COOP-CT-2004-508220

ICACOST

Individually configurable, automatic cost calculation system for 3-d laser cutting

Co-operative research projects

Horizontal Research activities involving SMEs (CRAFT)

Publishable Final Activity Report

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Project coordinator name: **Dr. Andreas Ostendorf**
Project coordinator organisation name: **LASER ZENTRUM HANNOVER e.V.**

Report version 1

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1. Project execution.

The objective of the ICACOST project was to develop an individually configurable cost calculation system for SMEs of the sheet metal industry. This tool shall support the offer cost calculation and negotiation process. Especially the calculation of the machining time, the fixture costs and a feasibility check per workpiece are in the focus of interest. Therefore, tools such as the 3-d viewer, the characteristic number generator, the machining time calculation module and the cost estimation module for fixtures were developed.
Also, an inquiry, offer and order administrating standard form, based on a database with plausibility check functions was integrated. These objectives were completely achieved during the ICACOST project. They are summarized within the table 6.1.1.

Objectives	Content
1. 3-d viewer	*Visualisation and definition of tool paths and positioning paths in CAD files*
2. Characteristic Number Generator	*Analysis of CAD files for an expenditure representation concerning 3-d laser cutting*
3. Machining time calculation module	*Calculation of machining time based on the process parameter database*
4. Cost calculation tool	*Maintenance of relevant business factors for the 3-d laser cutting. Cost calculation of offers based on a standard form and business database*
5. Fixture cost estimation module	*Estimation of fixture costs based on the fixture parameters database*

Table 6.1.1: Main Objectives

Nowadays a quick and reliable production planning and offer calculation is in the focus of interest. Not only the branch of laser cutting requests this kind of software tools, also other branches. For example a quick planning software tool for moulds in the branch of casting was developed. This tool is also used for a structured offer calculation. (cf.: www.impc.rwth-aachen.de) Similar ideas were done for deep drawing tool manufacturers.

Other research activities try to explore general characteristic numbers to describe complete manufacturing systems. Also other software products to calculate offers were developed and available into the market. Please see: Digital – cost mock up system of Facton GmbH or the CALCUMAX application of Megatech Software GmbH. Therefore, the ICACOST project follows the trend of developments and improves the state-of-the-art concerning the cost calculation for the field of 3-d laser cutting. In general each contour cutting process can be supported, also water jet cutting, flame cutting and laser welding. The ICACOST project is still interesting because of a lack of similar calculation tools, which can perform the tasks of ICACOST. Reviews of the market have shown that no product can be procured to solve the cost calculation problem for the 3-d laser cutting. The University of Erlangen has worked on a similar tool but this has not resulted in an available product. (cf.: www.lft.unierlangen.de/cgibin/projekte)

During the ICACOST project, the consortium has developed a 3-d viewer as main program, combined with a characteristic number generator for sheet metal parts. The 3-d viewer enables the visualisation and conversion of various formats and the selection of contours as well as their definitions as tool paths within a CAD file. Required positioning paths for laser machines will be defined automatically based on the tool paths. By the use of the defined tool paths, the characteristic number generator obtains a set of characteristic numbers, which are describing the workpiece and all contours to process concerning their expenditures for the

manufacturing process of laser cutting. The idea to define the characteristic numbers was worked out by analysing various CAD files concerning their geometries. The LZH was able to find basic geometry elements, which were present in all CAD files. Due to these characteristics the laser machines consume more or less time during the cut of contours. Special form elements, such as small drillings or material bridges were only able to become manufactured by special tools and procedures. The existence of these characteristics decides about the feasibility to cut a workpiece using a laser machine with the given capabilities. Thus, accessing the set of characteristic numbers an employee can perform a quick just-in-time feasibility check and expenditure estimation for the actual workpiece. In figure 6.1.1 an overview about the complete set of characteristic numbers per workpiece is displayed. Following the definition of the ICACOST project the characteristics of workpieces are divided in workpiece characteristic numbers (type of workpiece, bounding box…) and contour characteristic numbers (cutting length, number of angles…).

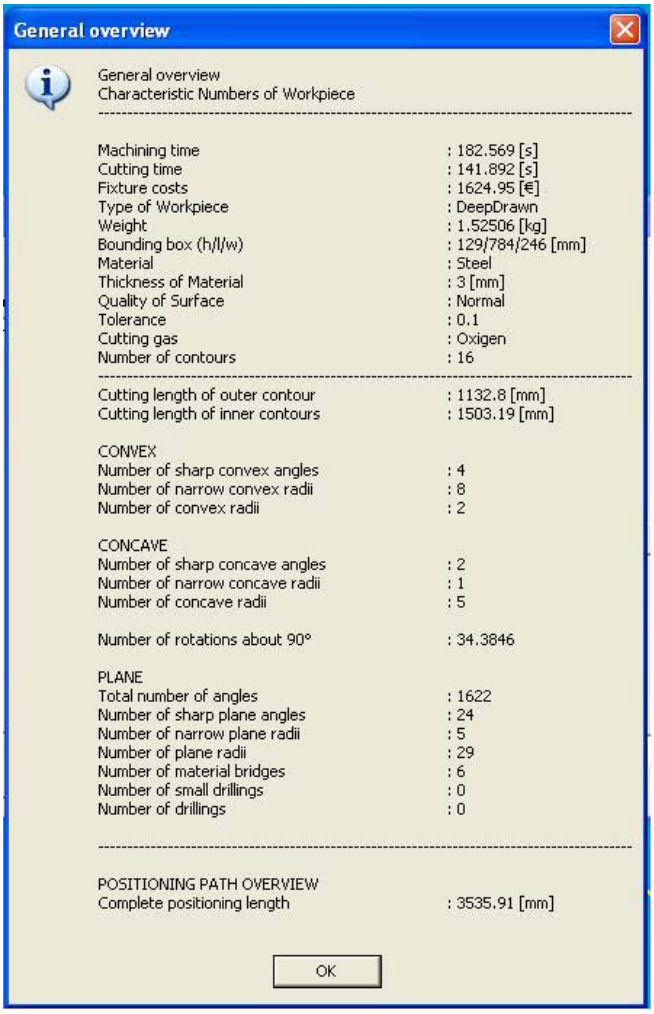

Figure 6.1.1: Set of characteristic numbers per workpiece

Beside the overview list of characteristic numbers, the software also generates the chain of form elements as base for the machining time calculation. The chain of form elements describes all contours as sequence of characteristic numbers in a way that the ICACOST software can calculate a machining time per single form element by using the defined set of process parameters. Please see figure 6.1.3, for the set of process parameters.
By this, the characteristic numbers will be used to calculate the machining time automatically as well as to check the feasibility by comparing the capabilities of the company and their

machines with the workpiece characteristics. Also the fixture costs can be estimated by accessing the workpiece characteristic numbers.

Figure 6.1.2 explains the decision chain, which needs to be followed to consider all influences on the laser cutting process. The process parameters for example depend directly on the machine in use and the material and its thickness. Also the cutting gas and tolerances are important. This is defined as the actual cutting case. To store the process parameters per cutting case, a database is implemented. It contains all information concerning the machine capabilities in the form of pre-configured cutting cases. Figure 6.1.2 shows the implemented structure of a cutting case as well as the set of positioning path parameters relating to the mentioned cutting case. The positioning path parameters are a part of the set of process parameters that are used to describe the cutting and positioning process.

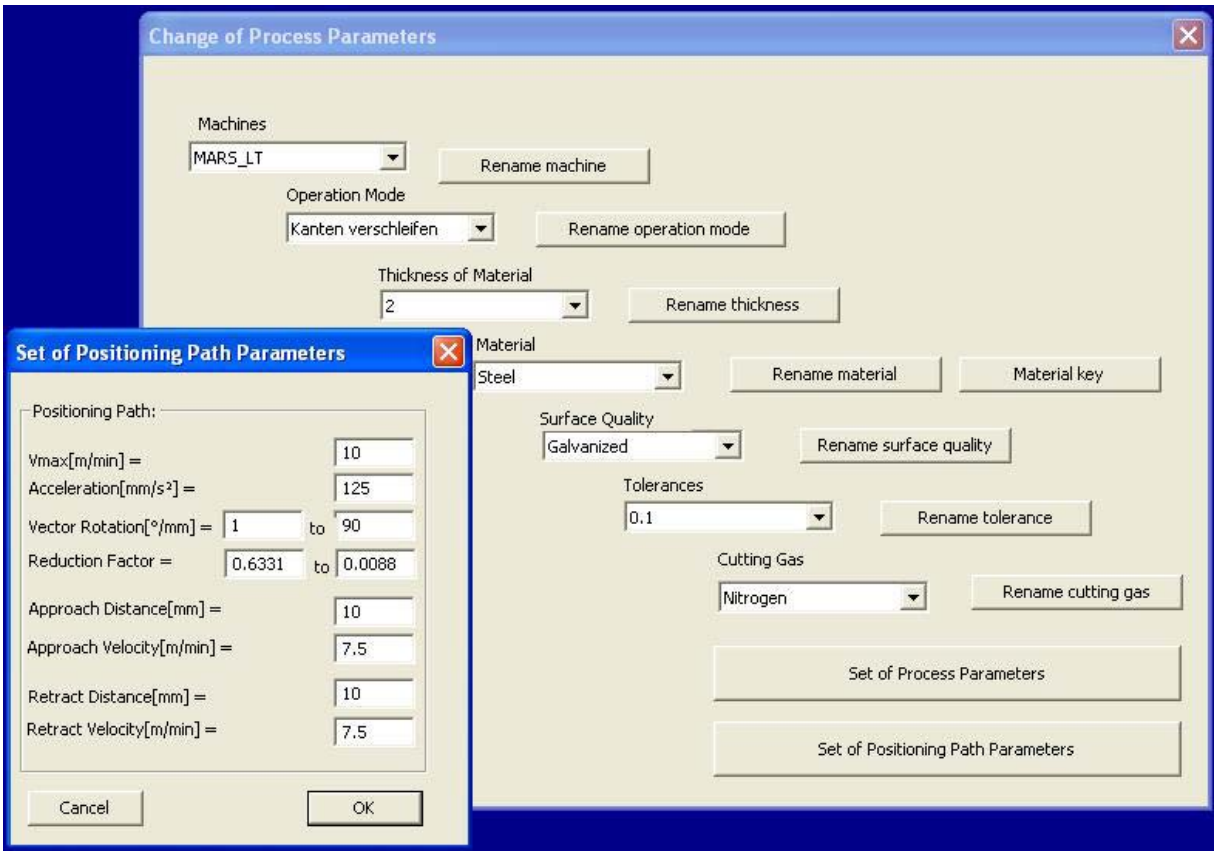

Figure 6.1.2: Cutting case structure

The machining time calculation is performed by linking the characteristic numbers of each contour with the process parameters of the database. Thus, for each cutting case, the process parameters need to be defined once and are accessible for further cost calculations. As example, a set of process parameters for one cutting case is displayed in figure 6.1.3.

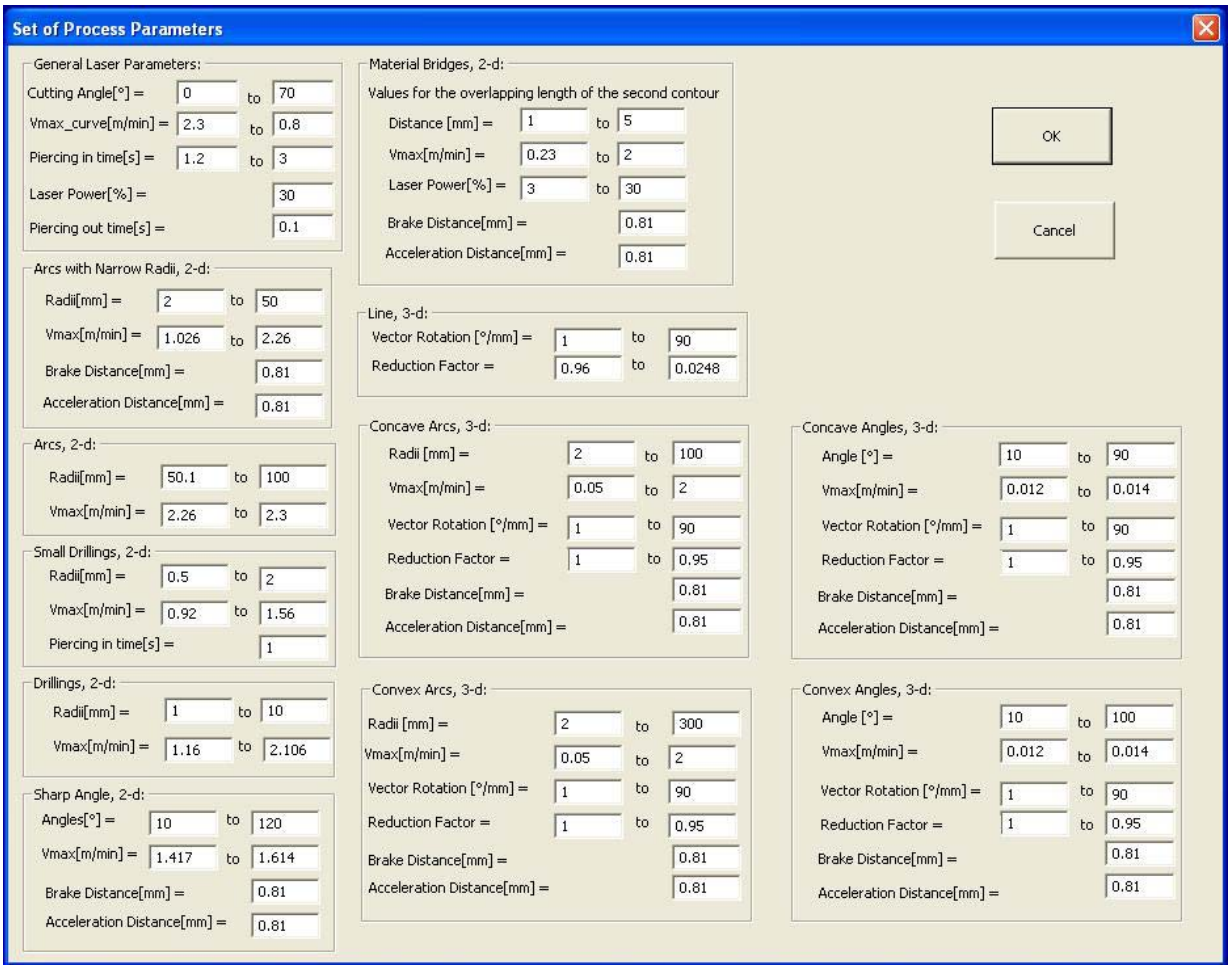

Figure 6.1.3: Set of Process Parameters

In order to generate the sets of process parameters a calibration run for each cutting case needs to be performed. Therefore, special calibration contours for each contour characteristic number are defined. Each calibration contour contains only one characteristic number and straight cuts. The time to perform straight cuts is known. Thus, all additional time the machine needs to process the contour are caused by the actual measured characteristic number. Therefore, an average velocity within the characteristic number can be obtained. Analysing the measured times by mathematical equations describing the machine kinematics, the machine behaviour is obtained and herewith the process parameters are calculated.

The calibration process is successfully performed for the laser machines of the industrial partners and the LZH. A set of process parameters was obtained to use it for further machining time predictions. In most cases the ICACOST software was able to predict the machining times with deviations in the range of 1.0 - 8.5 percent. These results are acceptable to calculate prototypes and small series. The goal of ICACOST project concerning the characteristic numbers and the machining time calculation is completely fulfilled by these results.

In addition, a company specific configurable cost calculation tool for the offer preparation was developed. It contains all business factors that influence the offer calculation of a usual SME in the sheet metal branch. This offer calculation tool consists of a standard form for data input and a representation mask and a database to store inquiries, offers, orders and post-calculated orders. Based on the actual configured company data, the system calculates a price per workpiece and per offer by accessing the calculated machining time. As plausibility

check, the user can access post-calculated orders by searching the database for similar workpieces described by customers, date and time as well as characteristic numbers.

The combination of the 3-d viewer, the characteristic number generator, the machining time calculation and the standard form enables a quick and reliable offer calculation. A tool for high quality pricing is the result. The pre-configured tool can be used by employees, which are less skilled in laser cutting. Thus, the high qualified technical employees can care about their main technical tasks.

The main intention to use ICACOST is to perform reproducible and reliable offers in a short time. But it can also be employed to win a first overview for planning the work shop. Therefore, the standard form was extended by output fields describing the complete manufacturing time of the actual offer and the number of parts per hour. Figure 6.1.4 displays the standard form for cost calculations.

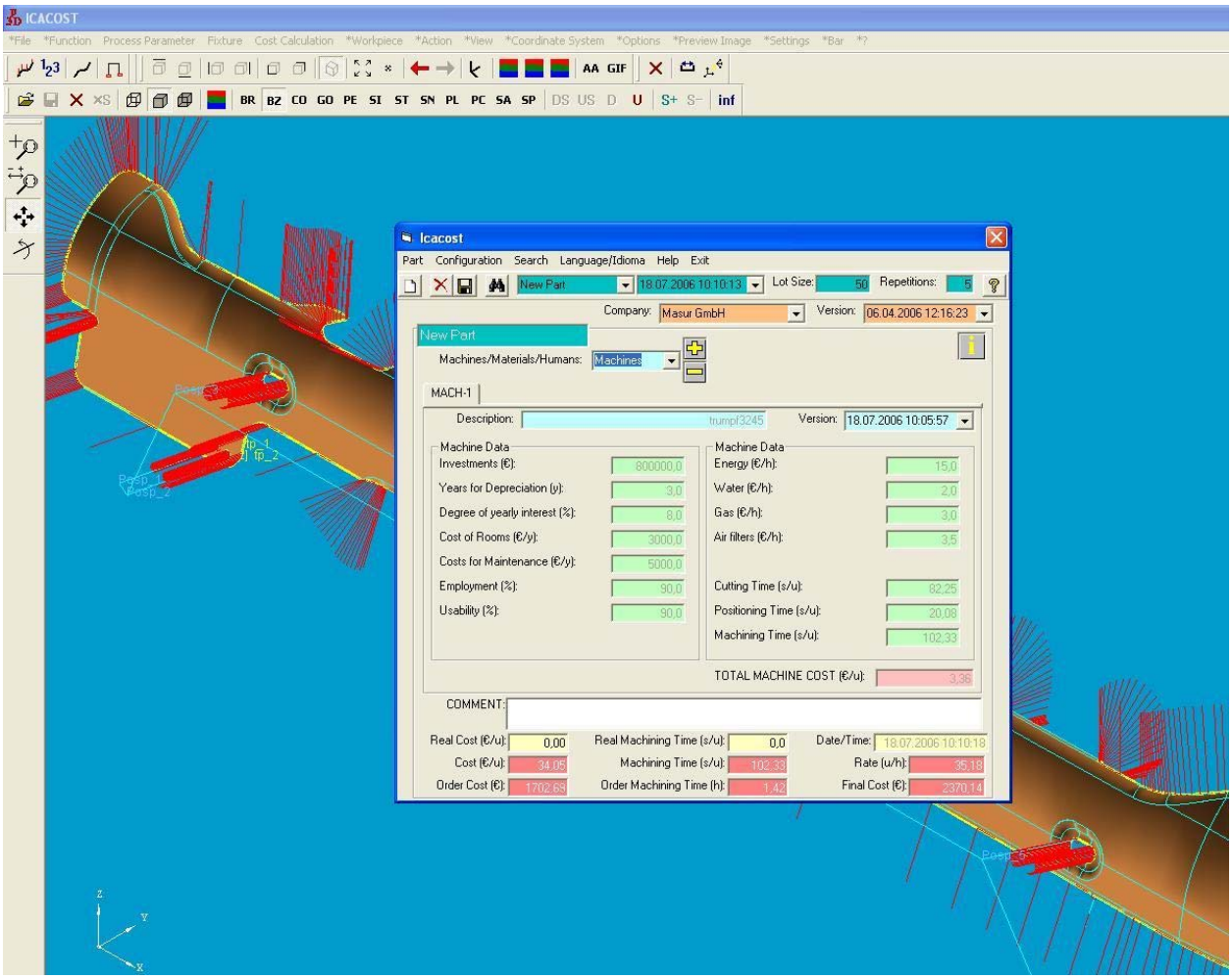

Figure 6.1.4: Standard form for cost calculations

Due to the fact that also other contour processing machines (water jet cutting, flame cutting) have a similar contour processing behaviour in comparison to laser machines, ICACOST can also be employed to calculate the machining time and offers for these production processes.
Thus, the foreseen market is the enterprise resource planning department of SMEs in the sheet metal branch. The system can be used for all SMEs, dealing with contour processing services of sheet metal workpieces. A complete negotiation process can be performed as well as the storage of negotiation data for documentation purposes. A prototype of the described cost

calculation system ICACOST is available and installed at all industrial partners of the ICACOST consortium.

The ICACOST project involves six industrial partners working in the sheet metal branch in the field of laser cutting and welding: MARS, CLW, Wilco, Tube-C, Las-T, GLI. In addition the Spanish RTD performer Robotiker is involved to specify the influencing business factors and to implement the developed standard form and database. These tasks are successfully completed. The German RTD performer Laser Zentrum Hannover e.V. (LZH) is the project co-ordinator. The technical tasks to be performed are related with the handling of CAD files and laser cutting. The LZH has developed the 3-d viewer and the characteristic number generator. The process parameter database, the machining time calculation tool and the fixture-cost estimation tool are also successfully completed. Thus, the prototype of the cost calculation system is available at MARS Lasertechnik GmbH. In case of interest, please contact the ICACOST web-page: http://icacost.lzh.de

Part. no.	Participant name	Participant short name
1	MARS Lasertechnik GmbH	MARS
2	CLW Clausthaler Laser- und Werkstofftechnik GmbH	CLW
3	DISMODEL S.A.	DISM
4	Wilco Wilken Lasertechnik GmbH	WILCO
5	Gualini Lamiere International SPA	GLI
6	TubeCut e.K.	TUB-C
7	LASER-TECH spol.s.r.o. Olomouc	LAS-T
8	Laser Zentrum Hannover e.V.	LZH
9	Fundación Robotiker	RTK

2. Dissemination and use.

During the ICACOST project, the consortium has developed a 3-d viewer combined with a machining time calculation module for the laser cutting of sheet metal parts. In addition, a configurable offer cost calculation tool with a plausibility check database for SMEs of the sheet metal branch was developed.

The 3-d viewer enables the visualisation and conversion of various formats. The viewer enables the selection of contours as well as their definitions as tool paths. Required positioning path for laser machines will be defined automatically based on the tool paths. A complete work description can be prepared based on this viewer. Based on the defined tool paths, the characteristic number generator obtains a set of characteristic numbers describing the workpiece and all contours to process concerning their expenditures for the manufacturing. Accessing these structured represented data an employee can perform a quick just-in-time feasibility check and expenditure estimation for the actual workpiece. These characteristic numbers will be used to calculate the machining time and the fixture costs automatically.

The configurable offer cost calculation tool consists of a standard form as data input and representation mask and a database to store inquiries, offers, orders and post-calculated orders (plausibility check database). Based on the actual configured company data, the system calculates a price per workpiece and per offer by accessing the calculated machining time. As plausibility check, the user can access post-calculated offers by searching into the database for similar workpieces described by characteristic numbers. The main advantages are given by the combination of the 3-d viewer, characteristic number generator and the cost calculation tool. These three tools combined into one systems will enable a user to calculate offers very quickly and reliable. A high quality pricing is the result. The pre-configured tool can be used by employees of the sales department, which are less skilled in laser cutting. Thus, the high qualified technical personal can care about their main tasks.

Additionally, during the project were developed a calibration procedure for contour cutting machines in order to connect the machine behaviour into the algorithms that calculate the machining time. This calibration procedure is under development and will be the solution to calibrate contour cutting machines using a short space of time.

The foreseen market is the enterprise resource planning department of SMEs in the sheet metal branch. The system can be used for all SMEs, which are dealing with contour processing services of sheet metal workpieces. A complete negotiation process can be performed. Additionally the negotiation data can be stored for documentation purposes. The cost calculation system is into the state of a prototype.

For collaboration and further research, all SMEs of the sheet metal branch are welcome, which are interested in using this system for their daily work. The system needs to be tested and improved by consulting services. These tasks are given to potential collaboration partners. All intellectual property rights as well as all copy rights are owned by the ICACOST industrial partners.

Contact details:

Laser Zentrum Hannover e.V.
Hollerithallee 8
D-30419 Hannover
Fax: +49511 / 2788 – 100
Phone: +49511 / 2788 – 121
Web: www.lzh.de

Dipl.-Ing. Markus Masur
Phone: +49511 / 2788 – 437
E-mail: m.masur@lzh.de

Dipl.-Ing. Fernando Liébana
Phone: +49511 / 2788 – 324
E-mail: f.liebana@lzh.de

Department: Production and Systems
Group: Industrial Engineering

Dipl.-Ing. Heinz Reinhold
Phone: +49 3621 71480
Fax: +49 3621 7148 99
E-mail: office@mars-lasertechnik.de
MARS Lasertechnik GmbH
Am Köpfchen 9
99869 Emleben