). Especially, the impact and interaction of the control parameters that manipulate the processes was investigated. After setting up the control system hardware for both lines, the metamodels and control strategies were implemented into the systems, in close cooperation with WP4. In order to detect sensor or signal errors, a health system was added to the control system.

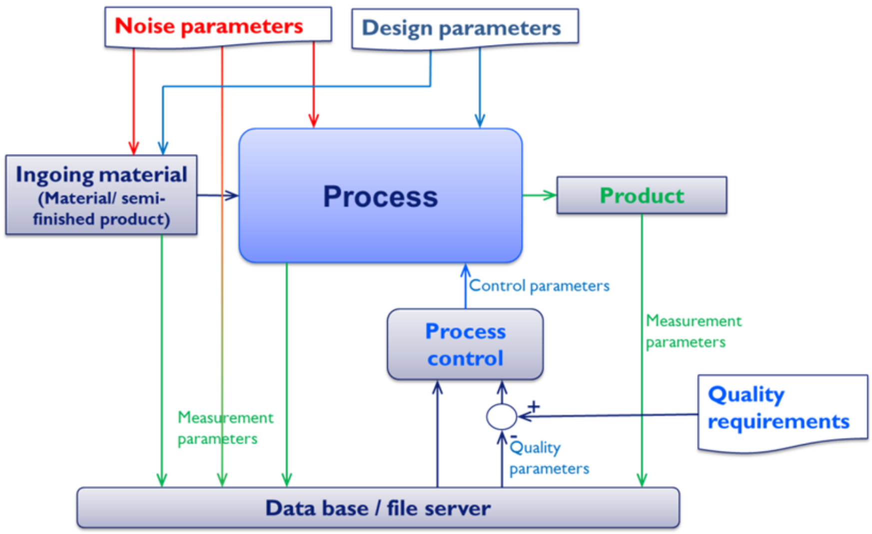


Figure 4 – Control design with parameter definition

The WP consisted of the following tasks:

- T6.1 Design of the closed-loop control system
- T6.2 Specification of the control parameters
- T6.3 Design and manufacturing of the control system
- T6.4 Implementation of the knowledge system from WP4 into control system hardware
- T6.5 Implementation of system health

Results/Innovations

For both demonstrator lines, open systems have been developed that enable metamodel based process control. For the AM process, a control strategy was defined that consists of three control cascades. The AM test rig was implemented with the real-time control system XPC that is able to reach fast control cycle times of up to 50 µs. This enables a valuable control within the inner control cascade controlling the laser power. The control ability has been shown on a closed loop control with a RGB sensor, and the controller manipulated the laser power in a way that the control deviation decreases.

The developed cascade 2 control exceeds the state of the art AM process control and demonstrates new approaches of optimizing temperature fields within the printing process for reduced thermal stresses and part deformations by an OCT sensor with a data acquisition rate of up to 70 kHz. The communication between the sensor systems, XPC and main PC was established. Thus, an automatic data acquisition during the SLM process is possible.

The test rig for the MF process was realized within a software PLC running on a Windows environment. A real-time control system with the required hard- and software applications has been developed for the test rig. A UDP metamodel server allows the control algorithm to use the models in the PLC and updates these metamodels using experimental data at fixed time intervals.

A real-time control can be reached with the system and has been validated during tests. The control ability and defect reduction has been shown on a long term test. Furthermore, a system health monitoring was integrated into the MF demonstrator process.

Conclusion

Work Package 6 was executed according to plan. The gained knowledge was captured in 5 deliverable reports. For both demonstrator lines, a suitable control strategy could be added to the processes. These open systems enable intelligent metamodel based control methods and offer the possibility to adapt the models and strategies easily when needed.

1.3.7 WP7: Integration & Demonstration

Objective

As a main objective of the MEGaFiT project, two pilot production lines were developed and established, one on Additive Manufacturing (AM) and one on Micro Forming (MF), whose purpose it is to prove the project results to the outside world. Hence, it was the major objective for WP7 to set-up these pilot production lines, integrate all MEGaFiT components and demonstrate their functionality. This comprises especially the functionality of the control mechanisms and proof-of-concept of the MEGaFiT components which will lead to the reduction of defects in producing real products. In order to achieve this objective, the following approach – divided into four consecutive tasks – was chosen:

- T7.1 Set-up pilot production processes in industrial settings
- T7.2 Integrate knowledge & systems from WP3-6
- T7.3 Demonstration on two pilot production lines
- T7.4 Summary of improvements and evidence of defect reduction

Results/Innovations

All efforts in tasks T7.1 through T7.3 led to the successful installation of both pilot production lines for AM and for MF as shown in Figure 5. The main innovations for the AM line were implementations of sensors such as a thermal camera for optimum distribution of laser energy, an RGB sensor to control laser beam power and an OCT sensor for detection of deep penetration welding which were all never used before in according equipment. For MF, the main innovations were the introduction of an inline coil strip thickness measurement, an inline 3D-camera system for flap angle measurement, an offline 3D-camera system for geometrical measurement and an integrated Health Monitoring System (HMS).

Figure 5 – Both demonstration lines in their final state: (top) The Additive Manufacturing process and (bottom) the Microforming production line.

For both pilot production lines, it could be demonstrated that the online and/or inline measuring system allow adaptive, closed-loop process control as verified by dedicated methods for proof-of-concept. In both cases, this proves great potential for increase of product quality, decrease of defective parts and hence, an overall reduction of costs.

Conclusion

The improvements for AM comprise a reduction of post processing as well as production time and lead to an overall of 25% cost savings with scrap rates less than 5%. For MF, it could be shown that the defect reduction by inline measurement and the HMS even lead to scrap rates below 1%.

1.3.8 WP8: Knowledge Management

Objective

Main goal of WP8 was the coordination of the communication with the scientific world and all the public interested on MEGaFiT and the topic of zero-defect manufacturing, spreading the acquired knowledge and showing the possibility of transferring the results to various industrial applications. The dissemination of the project results was therefore of primary importance and publications in scientific journals as well as all the possibilities of the internet were used.

The project results, in order to be exploited, were first of all identified either as commercial product or as important development of a company know-how. Also, the protection of the acquired knowledge through patenting was considered.

Finally, a guideline was produced in order to ease the transfer of the project results to other applications and production chains within the European community.

The WP consisted of the following tasks:

- T8.1 Dissemination of the project content and results showing the impact on different industrial applications
- T8.2 Exploitation of the project results
- T8.3 Standardization of results for quality management systems

Activities

The knowledge management consisted of many aspects. In the first stage of the project, a website was setup. It acted as an electronic shop window for zero defects manufacturing project including advertising conferences and workshops with consortium participation. During the project, dissemination was addressed via other channels, like 6 scientific publications and 28 communications at conferences and fairs. At the universities, the educational program was adapted to include the MEGaFiT experience. Additionally, several Bachelor and Master theses concluded or still going on, on the MEGaFiT topic.

Within this work package, coordination and planning of exploitation was performed. This included two exploitation strategy seminars. This led to the production of the Plan for Use and Dissemination of Foreground, in which 9 exploitable results have been identified as well as areas of direct use of project results. One remarkable fact is 1 approved patent and 1 patent request pending.

To strengthen the impact of MEGaFiT, several joined activities were performed within the Clustering initiative 4ZDM with other 3 European projects dealing with the topic of zero-defects manufacturing.

The MEGaFiT methodology was captured in the final deliverable: "Production of a guideline for reducing manufacturing defects".

Conclusion

The dissemination and exploitation of MEGaFiT have successfully spread the knowledge produced within the project in the scientific community as well as in the industry. The planning of the exploitation strategy helped the partners in focusing on a reduced and selected number of exploitable results. New products, patents and follow up projects show that this approach has been successful.

Finally, besides journal papers and conference speeches, the produced guideline represents baton for new applications and further development of the MEGaFiT approach, easing the implementation also in other business cases.

1.4 Potential impact and main dissemination activities and exploitation results

1.4.1 Main dissemination activities

Efforts to involve other actors and spread awareness

On top of the publications and presentations, the following aimed to actively involve other parties in the field of Industry 4.0:

- MEGaFiT actively participated in the 4ZDM cluster, i.e. presenting the cluster at the HLG Manufuture meeting on November 5, 2013 in Mannheim and a poster on the Regional Industrial Workshop Fabricación "Zero" Defectos (ZDM) in Donostia-San Sebastián - Gipuzkoa (Spain).
- The MEGaFiT project has been presented by Remco van Ravenswaaij at the IDDRG 2013 Conference and the Micro-forming Industry Workshop in Bremen on November 13, 2013.
- The Dutch Ministry of Economic Affairs has invited TNO to demonstrate the fast OCT sensor setup on the Hannover Messe (the biggest event for industry), as a real-life example of successful cooperation for the benefit of EU industry. The sensor was successfully demonstrated there. Talks were given to many representatives from industry, as well as the Dutch ambassador to Germany and to the Dutch minister of economic affairs Mr. Henk Kamp. On the event, Philips and TNO presented at April 9th 2014 a shared presentation.
- The MEGaFiT methodology was shared at the Industry Colloquium in Zurich on October 9th 2014 with the focus at Industry 4.0.

1.4.2 Exploitation results

Exploitation of the project results was key for all partners. In the Description of Work (DoW), an estimation of the project results was made. In Table 3, both are summarized per partner.

Table 3 - Overview of the exploitation as defined in the DoW compared to the end of project exploitation

Exploitation results as defined in the DoW	End of project exploitation

LFT	Dissemination and exploitation of MF achievements to industry and research:
	• Further step in understanding the particularities in microforming by applying knowledge on industrial process
	• Important contribution for further research on microforming
	• Introduction of new contents to lectures on microproduction technologies e.g.
	  • "Mikroumformtechnik"
	  • "Maschinen und Werkzeuge der Umformtechnik"
	  • "Sonderthemen der Umformtechnik"
	• Contributions to conferences

ETH's spin-off *3R-technics* will take advantage of the data for the validation of its regression models.	FEM models & control algorithms dissemination and application in in-house Q-Guard system. Additionally: • Valuable know how for other similar projects has been generated • Dissemination of results at conferences, workshops, etc. • Use of identical approaches for the quality control of further forming processes
UT	• Contributions to conferences and workshops

<table>
<tr><th>Exploitation results as defined in the DoW</th><th>End of project exploitation</th></tr>
<tr><td></td><td>Enhanced visibility leads to invitations to participate in follow-up research projects
A Master’s project is starting on representation of measured data for control</td></tr>
<tr><td>BIAS will use the demonstrator results to show fast 3D-measurement of complex objects for marketing with the goal to be recognised as a partner for individual measurement solutions. In addition BIAS will transfer the results together with an VEW to a new fast and flexible 3D-measurement system that will become available to the European manufacturing industry.</td><td>Fringe Projection 3D measurement system:
Development of commercial fringe projection systems for the industry
Acquire research grants based on the achievements
Control:
Transfer of software PLC programs to further monitoring and control applications
Adaption of software PLC knowledge to further research projects
Collaborative research centers (SFB747) follow-on tool project at BIAS benefits from Beckhoff PLC by use of an measurement system based on MEGaFiT measurement system structure</td></tr>
<tr><td>Rihs The results of this project will have a high impact of the existing volume production. The production and assembly processes will be optimised through lower defect rates. This will help to achieve a competitive and sustainable production in a high price country. We expect – just in the field of the Multilam high voltage connectors - annual savings between 300 kEUR.</td><td>To control the cutting-force
To achieve a high quality of products is a preventive maintenance desirable. Through the measurement of cutting forces, premature wear or even a cutter break during the process can be automatically detected.
Hydraulically controlled blank-holder
Experience from the deep-drawing process can be derived for example on the production of watch parts or also for various electronic components.
Bending and back bending
At E.Rihs many different springs for electrical contacts are made. These must always demonstrate a defined height. Through various influences (material, environmental), these often have to be adjusted manually. By automatically setting, the process reliability can be significantly increased.</td></tr>
<tr><td>TNO: High throughput 3D sensors are a new product line for the industry and TNO next to the current product portfolio of 2D sensing methods. The MEGaFiT project will position TNO in the forefront of the technology that will consequently be applied in other domains such as 3D integration of semiconductor chips within the semiconductor production It is expected that industrial 3D sensing will create at least 10 full time research positions at TNO. TNO expects to apply most of the knowledge gained in MEGaFiT to other products and applications e.g. in the production of integrated semiconductor devices/systems and in follow-up project, which ensures application in more</td><td>Fast 3D OCT is suitable for a broad range of in-line inspection applications.
Benefit for TNO:
Justification: tangible example of fulfillment of designated TNO role to support industry with applied R&D
Income from projects to further develop in-line inspection technology
Aiming at 10 FTE extra on in-line inspection in the next 2-3 years.</td></tr>
</table>

Exploitation results as defined in the DoW	End of project exploitation
industrial sectors.	
SIE/SCR will exploit the project's result by improving existing processes and manufacturing systems. Implement new machine standard with results from the project will strongly reduce defects, resulting in an annual saving of 3 MEUR. Extend use of additive manufacturing for more products after higher requirements can be met due to the product results.	Aiming to transfer the MEGaFiT results to 1 or 2 OEMs to enable: • Results are expected to have impact in a variety of products, e.g. turbomachinery equipment, railway components, healthcare imaging device parts as well as tools for manufacturing • On the service side, the results will foster service business, i.e. specifically spare parts business for the above mentioned applications • Only with the scrap reduction achievable with MEGaFiT many use cases become economically viable
TUHH will use the results of the project for further developments in the field of additive manufacturing as well as for education purposes. As there is a close cooperation with spin-off LZN and regional and supra-regional companies there will be a fast transfer of research results in industrial process chains and thus industrial benefit. By innovations of the project in terms of improved product quality the industrial application of additive manufacturing/laser melting technology will be expanded both national and on an European level. The control software can be offered as a free or commercial toolbox which can be implemented in commercial software (eg Matlab, PLC).	Introduction of new contents to lectures: • "Laserproduktionstechnik" • "Laser Systems and Process Technologies" • "Rapid Production" Contributions to conferences Enhanced conditions for public funded and industrial follow-up projects due to developed versatile test rig: • research on new materials • developing new exposure strategies • understanding the process transfer of results to industrial process chains
PRC's exploitation activities will be performed during final phases of the project and for a period of at least one year after the end of the project aiming to create maximum benefit. Commercial exploitation relates to all cross-functional exploitable results of MEGaFiT. Precitec will encompass sales activities for products manufactured with the know-how of the developed technologies via trade fairs and exhibitions to address and acquire new customers by presenting new products and innovations manufactured with the MEGaFiT technologies the marketing and sales channels of Precitec publications issued by Precitec and/ or the technology network of the RTD performers active participation in industrial seminars and networks to communicate selected exploitable results.	• Precitec will continue the cooperation with LZN to further develop the sensor device and the performance • Precitec will get in contact with machine suppliers to discuss their interest with respect to the applicability of the sensor into commercial systems • The approach of MEGAFiT can be transferred to other laser processing applications with galvo-scanners • Additional sales about 0.5 to 2 M€ per year
UniHB The engineering of closed-loop control systems depends on an in-process measurement, which is only used in a few fields. This project offers an exemplary application of the new technology. The methods of closed-loop (quality) control, which will be developed within this project, can be easily adapted to	• Transferring the process control knowledge to further applications and projects • Enhancement of the control strategies for selective laser melting machines (in follow-up project) • Further scientific / methodical development of model based control applications (e.g.

Exploitation results as defined in the DoW	End of project exploitation
other types of processes. The bottleneck will be an adequate in-process metrology to close these control loops for different processes. This will result in future research needs in the field of in-process metrology, which can be performed by BIMAQ. Furthermore, the results affect the teaching of the University of Bremen and influence young academics.	different types of metamodels) • Optimization and extension of self-learning strategies • Integration of the developed methodology into lectures, student projects and theses
NOESIS will exploit the results of the project in its software and services for addressing requirements of functional performance engineering in industrial contexts. More specifically, this includes the optimisation methodologies developed for material property assessment, the enhancements to the integration framework component into OPTIMUS (integrated software for engineering process management and multi-attribute optimisation). It is expected that this innovative product design tool will extend the capabilities of current engineering tools and support improvement of functional performances in engineering disciplines.	Exploit in product: Adaptive DOE and modeling • Software prototype is being industrialized • First part (Adaptive DOE) is getting extended beyond MEGaFiT results to be ready for next Optimus release (10.16, expected Q1/2015) • Second part (Ensemble modeling) is being finalized and will be planned for release in the product in Q3-Q4/2015 • Deploy at customer site for CAE Extend deployment possibilities in manufacturing process control industry (new opportunity)
S&T sees this project as one of the major vehicles to transfer data analysis techniques from the space and science market to a more industrial market, where applications are foreseen to optimise the use of machineries. Based on their experience in the space & science market, a market opportunity of at least €1.5M is expected. A toolbox to monitor production equipment for off-nominal behavior and predictive system health management will be developed which will be used to develop similar products as for the Megafit project;	• An alpha version of the System Health And Performance Monitoring (SHAPE) platform has been developed through the MEGaFIT project. • Analysis algorithms/routines for vibration analysis have been developed and added to the software "toolbox" for future projects. • A prototype data management and plotting tool will serve as a template for future applications. • Experience and training in the use of several unique communication protocols was gained and will serve in future projects.
VSL, as a national metrology institute, will help the industry with its current and future needs. VSL foresees that in the near future fast, accurate, dynamic, real-time and in-line measurements will become of growing importance for the process industry. VSL plans to extend its services on these dynamic, in-line measurements. The current proposal will help VSL to further build technical knowledge in this field.	• Traceability concept can be used to provide tailored services to customers for similar inline measurement systems • Knowledge from MEGaFiT will be used as input for further research projects
VEW, The integration of VEW into a European project opens up new vistas for the market of optical metrology for the company. Because the number of units of optical measurement equipment is not very high, only the access to the European market allows for the development of new technologies and the corresponding measurement systems.	• Development of commercial fringe projection systems for the industry • Integration at Philips in one or more production lines after having reduced the measurement time • With Philips as pilot acquisition of other customers

1.5 Address of project public website and relevant contact details

At the beginning of the project, a public website has been established (www.megafit-project.eu). The website contains two parts, a public part and a consortium only part. The public part gives an overview of the objectives of the project and is used to inform the public of the progress of the project. It contains project news, aims, and progress updates, in addition to an overview of the partners, dissemination and links.

The consortium only part was used for internal communication, storage of submitted deliverables and reports, exchange of data and reporting within the MEGaFiT project.

After the amendment, the MEGaFiT consortium consisted of 16 partners from 6 countries:

Beneficiary		Name	e-mail
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16	VSL	Marijn van Veghel	MvVeghel@vsl.nl
17	VEW	Christoph v. Kopylow	VEW-GmbH-Bremen@t-online.de

At the beginning of the project, the Italian research institute Centro Ricerche Fiat (CRF) was part of the consortium. CRF exited the consortium by October 31st 2012.