FINAL ACTIVITY REPORT
(PUBLISHABLE)

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PROJECT N° : 508143

ACRONYM : TAF – Turn And Finish

TITLE : Development of a Combined Hard Turning and Superfinishing Technology

PROJECT CO-ORDINATOR : Hembrug B.V.

PARTNERS : Hembrug B.V., NL
Cerobear GmbH, D
HWG Wälzlager, D
SC Diasfin SA, RO

RTD Performer : Fraunhofer IPT, D
Technical University of Miskolc, HU

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Publishable executive summary

European SMEs, which produce high precision parts (i.e. bearing-, hydraulic components) are facing a steady loss of competitiveness in their growing markets, since existing manufacturing technologies do not fulfil increasing demands on part quality and variety. At the same time the competition has worsen due to up-comming low wages countries outside Europe and an increasing cost pressure. As a result, a new technology must be provided to sustainably ensure the competitiveness and survival of the SMEs.

Therefore, the main objective of the project is to develop a combined process of high-precision hard turning and superfinishing in an integrated machining center to permit a flexible production of high-precision parts made of hardened steel. The combined hard turning and superfinishing process (TAF) will substitute the current process chain of grinding and superfinishing, leading to a drastic reduction of non-productive times and thus to a significant increase of the productivity of the end users of the technology.

The achievement of the objectives will require the development of an innovative technology, which will encompass the following:

- development and integration of a compact superfinishing device into a high-precision lathe;
- combination of the kinematics of a high-precision lathe equipped high-frequency direct motor drives with the kinematics of the compact superfinishing device;
- machining technology development and optimisation;
- optimisation of superfinishing tools.

Besides contributing to an improvement of the bonds between Member States and Candidate Countries and to an considerable increase the competitiveness of the participating SMEs the project will encompass scientific, technical and societal objectives, which can be summarised as follows:

- A better scientific and technical knowledge of superfinishing.
- An expansion of the use of superfinishing to other engineering applications and, consequently, enhancement of the life time and reliability of components, machines and other mechanical systems.
- A significant reduction of the use of emulsions in the machining process by using only one machine instead of many.
- The risk of inhaling hazardous oil mist produced in grinding operations increases if the worker spends long time trying to align the parts after re-clamping. By producing parts by means of turning and

superfinishing on only one machine, this risk will be considerably reduced and thus there will be an improvement of the health condition of European workers.

In the following the companies of the project consortium and their tasks are described.

Hembrug B.V. (Hembrug) **co-ordinator**
Hembrug's main tasks in the project are the project co-ordination, execution of measures to prepare the exploitation of the results, as well as the adjustment and improvement of a high-precision lathe that is suitable for the new process chain.

Cerobear GmbH (Cerobear) and
Horst Weidner GmbH (HWG) **end user**
Cerobear and HWG contribute to the technical development and evaluation of the combined hard turning and superfinishing machining on relevant demonstration parts and perform mechanical testing of bearing components. In the TAF project, besides the R&D department also production and quality insurance departments will contribute to the production of reference parts. Mechanical testing will be performed on bearing test facilities. Both end users have profound expertise in machining of hard to machine materials, both with undefined (grinding, finishing) and with defined cutting edges (hard turning). In addition to this HWG has profound Know-How in the honing technology and gives technical advise to ensure a secure development of the combined process.

Diasfin S.A. (Diasfin) **honing tool manufacturer**
Diasfin supplies the project with honing tools, which will be improved during the project work to make the TAF system reliable.

University of Miskolc (TU Miskolc) **RTD Performer**
Main tasks of the University of Miskolc are the development and optimisation of the superfinishing device which will be integrated into the high-precision lathe. Besides, the TU Miskolc works in close co-operation with the partner Hembrug on modifications of the lathe for the execution of the superfinishing process kinematics.

Fraunhofer IPT (IPT) **RTD performer**
Main tasks of the Fraunhofer IPT are the process optimisation and development.

1 Technical overview

The following chapters describe the technical overview of each project period up to the respective status at end of the particular project period.

1.1 Project period 1 (months 1 – 6)

1.1.1 Summary of the objectives

According to the work plan proposed by the RTD Performer and the decisions taken by the project consortium during the Kick-off meeting, the objectives for the first project period can be summarised as follows:

- to define the test parts which will be machined in the next workpackage according to the users needs concerning
  - material
  - contours
  - range of dimensions (outer/inner diameter)
  - range of tolerances

- to manufacture test parts for the machining tests according to the specifications defined.

- to select
  - cutting tools for the hard turning process
  - a suitable emulsion for the combined machining process in order to avoid the use of honing oil
  - suitable filters to be built in the lathe to prevent that small honing chips get into the coolant circuit

- to make suggestions for a design of a prototypical superfinishing device, which will be discussed and finalised at the Six-Months Meeting.

- to design and manufacture superfinishing tools for the TAF system. By means of a close co-operation of Diasfin (superfinishing tools manufacturer) and the University of Miskolc, a suitable clamping systems for the superfinishing tools will be defined. The clamping system will be easy and quick in order to change worn out tools rapidly without any loss of accuracy regarding the result of the machining. Also Diasfin will provide the Fraunhofer IPT with dressing tools for resharpening the honing stones.

- to modify the high-precision hard turning lathe stationed at the Fraunhofer IPT in order to enable the integration of the prototypical superfinishing device.

1.1.2 Overview of the technical progress

A preliminary definition of the test parts was carried out during the Kick-Off Meeting and a final drawing was sent to all partners later on. The drawings of the test parts are shown in the following figure.

Test part 1 outer bearing ring

Test part 2 inner bearing ring

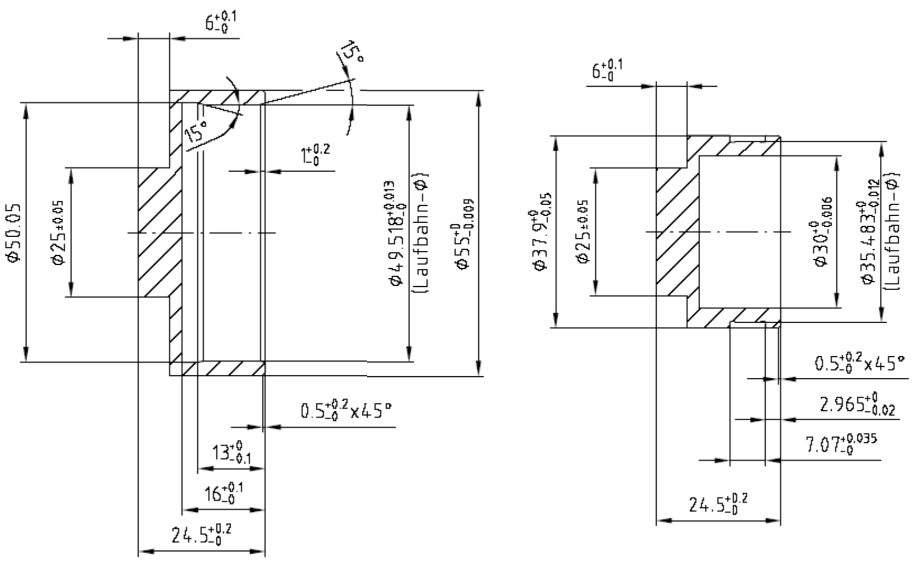


Fig. 1: Drawings of the test parts after machining with the TAF system

As material 100Cr6 was chosen. But the partners agreed to the possibility of investigating other materials during the project which will be defined later.

The test parts in a batch size of 30 pieces each (inner and outer ring) were manufactured and submitted to the Fraunhofer IPT by Cerobear. The company HWG will also manufacture a comparable batch size of test pieces and submit these to the Fraunhofer IPT. In addition to this HWG will carry out tests encompassing honing of previously ground test parts. Afterwards test parts which were hard turned by the Fraunhofer IPT will also be honed at HWG. The time needed for the honing operation to attain the final roughness of Ra = 0.02 µm will be recorded and compared concerning the initial roughness of the ground and hard turned test pieces.

For the hard turning operation attainable roughness values between Ra = 0.07 µm and Ra = 1.0 µm were defined. Concerning the roundness and straightness no specific values were defined for the test pieces.

As cutting tools for the hard turning operation a tool geometry with cutting edge radii of 0.4 mm and 0.8 mm with brushed and chamfered cutting edge preparation were defined. As cutting material DBC50 (with the possibility of changing the material within the project to attain better roughness values after hard turning) was chosen.

After the combined machining with the TAF system a roughness of Ra = 0.02 µm should be attained.

For the honing tools the preliminary design shown in Fig. 2 was defined. The specific values of the hones will be finally defined by Diasfin in close co-operation with the TU Miskolc after an agreement concerning the clamping system to fix the honing stones to the honing device.

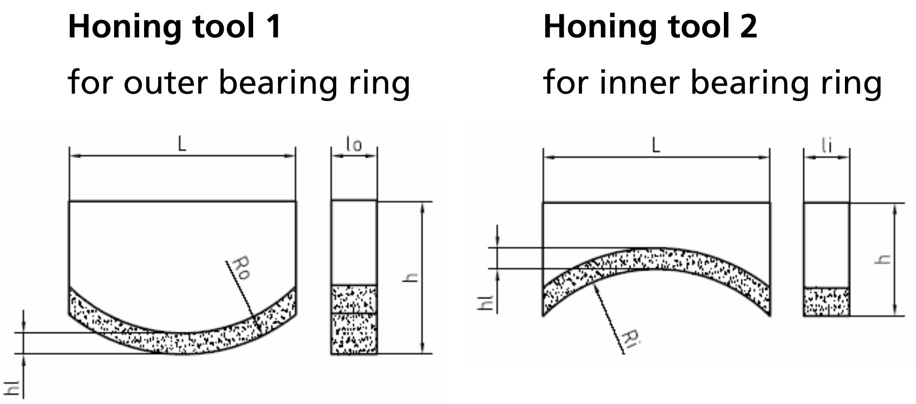


Fig. 2: Preliminary design of the honing stones

For the project related investigations of different honing steps the following suggestions were given by Diasfin:

- D 91 M 100
- D 46 M 100
- D 14-20 M 100

in which:

D	diamond grain
91 / 46 / 14-20	grain size in µm
M	metal bond
100	concentration of superabrasives in the active layer

For the dressing operation and the activation of the diamond layer of the honing tool the following suggestions of Diasfin were given:

honing stone	dressing tool
D91	21C - 120 (150) M (L) - 4V
D46	21C - 220 (240) J (K) - 4V
D 14-20	21C - 400 (500) H - 4V

in which:

21C	black silicon carbide
22C	green silicon carbide (recommended for activating the layer)
120 / 220 / 400	grain size (fine to dust fine)
H / J / K - M / L	hardness grade (soft - medium)
4	bond structure (medium)
V	ceramic bond

Concerning the design of the superfinishing device the TU Miskolc presented several suggestions at the Six-Months Meeting. During the discussion it was agreed to realise some slight modifications concerning to use spring bearings for the linear motor swinging units instead of linear guide bearings because of an increased lifetime. The chosen variants for the superfinishing device are:

superfinishing head:	TAF-II-03-03
clamping:	TAF-II-02-01
linear motor swinging part:	TAF-II-01-03

Drawings of the above mentioned variants are not attached to this report because of the receivable modifications.

The modification of the high-precision hard turning lathe will be carried out together with the integration of the prototypical superfinishing device. Hembrug and the TU Miskolc will work closely together concerning this topic.

A suitable emulsion for the combined machining process in order to avoid the use of honing oil was identified to be the emulsion SCC 205 from Sunnen. This emulsion is capable for both hard turning and honing processes.

To prevent that small honing chips get into the coolant circuit a filter fleece of 10 µm mesh size will be applied to the Hembrug 50 CNC lathe.

1.1.3 Comparison of planned activities and work accomplished

The following table shows a comparison of tasks planned for the first project period with the work accomplished.

Planned tasks	Who	Accomplished
- define materials and contours (test parts) to be machined	Fraunhofer IPT All partners	Yes
- Manufacturing of test specimens	Cerobear HWG	Yes
- Provide the RTD Performer with test parts of the chosen material, pre-machined with the defined tolerances	Cerobear HWG	Yes
- Selection of • cutting tools • an emulsion suitable for the operation for the combined process • a suitable filter	Fraunhofer IPT	Yes
- final design of the superfinishing device	TU Miskolc	Yes
- definition and specification of superfinishing tools	Diasfin	Yes
- manufacturing of the superfinishing device	TU Miskolc Hembrug	No, scheduled for project month nine/ten
- modification of the high-precision hard turning lathe at the facilities of the Fraunhofer IPT	Fraunhofer IPT Hembrug TU Miskolc	No, scheduled for project month nine/ten

Tab. 1: Comparison of planned tasks and work accomplished

Due to the decision made by the consortium at the Kick-Off meeting, the manufacturing of the superfinishing device and in consequence the modification of the high-precision hard turning device will be completed in project month nine or ten.

1.1.4 Comparison of planned and accomplished deliverables

Deliverable No	Deliverable title	Envisaged delivery date	Accomplished
D1	Specification of test parts, superfinishing tools, cutting tools, coolant and filter	3	Yes, stated in the Six-Months Report of TAF (see D3)
D2	Prototype TAF system	6	No, due to the above mentioned reasons it has not been completed yet but it will be completed at the Mid-Term Meeting scheduled for March 31st 2006
D3	Status report including documentation about the design of the superfinishing device	6	Yes, submitted on August 9th 2005

Tab. 2: Comparison of initially planned and accomplished deliverables (months 1 – 6)

1.2 Project period 2 (months 7 – 12)

1.2.1 Summary of the objectives

According to the work plan proposed by the RTD Performer and the decisions taken by the project consortium during the Six-Months follow-up meeting, the objectives for the second project period can be summarised as follows:

- to finalise the design of the superfinishing device in co-operation with Hembrug and Diasfin
- to manufacture the superfinishing device
- to modify the high-precision hard turning lathe and to implement the superfinishing device
- to prepare test parts (inner and outer ring) for tests at the Fraunhofer IPT according to the part definitions made during the Kick-Off Meeting
- hard turning and examination of test parts in order to attain different roughness values (0.07 µm < Ra <0.1 µm) and to identify suitable machining parameters for the hard turning operation
- honing of ground and hard turned test parts with different initial roughness values to attain the final roughness of Ra = 0.02 µm, recording of the time needed for the honing operation with different initial roughness values and pre-machining steps (hard turned, ground)
- to compare the process times concerning the initial roughness of the ground and hard turned test pieces in order to derive initial parameters for the combined TAF process from these results
- to carry out initial tests with the combined process, to identify possible improvements concerning the superfinishing device and/or the honing tools and to execute process layout tests resulting in a first optimisation of the TAF process

1.2.2 Overview of the technical progress

As planned, the design of the superfinishing device was completed by the TU Miskolc in close co-operation with Hembrug and Diasfin. The design encompassed the following

- linear motor swinging unit
- radial clamping unit of the honing head
- the honing head

During the manufacturing of the single components of the superfinishing device some deferments occurred dispositional to reasons at the manufacturing companies. Additionally concerning the linear motors a delivery delay occurred due to logistic problems of the manufacturing company. Figure 6 shows the as much as possible completed device without the linear motors (set-up for machining of the outer bearing rings).

The integration of the prototypical superfinishing device was carried out in combination with the modification of the high-precision hard turning lathe. Hembrug and the TU Miskolc worked closely together concerning this topic.

For the clamping of the superfinishing stones a solution was suggested which enabled the changing of the clamping part with possibilities to fix various superfinishing stones with varying widths. Figure 3 shows the final design of the honing stones for the honing process of the outer and the inner bearing ring which was finally defined by Diasfin in close co-operation with the TU Miskolc after an agreement concerning the clamping system to fix the honing stones to the honing device.

Honing tool 1
for outer bearing ring

Honing tool 2
for inner bearing ring

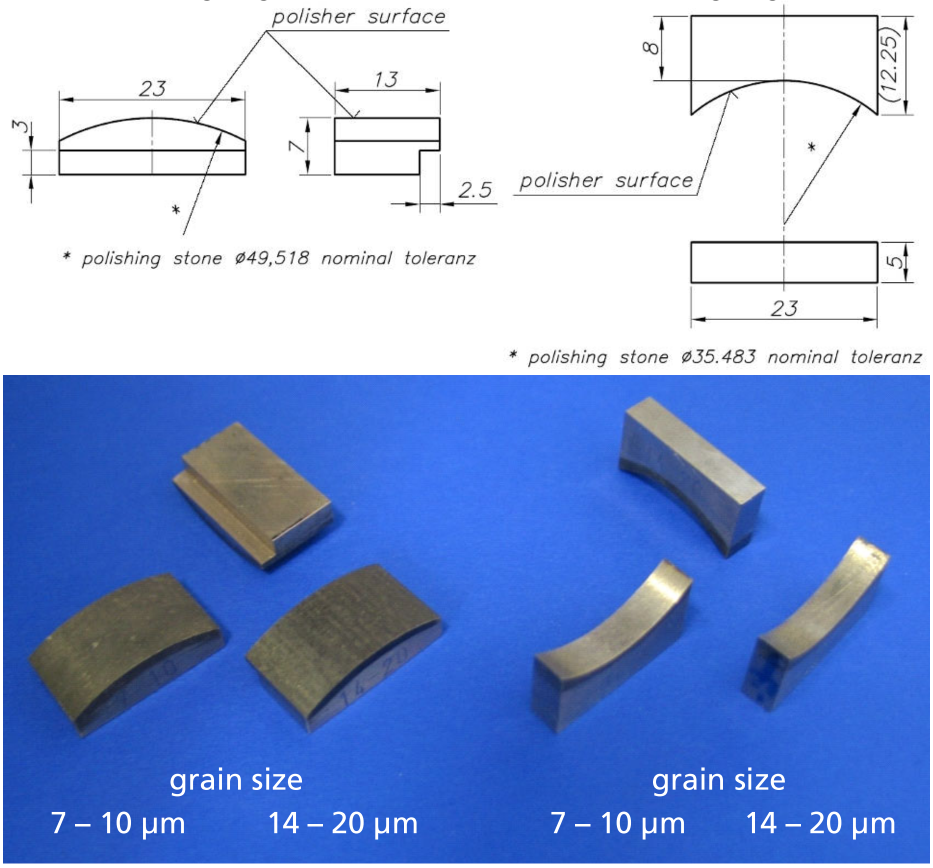


Fig. 3: Final design of the honing stones and samples

For the project related investigations of different honing steps the following suggestions were given by Diasfin:

- D 91 M 100
- D 46 M 100
- D 14-20 M 100

in which:

D	diamond grain
91 / 46 / 14-20	grain size in µm
M	metal bond
100	concentration of superabrasives in the active layer

For the dressing operation and the activation of the diamond layer of the honing tool the following suggestions of Diasfin were given:

honing stone	dressing tool
D91	21C – 120 (150) M (L) – 4V
D46	21C – 220 (240) J (K) – 4V
D 14-20	21C – 400 (500) H – 4V

in which:

21C	black silicon carbide
22C	green silicon carbide (recommended for activating the layer)
120 / 220 / 400	grain size (fine to dust fine)
H / J / K – M / L	hardness grade (soft – medium)
4	bond structure (medium)
V	ceramic bond

As suitable emulsion for the combined machining process in order to avoid the use of honing oil the emulsion SCC 205 from Sunnen was identified. This emulsion is capable for both hard turning and honing processes. To prevent that small honing chips get into the coolant circuit a filter fleece of 10 µm mesh size will be applied to the Hembrug 50 CNC lathe. Both, the emulsion and the filter fleece, are already available at the Fraunhofer IPT.

The test parts in a batch size of 30 pieces each (inner and outer ring) were manufactured and submitted to the Fraunhofer IPT by Cerobear and HWG.

For the hard turning operation attainable roughness values between Ra = 0.07 µm and Ra = 0.1 µm were defined as initial roughness for the superfinishing operation. Concerning the roundness and straightness no specific values were defined for the test pieces. The accuracy of the hard turning process is absolutely reliable below 1 - 2 µm regarding these specific tolerances due to the employed lathe (Hembrug Slantbed Microturn 50 CNC linear) and will therefore constitute no error cause for the combined process. As cutting tools for the hard turning operation a tool geometry with nose radii of 0.4 mm and 0.8 mm with chamfered and brushed cutting edge preparation (Type: S) were defined. As cutting material DBC50 (with the possibility of changing the material within the project to attain better roughness values after hard turning) was chosen.

Within the preliminary hard turning tests it was envisaged to achieve different roughness values by combinations of the two defined nose radii and variations of the feed rate. The first tests encompassed turning tests machining the inner ring.

The following process parameters were used for the machining of the raceway:

cutting speed:	v_c = 160 m/min
depth of cut:	a_p = 25 µm
cutting edge preparation:	S (chamfered and brushed)

Tool 1:

nose radius:	r_ε = 0.8 mm
used feed rates:	10 to 50 mm (steps: 10 mm)
machined parts:	1 to 10

Tool 2:

nose radius:	r_ε = 0.4 mm
used feed rates:	5 to 50 mm (steps: 5 mm)
machined parts:	11 to 30

Figure 4 shows the achieved diameter values for both tools and the feed rate variations. The first three parts of each test series (1-3 and 11-13) were used for the set-up of the tool. Since the main interest of these test series focussed on the attainable roughness the deviations of the desired raceway diameter (35.477 mm) of the six test parts did not have any influence on the outcome of the tests.

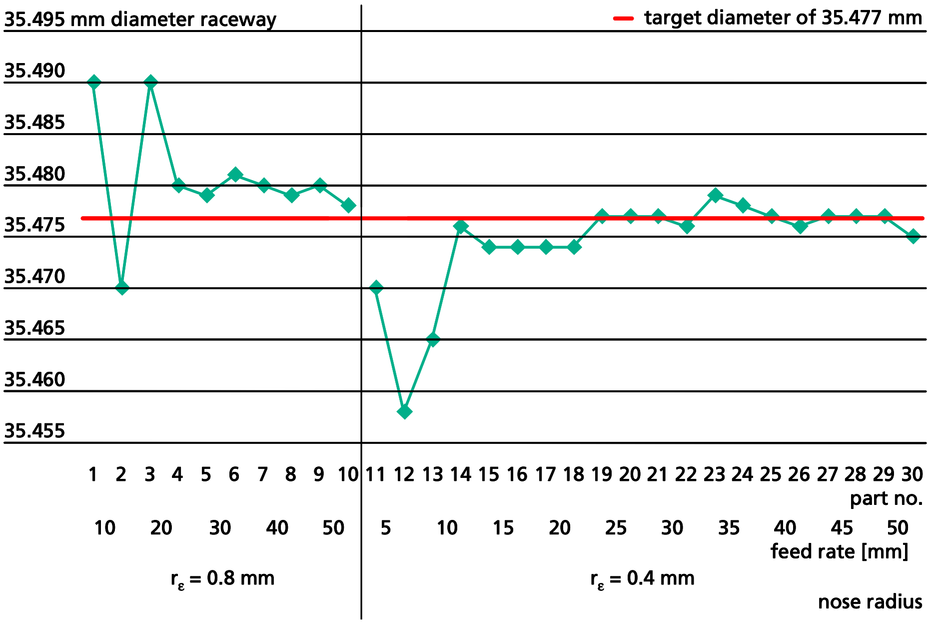


Fig. 4: Diameter values of the preliminary turning tests (inner bearing rings)

As can be seen in Figure 5, with each feed rate two rings were manufactured. Afterwards the roughness of each raceway was measured.

The roughness values are displayed in Figure 9. To make it easier to display both Ra and Rz values in one diagraph the Rz values were devided by 10. Like shown in Figure 9 the targeted values of 0.7 µm ≤ Ra ≤ 0.1 µm could easily be attained.

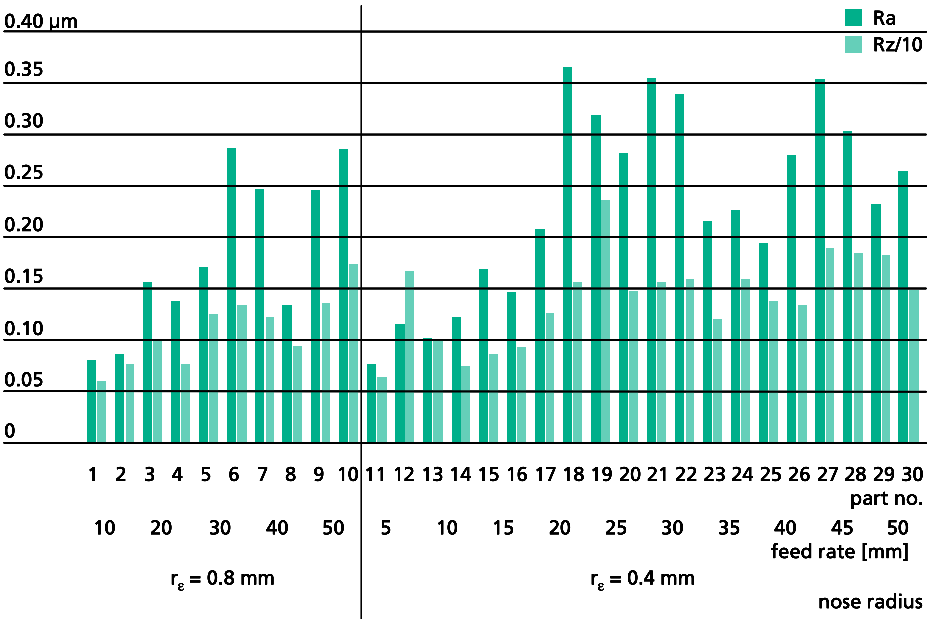


Fig. 5: Roughness values (Ra, Rz/10) of the preliminary turning tests (inner bearing rings)

Within the last project period Hembrug has developed a process for the finish hard turning of spherical roller bearings. After serious analysis adjustments at several places in the whole process chain have been made, in order to achieve the required results. For example the stiffness of tooling, toolholders and driving pins has been increased and a new life centre on the tailstock was developed to improve the roundness of the part. The roller bearings are being manufactured in an automated environment. Apart from a waviness within 1.5 µm the Ra value was particularly critical (within 0.2 - 0.3 µm in serial production). After turning the parts have to be superfinished, and the starting situation for that process should be optimal in order to minimize the process time for the superfinishing operation. These efforts will help to create a good starting situation for the combined TAF process of hard turning and superfinishing of the parts on the Slantbed Mikroturn 50 CNC linear lathe.

At the six-months meeting, HWG agreed to honing of test parts manufactured by means of hard turning by the Fraunhofer IPT. After a discussion with the executive staff of HWG it was stated that the honing of the cylindrical raceways of the test parts is not possible at HWG due to the layout of the honing machine. Therefore it was decided to compare parts with ground and hard turned surfaces which can be honed with the honing equipment of HWG. Due to capacity problems at HWG these tests can be carried out earliest at the end of March 2006. Therefore the envisaged presentation of the results will be accomplished in the middle of April 2006.

Since these results are indispensable for the process layout of the combined machining the Fraunhofer IPT ordered some honing tests carried out on the previously turned parts. These tests will encompass a constant honing operation regarding the process parameters of

- pressure
- oszillation
- feed rate
- honing oil
- honing stones

In addition to this the time of the honing operation will be held constant at 12 seconds. Due to the fact that the parts have different roughness values a statement can be made concerning the influence of the initial hard turned roughness of the raceway on the roughness after the honing operation. The results of these investigations will be presented on the Mid-Term Meeting (March 31st 2006) at the Fraunhofer IPT in Aachen, Germany.

1.2.3 Comparison of planned activities and work accomplished

The following table shows a comparison of tasks planned for the second project period (months 7 – 12) with the work accomplished.

Planned tasks	Who	Accomplished
- final definition of the superfinishing device	TU Miskolc	Yes
- manufacturing of the superfinishing device	TU Miskolc	Yes
- modification of the high-precision hard turning lathe	TU Miskolc Hembrug	No, scheduled for project month 13
- preparation of the test parts (inner and outer ring) for tests at the Fraunhofer IPT	Cerobear HWG	Yes
- hard turning of test parts in order to attain different roughness values (0.07 µm < Ra <0.1 µm) - identification of suitable machining parameters for the hard turning operation - examination of the machined parts	Fraunhofer IPT	Yes
- Honing of ground test parts with different initial roughness values - Honing of hard turned test parts with different initial roughness values (parts submitted by the Fraunhofer IPT) - Recording of the time needed for the honing operation to attain the final roughness of Ra = 0.02 µm with different initial roughness values and pre-machining steps (hard turned, ground)	HWG (Fraunhofer IPT)	No, scheduled for middle of April due to capacity problems at HWG
- Comparison of the process times concerning the initial roughness of the ground and hard turned test pieces - derivation of initial parameters for the combined TAF process	Fraunhofet IPT (HWG Cerobear)	No, scheduled for middle of April (see above)
- Initial tests with the combined process - Identification of possible improvements concerning the superfinishing device and/or the honing tools - Process layout tests resulting in a first optimisation of the TAF process	Fraunhofer IPT (all)	No, scheduled for project month 13

Tab. 3: Comparison of planned tasks and work accomplished (months 7 – 12)

Due to the decision made by the consortium at the Kick-Off meeting, the manufacturing of the superfinishing device and in consequence the modification of the high-precision hard turning device was planned to be completed in project month nine or ten. During the manufacturing of the superfinishing device some delays were encountered which caused a general deferment of two months. In consequence the first tests of the combined process had to be postponed and will be presented at the Mid-Term Meeting which therefore also was shifted to end of march.

1.2.4 Comparison of planned and accomplished deliverables

Deliverable No	Deliverable title	Envisaged delivery date	Accomplished
D4	Advanced TAF system	12	No, due to the above mentioned reasons no tests and advancements were carried out so far but will be accomplished soon
D5	Mid-term review including documentation about the advanced TAF system and machining parameters and draft version of the Plan for using the dissemination of Knowledge	12	Yes (partly), preliminary Mid-Term review was submitted on March 17th 2006, machining parameters will be handed in later after the tests
D6	Publication of non-confidential results	12	Yes, information are stationed at the IPT and accessible for all visitors, personal discussions of the co-ordinator (Robert Nefkens, Hembrug) with prospective new customers of Hembrug

Tab. 4: Comparison of initially planned and accomplished deliverables (months 7 – 12)

1.3 Project period 3 (months 13 – 18)

1.3.1 Summary of the objectives

According to the work plan proposed by the RTD Performer and the decisions taken by the project consortium in the previous meetings, the objectives for the third project period can be summarised by machining tests with the prototypical TAF system. The results of these tests ought to be used for

- the improvement of the hard turning process with regard to the results achieved in the subsequent superfinishing process
- the identification of possibilities to improve the superfinishing device and the superfinishing tools
- the improvement of the high-precision hard turning lathe
- the identification and implementation of suitable possibilities of eliminating form errors (convex surfaces)

1.3.2 Overview of the technical progress

Frequency tests and modifications of the 50CNC

As described in the Mid-Term report, the superfinishing device was completed and mounted into the lathe stationed at the Fraunhofer IPT. Afterwards the connection of the honing device to the control of the lathe was carried out. For this the honing device had to be configured in the control as fourth axis. Afterwards the set up and optimisation of the basic values of speed, acceleration etc. were done as well as the set up of buttons of the control panel to move the honing axis in JOG-mode. At last the linear motor of the honing device was connected to the coolant circuit of the lathe in order to ensure a proper functioning. After these modifications first tests with the honing axis to identify the achievable frequencies and amplitudes of the machining system were executed.

As result a maximum frequency of 28 Hz was found. To increase the frequency a technician from Siemens (manufacturer of the lathe control) was asked concerning possibilities of reaching higher frequency values. He suggested to change the persistent NCU from the lathe control to a faster NCU. After this has been done new frequency and amplitude tests were carried out. The procedure for these tests was to programm certain values of amplitudes (0.25 mm to 1 mm in steps of 0.25 mm) with feed rates of 100 mm and 200 mm. In addition to this the feed override was varied in steps of 10%. To identify the attained frequency and amplitude the servo trace feature of the lathe control was used. Fig. 6 shows exemplarily the results of a test run with a feed rate of 100 mm and a programmed amplitude of 0.5 mm.

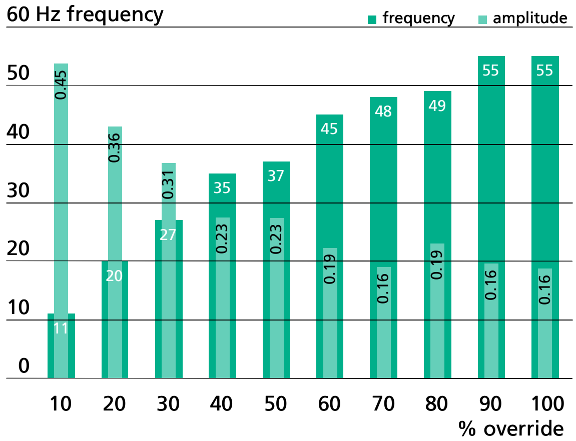


Fig. 6: Example of frequency test
(program values: feed rate F=100 mm, amplitude A=0.5 mm)

In other tests a maximum frequency of 72 Hz in combination with an amplitude of 12 µm could be achieved with the new NCU.

Figure 7 shows the results of the servo trace feature of the same test with an override of 80%. The measuring time of the servo trace was set to 1000 ms which equals 1 s. Therefore the achieved frequency could easily be identified by counting the peaks of the diagraph. The achieved amplitudes were given by the servo trace with maximum and minimum values. In this example an amplitude of 0.19 mm was achieved.

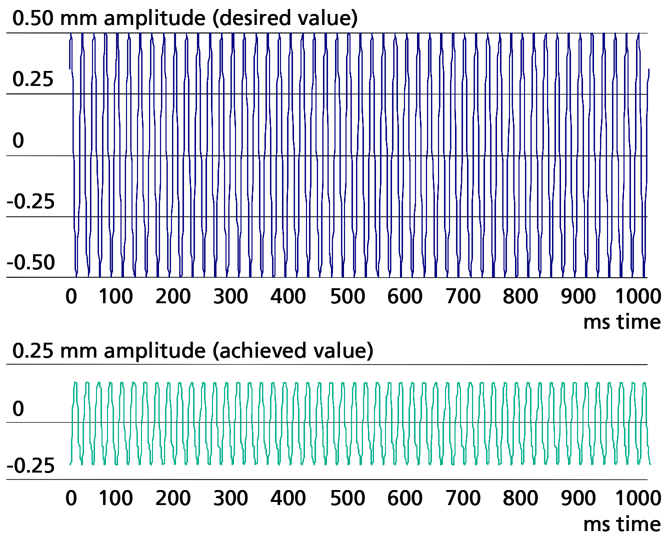


Fig. 7: Result of the servo trace feature, programmed and achieved amplitude value and frequency

In some tests errors were detected like shown in Fig. 8. All errors were recorded with the corresponding parameter combinations. In addition to this before each machining tests a servo trace test was made to avoid such errors for the honing operation. The reason for these errors was not further investigated due to the fact that they occurred only in 13 of 160 parameter combinations and in addition to this all desired values of frequency and amplitude can safely be achieved with different parameter combinations.

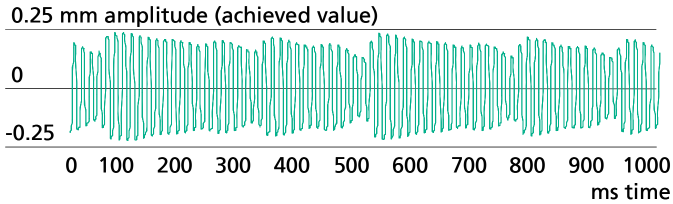


Fig. 8: Example of an error recorded during the frequency tests

Process parameters for the first tests of combined machining with the TAF system and external honing test results

For the hard turning operation process parameters were used in accordance to the previously carried out turning tests and with appointment of the consortium.

The honing process parameters were chosen in order to be able to compare the TAF honing process with a common honing process carried out by an external company on 20 parts (two batches of ten parts each) previously hard turned by the Fraunhofer IPT. The results of these external tests can be compared to the TAF tests with grain sizes of D14-20. For the external honing tests 8 seconds honing time and conventional parameters were used.

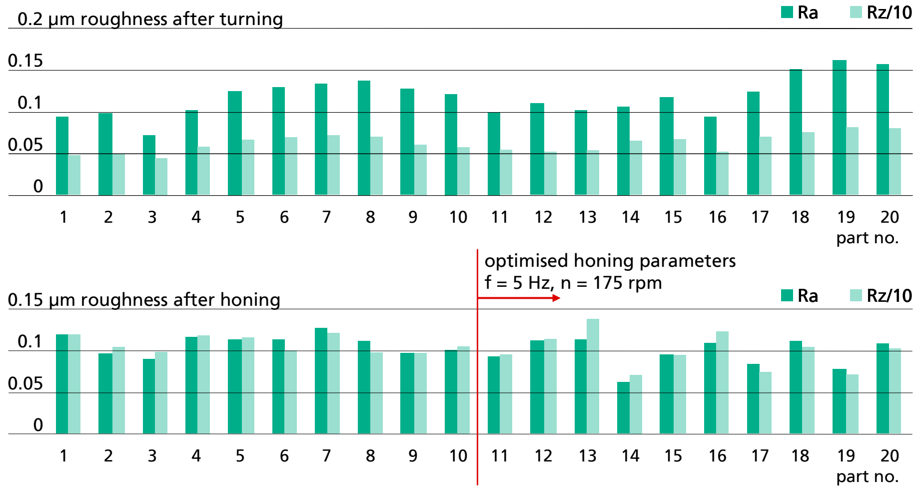


Fig. 9: Results of the external honing tests
(comparable to TAF results with grain size D14-20)

In Figure 9 it can be seen that a mean roughness value of Ra = 0.11 µm could be achieved for the first ten parts. With the optimised parameters a mean value of approximately Ra = 0.09 µm is possible. It also can be stated that the roughness values of the hard turned surfaces seem not to have an decisive influence on the outcome of the subsequent honing operation.

For the tests with the TAF system the following experimental plan was envisaged:

- hard turning with the above listed parameters
- manufacturing of batches of six parts with the same honing parameters
- on each part the roughness and the raceway diameter were measured
- a SEM picture of the 5th part of each batch was taken

Due to the fact that a combined machining of hard turning and honing in one clamping was planned, each batch of the six parts was divided and before and after of each of the three parts an only turned part was manufactured (Fig. 10).

one part turned	three parts turned & honed	one part turned	three parts turned & honed	one part turned

Fig. 10: Proceeding of the TAF tests for one batch

With this execution the only turned parts could be measured extensively and a possible trend of the pre-machined parts concerning roughness, diameter, roundness and cylindricity could be detected. Fig. 11 shows results of the measurements in question on five only turned parts.

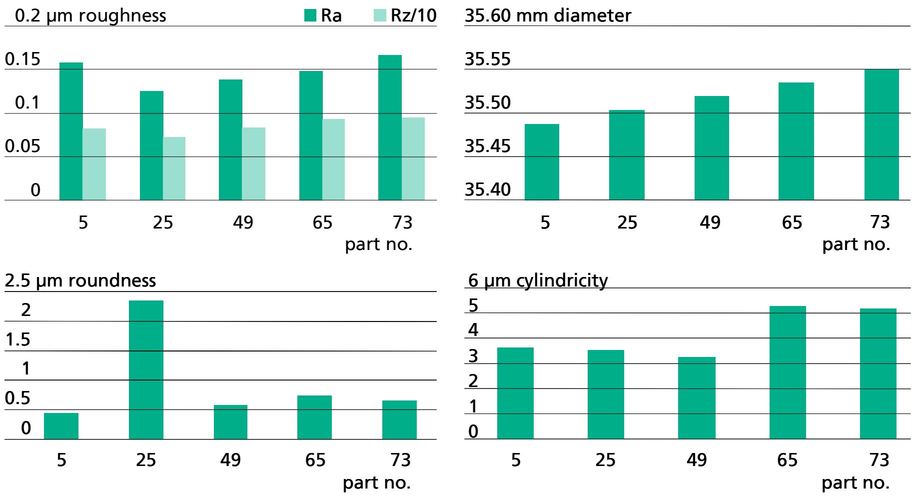


Fig. 11: Measurement results of five only turned parts

It can be stated that the roughness values are quite constant around a value of Ra = 0.15 µm. The slightly increasing diameter and the varying values of cylindricity can be explained by growing tool wear. Concerning the roundness values the extremely high value of part 25 can only be declared as irregularity due to the fact that the following parts have roundness values of approximately 0.6 µm.

Results of the TAF honing tests

As explained before the hard turning parameters were held constant and the honing parameters for each test run were varied in frequency and time.

In each test run the honing stone pressure was held constant. For the other tests only the grain sizes of the honing stones were varied to D14-20 and D7-10. This procedure for the test runs was chosen to identify possible influences of the frequency and the honing time on the roughness output of the honing operation. In the following exemplary results are displayed and shortly interpreted.

Results of D46

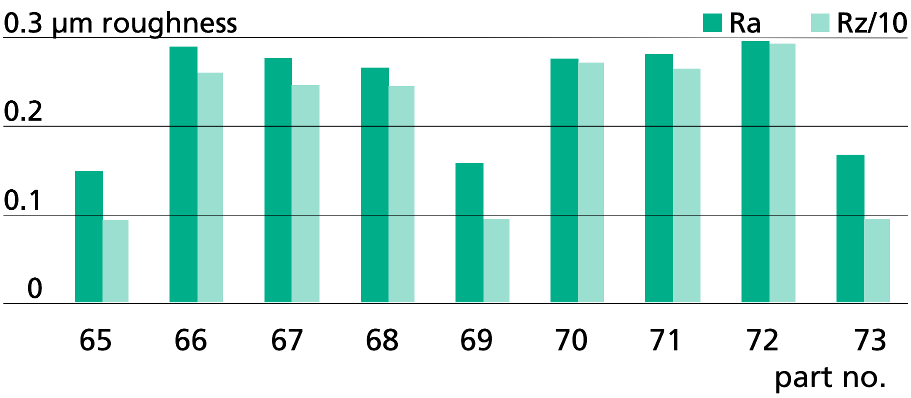


Fig. 12: Roughnesses of parts honed with D46 (T = 8 s)

What can be seen exemplarily for the result of the honing operation with a grain size of D46 (Fig. 12) is that the roughness values after hard turning (parts 65, 69 and 73 which were quite constant at Ra = 0.15 µm) were increased by the honing operation. This leads to the conclusion that grain sizes of D46 are not applicable for the combined TAF process.

Results of D14-20

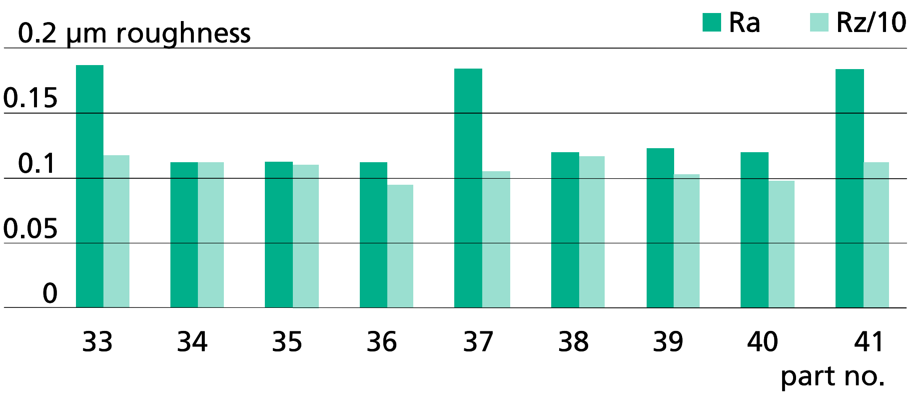


Fig. 13: Roughnesses of parts honed with D14-20 (T = 16 s)

The roughnesses of the turned parts in this batch (parts 33, 37 and 41) were also constant of about Ra = 0.17 µm. After the honing operation with the TAF system the roughnesses could be decreased around a value of Ra = 0.11 µm. These results are comparable to the results of the external honing tests concerning the used honing stone grain size. The roughnesses from all parts in this batch (also with the parameter variations) were decreased to almost the same Ra value.

Results of D7-10

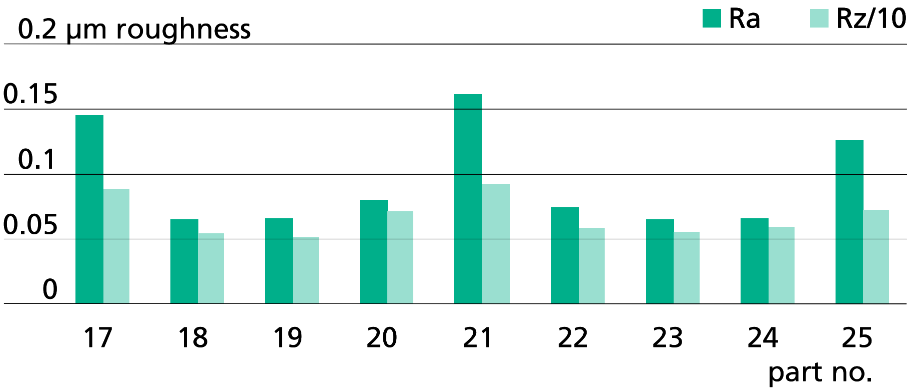


Fig. 14: Roughnesses of parts honed with D7-10 (T = 8 s)

Figure 14 shows exemplarily the results of the TAF honing tests with D7-10 grain sizes. With this grain size the best results were achieved. All Ra values of the three batches were below 0.1 µm regardless of the initial roughness after hard turning.

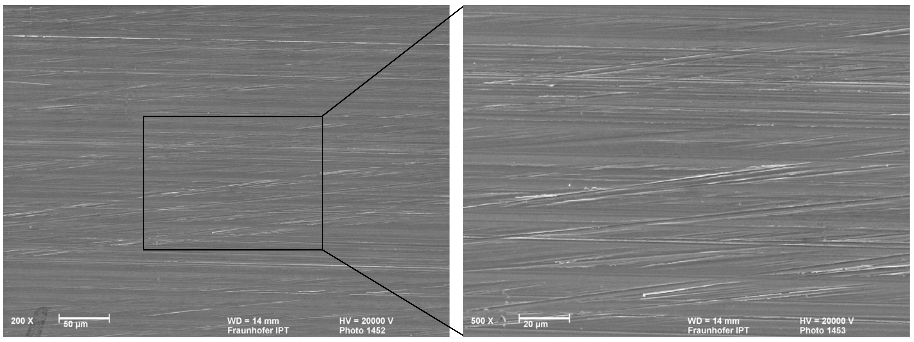


Fig. 15: SEM pictures of part 23

Figure 15 shows the SEM pictures of part 23 manufactured in the above shown batch with magnifications of 200 and 500. It can be stated that the cross grooves of the honing operation can be identified. It has to be mentioned that all surfaces had similar cross structures regardless the used grain sizes from which the conclusion can be drawn that the honing process works as desired and envisaged in the combined TAF process.

Verification tests

After the identification of grain size D7-10 as most suitable for machining the parts in question some verification tests were carried out:

- usage of a new cutting tool for hard turning
- machining with D7-10 grain size
- batch of three parts for each honing parameter combination

The roughness results of the first tests are shown in Fig. 16. The results of these tests confirmed the previously gained results.

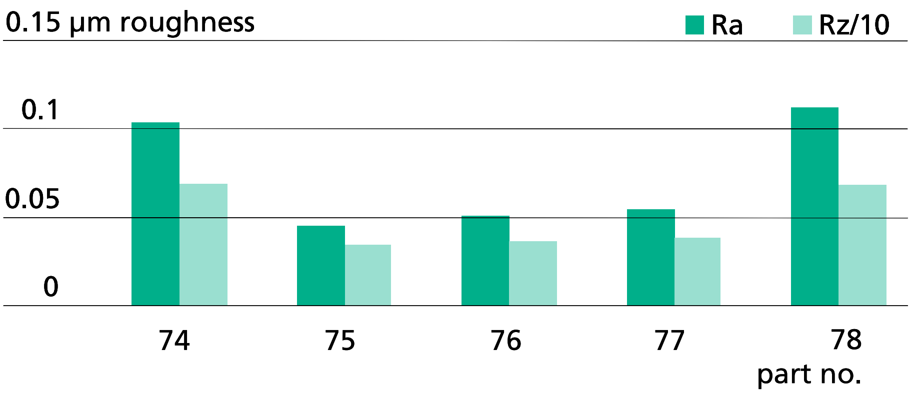


Fig. 16: Exemplary results of verification tests

Concerning the surface topography produced by means of the combined machining Fig. 17 shows the measurement results of a hard turned and a honed surface. It can be stated that the honed surface is characterised by a merely random scattering of the roughness peaks compared to the turned surface. These topography formations are usual for hard turned or honed surfaces. Also a decrease of the roughness (peak to valley width) is visible.

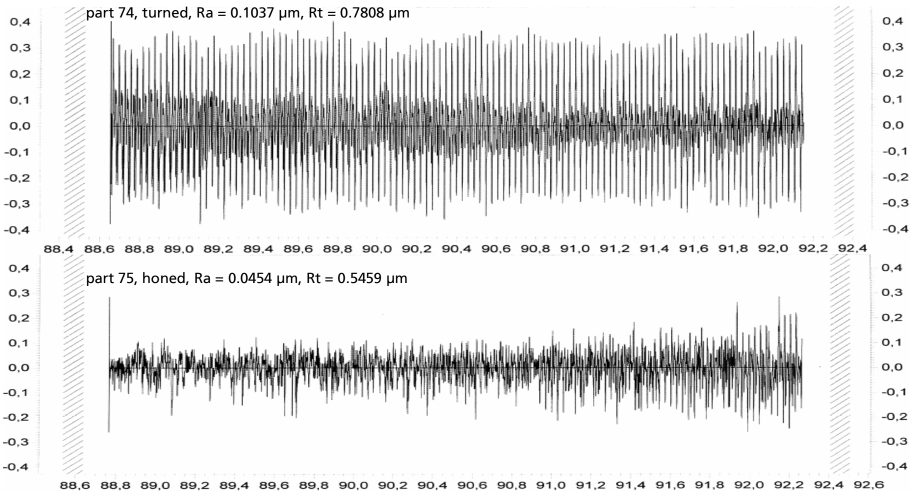


Fig. 17: Surface topographies from a hard turned (upper) and a honed (lower) surface

Further results and conclusions

As typical for conventional honing processes the roundness values attained after turning were not affected by the supefinishing process. The cylindricity values also are within usual precise ranges after the honing operation and a suspected form error (convex surface) did not appear. Since very accurate tolerances concerning roundness and cylindricity can be achieved by means of hard turning with a high level of reliability the restrictions defined at the start of the project could be fulfilled. Additionally the results of the combined machining tests and the verification tests led to the following conclusions:

- Honing stones with grain sizes of D46 and D14-20 are not applicable for the parts of the TAF project
- Grain sizes of D7-10 are most suitable
- Machining of the inner ring demonstrator with complex geometry (shoulders next to the raceway) has been carried out
- Doubling of the frequency for the honing process shows better results concerning the attainable roughness than doubling of the honing time
- Roughness values of the hard turned surfaces could be bisected
- Further tests aiming at the optimisation of both TAF system and TAF process have to be carried out

Also the feasibility of complete machining high precision parts by means of the TAF process could be proven which in consequence leads to the fulfilment of all Milestone 2 criteria.

1.3.3 Comparison of planned activities and work accomplished

The following table shows a comparison of both still to be made up tasks and tasks planned for the second project period (months 13 – 18) with the work accomplished.

<table>
<tr><th>Planned tasks</th><th>Who</th><th>Accomplished</th></tr>
<tr><td>- modification of the high-precision hard turning lathe (originally planned for month 9, rescheduled for project month 13)</td><td>TU Miskolc
Hembrug</td><td>Yes</td></tr>
<tr><td rowspan="2">- honing of ground test parts with different initial roughness values
- honing of hard turned test parts with different initial roughness values (parts submitted by the Fraunhofer IPT)
- recording of the time needed for the honing operation to attain the final roughness of Ra = 0.02 µm with different initial roughness values and pre-machining steps (hard turned, ground)
- comparison of the process times concerning the initial roughness of the ground and hard turned test pieces
- derivation of initial parameters for the combined TAF process</td><td>HWG
(Fraunhofer IPT)</td><td>Yes, for both the Mid-Term Meeting and the 18-Months Meeting</td></tr>
<tr><td colspan="2">Originally scheduled for middle of April 2006 at HWG, carried out by an external company due to capacity problems at HWG</td></tr>
<tr><td rowspan="2">- initial tests with the combined process
- identification of possible improvements concerning the superfinishing device and/or the honing tools
- process layout tests resulting in a first optimisation of the TAF process</td><td>Fraunhofer IPT (all)</td><td>Yes</td></tr>
<tr><td colspan="2">Originally scheduled for project month 9, rescheduled for month 13</td></tr>
<tr><td>- machining tests with the TAF prototype system (combined machining of hard turning and honing)
- improvement of the hard turning process with regard to the results achieved in the subsequent superfinishing process
- preparation of test specimens for the machining tests</td><td>Fraunhofer IPT
TU Miskolc
Hembrug
Cerobear
HWG</td><td>Yes</td></tr>
<tr><td>- identification of possibilities to improve the superfinishing device and the superfinishing tools based on the test results of the prototype TAF system
- improvement of the high-precision hard turning lathe</td><td>Fraunhofer IPT
TU Miskolc
Hembrug
Diasfin</td><td>Yes</td></tr>
<tr><td>- identification and implementation of suitable possibilities of eliminating form errors (convex surfaces)
- identification of the best suitable contact angle of the superfinishing tools with the part surface</td><td>Fraunhofer IPT
Diasfin
(Cerobear
HWG)</td><td>Yes</td></tr>
<tr><td>- pre-machining and providing of test specimens to be machined in WP 4 (end users)</td><td>Cerobear
HWG</td><td>Yes, constantly carried out by Cerobear and HWG during the project</td></tr>
</table>

Tab. 5: Comparison of planned tasks and work accomplished (months 13 – 18)

1.3.4 Comparison of planned and accomplished deliverables

Deliverable No	Deliverable title	Envisaged delivery date	Accomplished
D7	Mature TAF system	18	Yes, partly (modifications and improvements are in work)
D8	Status report including documentation about the mature TAF system and machining parameters	18	Yes

Tab. 6: Comparison of initially planned and accomplished deliverables (months 13 – 18)

1.4 Project period 4 (months 19 – 24)

1.4.1 Summary of the objectives

According to the work plan proposed by the RTD Performer and the decisions taken by the project consortium in the previous meetings, the objectives for the last project period can be summarised by machining tests with the advanced TAF system. The results of these tests ought to be used for

- the improvement of the hard turning process with regard to the results achieved in the subsequent superfinishing process
- extensive machining tests with the TAF system (combined machining of hard turning and honing)
- identification of the best process parameters for the combined TAF process
- compilation of the identified parameters and suggestions of usage of the TAF system

The envisaged work of the partners encompassed:

- the improvement of the connection to the lathe control with regard to an better control of the superfinishing device movement
- the preparation of test specimens by the end users for the machining tests with the geometry decided on the 18-Months Meeting
- the improvement of the honing tools (higher concentration of diamond grain of D7-10 honing stones, smaller diamond grain: D3-5 stones) and providing the Fraunhofer IPT with the improved honing stones

At the end of the last project period the following work contents were envisaged to be carried out:

- technical and economical evaluation of the TAF process
- suggestions concerning an improvement of the superfinishing device concerning its overall size

1.4.2 Overview of the technical progress

New part geometry and experimental plan

Within the last project period the optimisation of the combined TAF process was envisaged. For this extensive machining tests had to be carried out focussing on an adjustment of both processes (hard turning and honing) to each other. Since the general feasibility of producing the demonstrator parts has been proved at the Mid-Term Meeting the consortium had decided to use parts with geometrical modifications for the machining tests of the last period. Figure 22 shows the part which were suggested by the Fraunhofer IPT during the 18-Months Meeting.

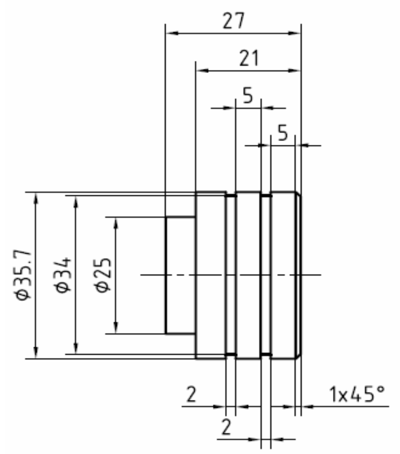


Fig. 18: Test part for the last project period

The vantages of the changed part are:

- a simple part geometry
- a reduction of total test machining time (turning)
- a possibility of machining two raceways with a desired diameter range of 35.483 mm to 35.471 mm (dimension of the demonstrator part)

For the optimisation tests the process parameters for hard turning were used in accordance to the previously carried out turning tests and with appointment of the consortium:

In order to achieve accurate diameter, roundness and cylindricity values the coolant (Sunnen SCC-205) was also used for the hard turning operation. For all tests only one turning tool was used.

The experimental plan encompassed:

- manufacturing of batches of four parts
  - two surfaces only turned
  - six surfaces with the same honing parameters
- on each part the roughness, the raceway diameter, the roundness and the cylindricity were measured

The proceeding of this experimental plan was similar to the one done in the third project period. As can be seen in Fig. 19 the first and fifth surface is only turned. This enables the possibility to get an overview about the development of the roughness values achieved by means of hard turning throughout the complete tests. Hence the influence of the initial roughness on the obtained roughness with the subsequent honing process can be detected.

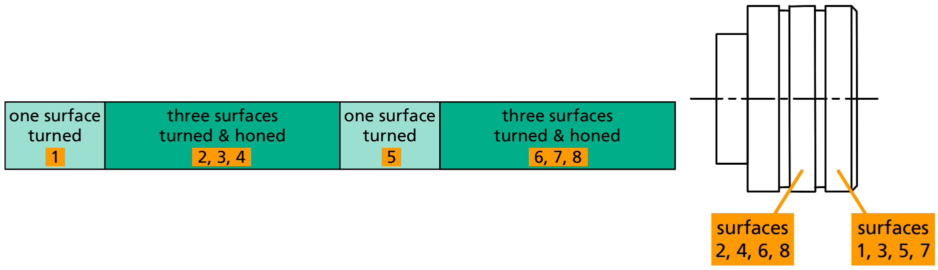


Fig. 19: Proceeding of the TAF tests for one batch

The complete tests encompassed the manufacturing of 192 surfaces (=96 parts). Concerning the above mentioned measurements only the roughness values will be discussed in further course due to the fact that for the values of roundness and cylindricity no limits have been set by the consortium. The average values are listed in the following:

roundness	0.91 µm
cylindricity	1.52 µm

Regarding the desired diameter a tolerance range of 12 µm (35.483 mm to 35.471 mm) was postulated and reached: all parts manufactured by means of the TAF system were within a range of 11 µm (35.483 mm to 35.472 mm).

For all tests the following honing parameters were held constant.

Tests without superposition of Z-axis movement

These tests were carried out in order to receive comparable information about the influence of the grain concentration and the grain sizes on the outcome of the honing operation.

The following parameters were used:

honing stone grain sizes	D7-10 (higher concentration = hc)
	D3-5
honing time	T = 8 s, 16 s

Figure 20 shows the attained roughness values of the combined machining with honing stone grain sizes of D7-10 (hc) and D3-5 with 8 and 16 seconds honing.

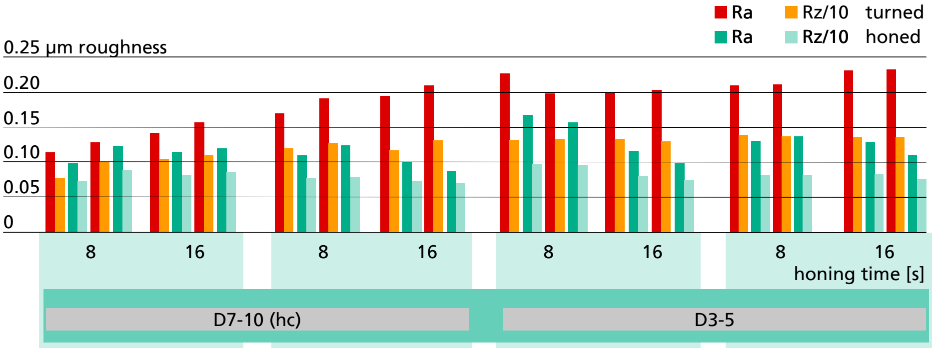


Fig. 20: Roughness values attained with D7-10 (hc) and D3-5

The following can be stated for the results with D7-10 (hc):

- slightly better results with honing
- doubling the honing time has only a slight effect on attainable roughness
- doubling of frequency results in almost bisecting the hard turned roughness

Concerning the tests with D3-5 the following conclusions can be drawn:

- doubling the honing time results in better attainable roughness
- doubling of frequency results in almost bisecting the hard turned roughness

Although the roughness values of the hard turned surfaces could almost be bisected with both grain sizes the roughness values after honing were still too high compared to the desired roughness value of Ra = 0.02 µm set at the beginning of the project.

Tests with superposition of Z-axis movement

For these tests the parameters listed below were used.

honing stone grain sizes	D7-10 (hc)
	D3-5
honing time	T = 8 s, 16 s

Figure 21 shows the kinematics of a honing operation in conjunction with a superponed Z-axis movement.

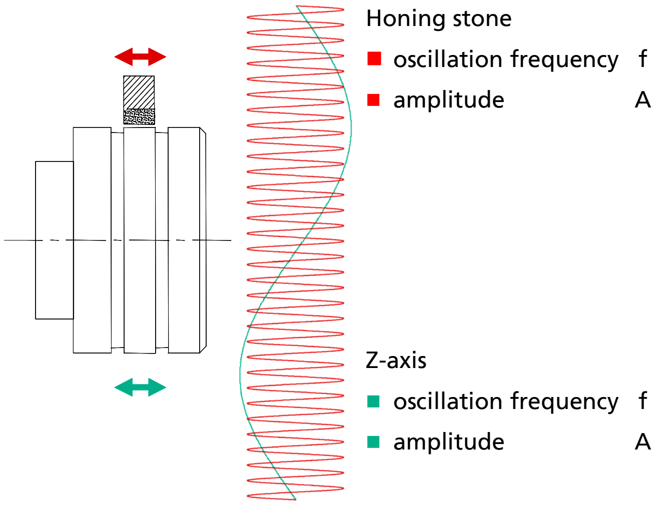


Fig. 21: Combined honing stone and Z-axis oscillation

The vantages of this combination can be summarised as follows:

- superposition of a high-frequency and a low-frequency oscillation
- a wider surface can be honed even with
  - a thinner honing stone
  - smaller honing amplitude
- better roughness values can be achieved

The roughness values achieved with this kinematic and honing stones with grain size of D7-10 (hc) are shown below (Fig. 22).

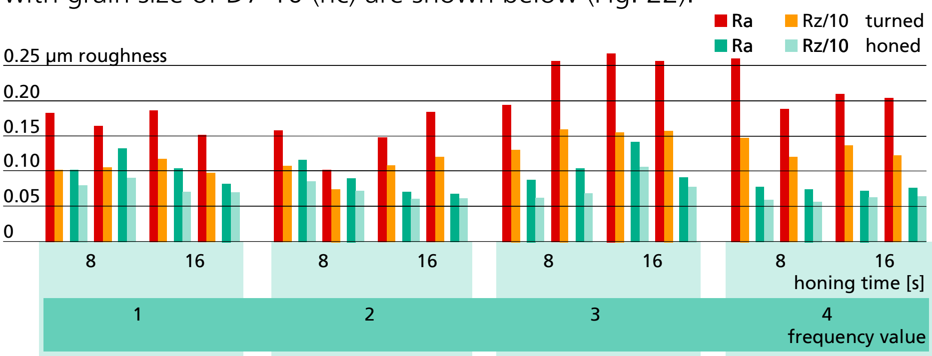


Fig. 22: Roughness values achieved with D7-10 (hc) and superponed Z-axis movement

As results it can be stated that:

- a higher honing frequency leads to better roughness results compared to the initial achieved roughness of hard turning
- doubling honing time at frequency value 1, 3 and 4 has no effect on roughness outcome

- doubling honing time at frequency value 2 leads to better roughness results

Figure 23 shows the results gained with the same process parameters and honing stones with a grain size of D3-5.

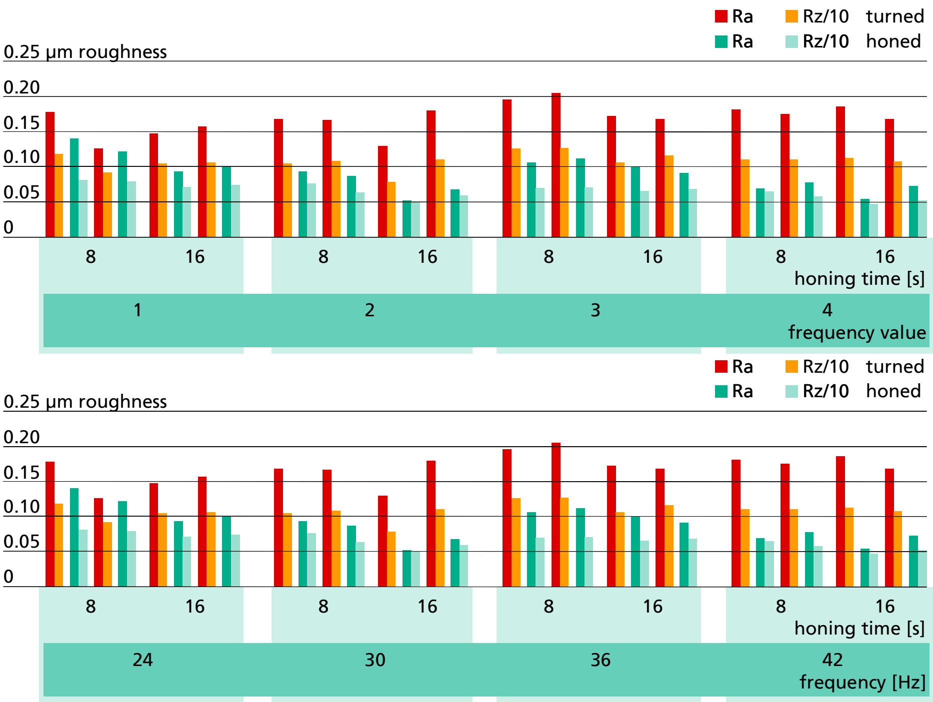


Fig. 23: Roughness values achieved with D3-5 and superponed Z-axis movement

Based on these results the following conclusions are drawn:

- best roughness results with frequency values of 2 and 4
- doubling honing time at frequency values of 1, 3 and 4 has no remarkable effect on roughness outcome
- doubling honing time at frequency value 2 leads to better roughness results

To summarise the results of both test series the following facts are listed:

- all tests were done with one turning tool
- the diameters were within the desired tolerance range
- higher honing frequency leads to better roughness results compared to the initial achieved roughness of hard turning
- superposition of Z-axis movement in conjunction with higher frequencies of the honing head shows better roughness results of the combined process

- doubling the honing time at frequency values of 1, 3 and 4 has no effect on roughness outcome
- doubling honing time at frequency value 2 leads to better roughness results
- honing with superposition of Z-axis movement leads to better roughness results than honing without
- best Ra values achieved so far: approx. 0.05 µm

These results led to the conclusions that verification tests were necessary for further optimisation of the TAF process.

Verification tests

Since the honing amplitude of 0.25 mm was instable at frequency value 4 and the results at a frequency value 2 were comparable the process parameters were set and the following variations of honing time were chosen:

- T = 30 s
- T = 45 s
- T = 60 s
- T = 75 s

- turning tool for raceway
  - first tests with old worn tool
  - additional verification tests with new tool

The results achieved with the combined process (with the worn turning tool) shows Figure 24:

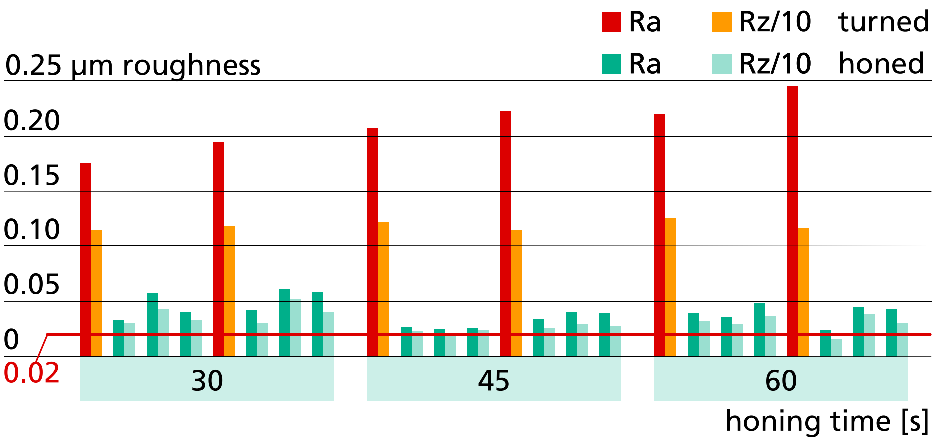


Fig. 24: Verification test results of the combined process (worn turning tool, D3-5)

From the results the following statements can be made:

- the turned roughness shows slight increase
- high roughness values after turning due to worn tool
- the roughness values after turning could be almost quatered by means of honing
- desired roughness value of Ra = 0.2 µm could not be reached
- achieved average value of Ra = 0.04 µm after honing

To have an additional verification of these results a repetition of these tests was carried out and showed comparable results with an average value of Ra = 0.046 µm. Since the initial roughness after hard turning seems to have an effect on the outcome after honing the tests were also carried out by using a new and not-worn turning tool. The batch size was changed to ten parts per batch which equals to 20 surfaces (five only turned sufaces and 15 sufaces processed by means of combined TAF process). Furthermore the honing operation was additionally performed with a duration of 75 seconds.

The results of these tests are shown in Fig. 25.

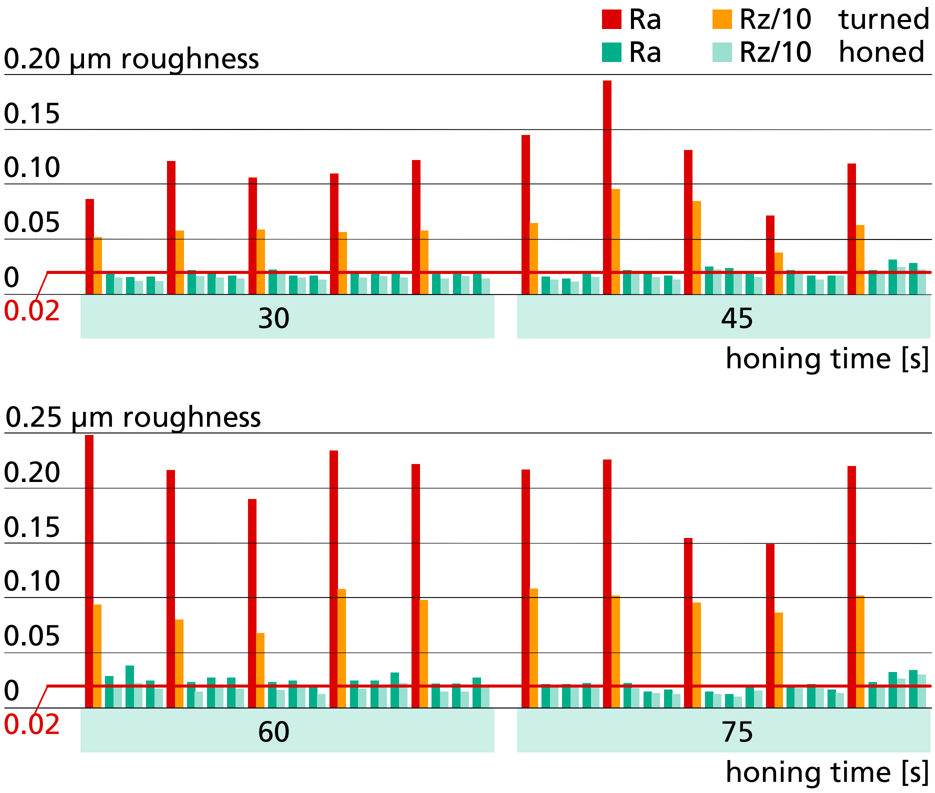


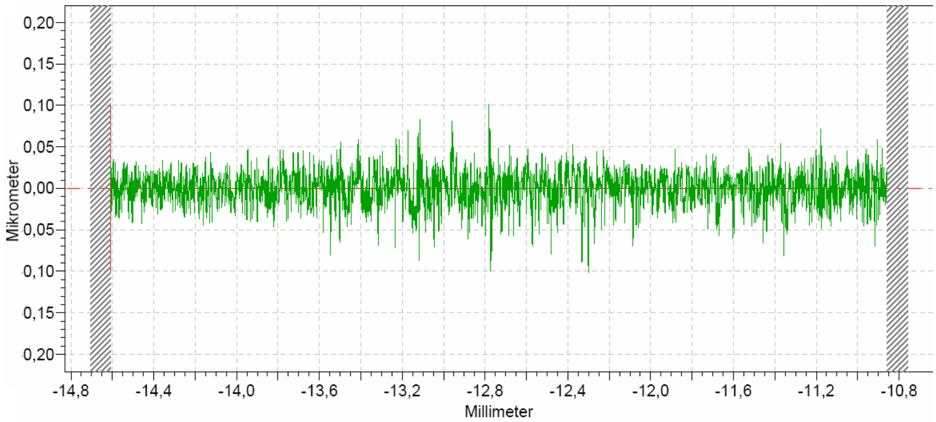
Fig. 25: Verification test results of the combined process (new turning tool, D3-5)

The average test results are listed in the following:

Ra	0.0207 µm
Max. Ra	0.0353 µm
Min. Ra	0.0133 µm
(Rz	0.1754 µm)
Diameter	35.478 mm
Max. Ø	35.483 mm
Min. Ø	35.472 mm

The results of these verification tests show that the desired roughness of Ra = 0.02 µm can be reached by producing cylinder bearing raceways by means of the TAF process.

Figure 26 shows in the upper part the roughness measurement of surface no. 3 of the first batch (honing time 30 s). The lower part shows the picture of the honed raceway surface (criss-crossed structure) taken by a white light interferometer.



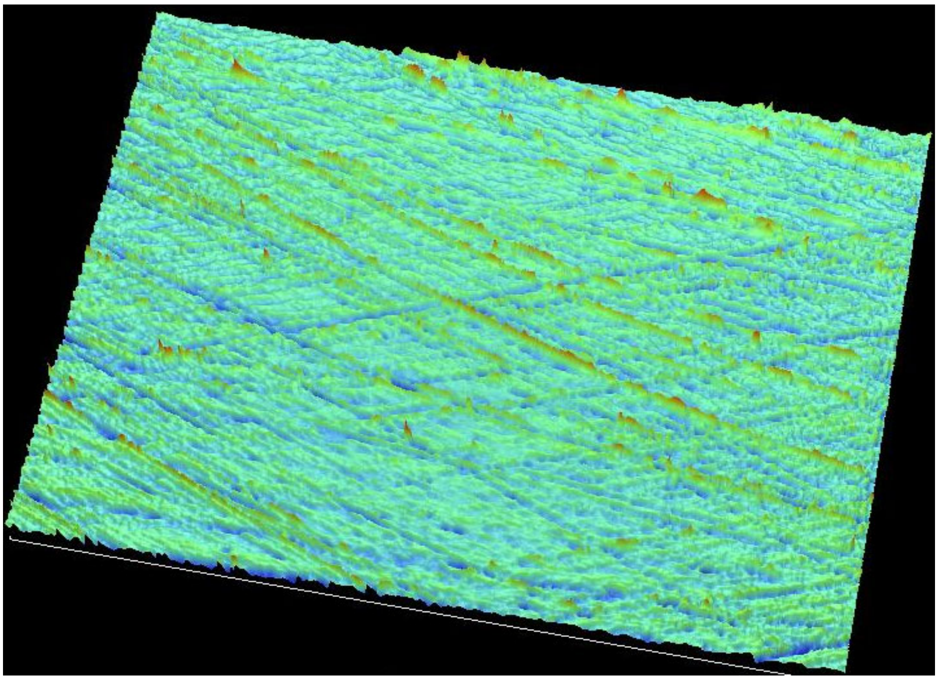


Fig. 26: Surface no. 3, honing time 30 s
above: roughness measurement
(Ra = 0.0157 µm, Rz = 0.1270 µm)
below: white light interferometer surface picture

After these verification tests a batch of ten demonstrator outer ring parts was produced with the process parameters identified in the described tests in order to proof the feasibility of combined machining with internal honing. The results of these tests were comparable to the tests carried out and described before.

In consequence the feasibility of the TAF system for producing cylindrical bearing components (inner and outer rings) have been proven.

1.4.3 Comparison of planned activities and work accomplished

The following table shows a comparison of tasks planned for the last project period (months 19 – 24) with the work accomplished with regard to the light changes in the workplan. The decisions were taken by the consortium during the 18-Months Meeting on July 7th 2006 in Bucharest and are listed in the minutes.

Planned tasks	Who	Accomplished
- preparation of test specimens by the end users for the machining tests with the geometry decided on the 18-Months Meeting - improvement of the connection to the lathe control with regard to an better control of the superfinishing device movement - improvement of the honing tools (higher concentration of diamond grain of D7-10 honing stones, smaller diamond grain: D3-5 stones), providing the Fraunhofer IPT with the improved honing stones - improvement of the hard turning process with regard to the results achieved in the subsequent superfinishing process - extensive machining tests with the TAF system (combined machining of hard turning and honing)	Fraunhofer IPT all	Yes
- identification of the best process parameters for the combined TAF process - compilation of the identified parameters and suggestions of usage of the TAF system - improvement of the superfinishing device concerning its overall size - technical and economical evaluation of the TAF process	Fraunhofer IPT TU Miskolc Hembrug	Yes

Tab. 7: Action plan for the fourth project period (months 19 – 24)

1.4.4 Comparison of planned and accomplished deliverables

Deliverable No	Deliverable title	Envisaged delivery date	Accomplished
D9	Final TAF system	24	Yes, stationed at the Fraunhofer IPT
D10	Report of the technical and economical evaluation results including the test results on real parts	24	Yes, see chapter 2.2 of this report and deliverable report
		No tests on real parts were carried out due to the fact that this deliverable item was decided by the partners to be left out during the 18-Months Meeting (see minutes of the 18 months meeting).	
D11	Final report including "operation instructions" of the TAF system and final version of the plan for using and dissemination of knowledge	24	Yes, see chapters 2.1 and 2.4 of this report
D12	Publications of non-confidential results	24	Yes, partly. A publication of non-confidential results will be carried out by the Fraunhofer IPT in »MaschinenMarkt« until end of march 2007

Tab. 8: Comparison of initially planned and accomplished deliverables (months 19 – 24)

2 General outcome of the project

2.1 Technical and economic evaluation

The two end-users in the project consortium (Cerobear and HWG) are both producing high-precision bearing components and complete bearings. Since both are using different strategies and process chains the TAF process has to be compared differently to both process chains for the technical and economic evaluation. Cerobear is only using the hard turning technology for their production and HWG is already using a process chain consistent of hard turning and honing but on two different machines. The evaluation was calculated for producing 50 raceways.

Technical and economic evaluation – Cerobear

For the evaluation the following values were provided by Cerobear for turning one raceway:

process time	300 s
achievable roughness Ra	0.05 µm < 0.07 µm
necessary tool change	after 10 raceways
time for tool change	5 – 10 min (300 – 600 s)

The following figure shows a comparison of production times of the actual process chain used by Cerobear and the TAF process chain with a comparison of the necessary tool costs.

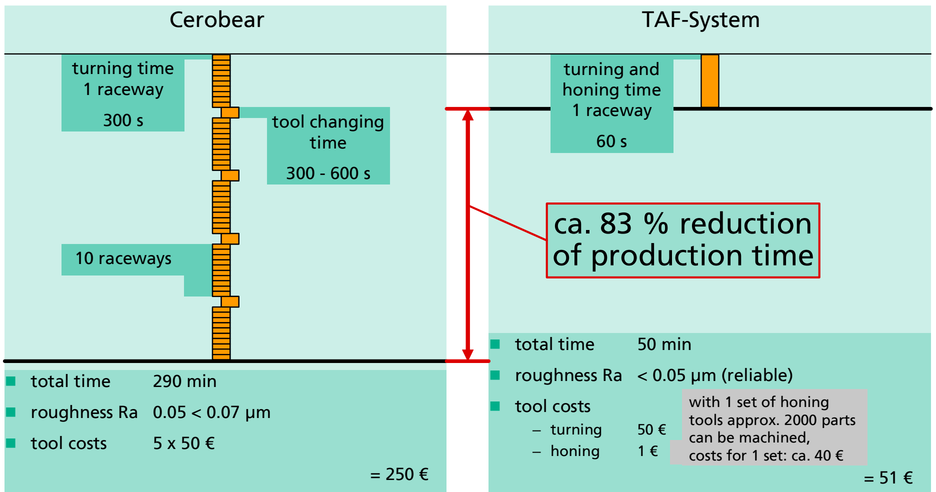


Fig. 27: Graphical comparison of production time and costs (Cerobear vs. TAF system)

From this comparison it can be stated that by means of the TAF system a reduction of production time by approx. 83 % and a reduction of tool costs of approx. 79 % is possible. Additionally it has to be asserted that with the TAF system better surface qualities are achieved reliably compared to the actual process chain used by Cerobear.

Technical and economic evaluation – HWG

For the evaluation the following values were provided by HWG for turning and honing one raceway:

process time	40 s
achievable roughness Ra	< 0.05 µm
time for machine change	250 s (5 s per part)
time for honing machine set-up	240 min

The following figure shows a comparison of production times of the actual process chain used by HWG and the TAF process.

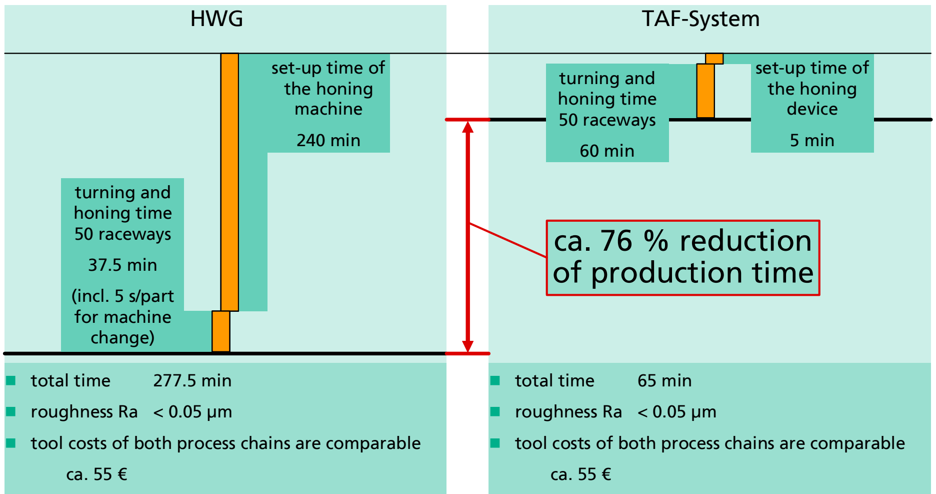


Fig. 28: Graphical comparison of production time (HWG vs. TAF system)

From this comparison it can be stated that by means of the TAF system a reduction of production time by approx. 76 % is possible. The tool costs for both processes are comparable.

2.2 Final conclusions

In the following the final conclusion regarding the results of the project are listed.

- Combined machining of hard turning and honing of bearing rings (inner and outer machining) by means of the TAF system is possible
- The defined restrictions concerning dimension and form of the machined workpieces could be attained
- The aim concerning the surface roughness defined during the Kick-Off Meeting of Ra = 0.02 µm can be reached with the TAF system
- The surface roughness after turning has an effect on the outcome of the subsequent honing process
- Best results by means of the TAF process could be achieved with roughness values of Ra ≤ 0.1 µm after hard turning
- Surface roughness values (Ra > 0.1 µm) achieved with hard turning can be compensated by longer honing time to attain desired final roughness values
- Manufacturing times for the raceway of a bearing ring can be cut up to 83 %
- Tool costs can be cut up to 79 %

For a commercial and industrial use of the TAF system the following suggestions were made.

- smaller overall size of the honing device to fit into a Hembrug 50 CNC
- capability for different workpiece sizes (bigger and smaller diameter)
- a simple solution for setting or adjusting the honing frequency and amplitude in the lathe control and NC programs
- an absolute way-measurement system for the honing device
- internal coolant (emulsion) supply for the honing operation capable for inner and outer honing operations

As final result of this project it can be asserted that the project aims have been reached completely.

3 Management and co-ordination aspects

3.1 List of meetings

The meetings listed below took place during the complete project period, i.e. from 02/01/2005 to 01/31/2007.

Subject	Time and place	Participants
Kick-off Meeting	01/28/2005 TU Miskolc	RTD Performers All partners (except Mr. Coluccio)
Technical Meeting	03/30/2005 Hembrug	RTD Performers Hembrug, Cerobear
Six-Months Meeting	07/08/2005 Hembrug	RTD Performers All partners
Mid-Term Meeting	03/31/2006 Fraunhofer IPT	RTD Performers All partners
18-Months Meeting	07/07/2006 Diasfin	RTD Performers All partners
Final Meeting	01/31/2007 Fraunhofer IPT	RTD Performers All partners

Moreover, contact between the RTD Performers and all partners was regularly made by phone and via e-mail, with the objective of gaining information about the project's progress and to make decisions/find solutions concerning the single sub-tasks.

3.2 Public presentations

No public presentations were planned for the first three project periods. Since the companies of Hembrug and the Fraunhofer IPT were participating on various fairs, it was envisaged to use such opportunities to present preliminary non-confidential results of the project work.

Additionally at the Fraunhofer IPT a poster and a handout describing the project idea are stationed at the hard turning area. Therefore all visitors who have a tour through the machine shop floor are informed about the project.

During the 18-Months Meeting in Bucharest the consortium agreed to a publication of non-confidential results in a journal presenting the results gained in the project work. The Fraunhofer IPT will take care of this publication in agreement with the consortium within two months after project end in a monthly journal called »MaschinenMarkt«. Additionally the TU Miskolc was host of a conference dealing with design, CAD/CAM and FE calculations on November 9th – 10th 2006. In this conference a presentation concerning the design of the honing device was held.

4 Appendices

4.1 Appendix 13 – Science and society reporting questionnaire

Completed by Drs. Robert Nefkens (Hembrug), co-ordinator of TAF.

A General Information on Contractor

1	**Contract Number:**	COOP - CT - 2004 - 508143
2	**Instrument:**	CRAFT
3	**Thematic Priority:**	Production Technology
4	**Title of Project:**	TAF – Turn And Finish – Development of a combined hard turning and superfinishing technology
5	**Name and Title of Coordinator:**	Drs. Robert Nefkens
6	**Period Covered, Start Date:**	01/02/05 **End Date:** 31/01/07
7	**EC Contribution to project:**	€ 317 800

B Ethics

8 Which (if any) of the following does your research project involve?

- O Human beings
- O Human biological samples
- O Personal data
- O Genetic information
- O Animals
- O Human embryos or human embryonic stem cells
- O Non human primates and other animals
- X None of the above

9 To what extent do you believe ethical issues are relevant to your research project?

- X Not relevant
- O Minor relevance
- O Significant relevance
- O Critical

10 Do you have Ethicists or others with considerable ethics experience involved in the project?

- O Yes
- X No

11 Did your project have a separate EC ethical review?

- O Yes
- X No

12 How much (including the value of time spent, as well as paid-out costs) do you estimate your project (when it is completed) will have spent on considering and dealing with ethical issues?

€ 0

C Gender (to be completed for all projects except IPs and NoEs)

13a Did you undertake Gender Equality Actions in your research project?

- O Yes
- X No

13b If no, why not?

- X Not relevant
- O Team not gender aware
- O No budget
- O Not supported (no will)
- O Other:

13c If yes, which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
O Design and implement an equal opportunity policy	O	O	O	O	O
O Implement mentoring schemes for women	O	O	O	O	O
O Family friendly working conditions	O	O	O	O	O

14 Was there a gender dimension associated with the research content?

- O Yes. If yes, please specify
- X No

15 How much (including the value of time spent, as well as paid-out costs) do you estimate your project (when it is completed) will have spent on considering and dealing with gender issues?

€ 0

D Science Education, Training and Career Development

16a Does this project anticipate having a direct impact on the local economy?

- X Yes
- O No

16b If Yes, is the project:

- X Stimulating employment
- O Retaining highly trained personnel
- O Creating possible spin-out/start-up companies

17 Does your partnership employ and train researchers?

- X Yes
- O No

18 Does your project involve working with young people at schools?

- O Yes
- X No

19 Is there any education material being produced directly or indirectly by your project?

- O Yes
- X No

20 How much (including the value of time spent, as well as paid-out costs) do you estimate your project (when it is completed) will have spent on considering and dealing with Science Education, Training and Career Development issues?
0 €

E Engaging With Actors Beyond the Research Community

20a Is the project likely to generate outputs (expertise or scientific advice) which could be used by policy makers?

O Yes
X No

20b If Yes, is this a primary or secondary objective of the project?

O Primary
O Secondary

21a Did your project engage in significant communication with the public before research commenced?

O Yes
X No

21b Was the focus or methodology of your project modified in response to any communication with the public?

O Yes
X No

22 Does your project involve someone whose role is solely to communicate with the public?

O Yes
X No

F Use and dissemination

23 How many articles were published ?

In refereed journals: 0 Other journals: 0

24 How many patents have been applied for ?

0

25 How many other Intellectual Property Rights were applied for?

0

26 How many spin-offs were created?

0

27 Have you issued press releases related to your project (and if so, how many)?

O Yes, number:

X No

28 Have you held media briefings? If so, how many, and on average roughly how many journalists attended?

O Yes, number of briefings: average number of journalists:

X No

29a Roughly how many items covering your project in the printed press, on radio or television can you identify?

Press: 0 Radio: 0 Television: 0

29b Roughly how many items were:

Specialist Press:	0	Non-specialist Press:	0
National Press:	0	International Press:	0

30a Was there on-line information about the project?

O Yes
O Specific web site
X No

30b Roughly how frequently has it been updated?

-

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31 Do you have an e-mail mailing list to send news about the project? If so, how many subscribers to the list are there?

O Yes, number of subscribers:
X No

32a Have you created or participated in an event (e.g. workshop, conference, information day) in order to communicate with the public (not just other researchers or the press)?

O Yes
X No

32b Roughly how many people attended these events and learned about your project?

-

33a Have you produced a video or DVD film about your project?

O Yes
X No

33b If so, how effective do you believe it has been in communicating with the public?

X Unable to assess

O Completely ineffective
O Mostly ineffective
O Partially effective
O Significantly effective
O Extremely effective

34a Have you produced posters, flyers or brochures about your project?

X Yes
O No

34b If so, how effective do you believe they have been in communicating with the public?

O Unable to assess

O Completely ineffective
O Mostly ineffective
X Partially effective
O Significantly effective
O Extremely effective

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35 In how many different languages were these products (video/DVD, posters, flyers, brochures) produced?

2 (ger., eng.)

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36 How have you distributed these products (video/DVD, posters, flyers, brochures)? Please tick all methods you have used.

X Sent on request
O Sent to schools/academic institutions
O Distributed through government agencies/public buildings/libraries etc.
O Sent to potentially interested non-governmental bodies (NGOs, citizen's associations etc)
X Other: Flyers and posters were freely accessible to visitors of the Fraunhofer IPT in Aachen, Germany

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G Total Communication Spend

37 How much (including the value of time spent, as well as paid-out costs) do you estimate your project (when it is completed) will have spent on communication activities (engaging with the public, use and dissemination) as described in the current questionnaire?

€ 2 500

H Comments

38 If you have any comments about your experience of meeting the Science and Society objectives within your project, or any suggestions of improvements to the programme please add them here:

4.2 Appendix 15 – Interim and final reporting questionnaires on workforce statistics

In the following all results from the questionnaire of appendix 15 broken down to each contractor are shown.

1. General information

1.1.	Contract No.:	COOP - CT - 2004 - 508143
1.2.	Thematic priority:	Production Technology
1.3.	Instrument type:	CRAFT
1.4.	Project acronym:	TAF
1.5.	Period covered (Start Date – End Date):	01/02/2005 31/01/2007
1.6.	Name and title of co-ordinator:	Drs. Robert Nefkens

2. Scientific leadership and management, and workforce statistics for the project completed by contractors

Hembrug

Type of position	No. of women	No. of men	Total	% women	% men
Scientific manager	-	1	1	-	100
Scientific team leader / work package manager	-	1	1	-	100
Experienced researcher (> 4 years)					
Early researcher (<= 4 years)					
PhD students					
Technical staff	-	5	5	-	100
Other					

Cerobear

Type of position	No. of women	No. of men	Total	% women	% men
Scientific manager	1	1	2	50	50
Scientific team leader / work package manager	-	1	1	-	100
Experienced researcher (> 4 years)					
Early researcher (<= 4 years)					
PhD students					
Technical staff	-	3	3	-	100
Other	2	-	2	100	-

HWG

Type of position	No. of women	No. of men	Total	% women	% men
Scientific manager					
Scientific team leader / work package manager	-	1	1	-	100
Experienced researcher (> 4 years)					
Early researcher (<= 4 years)					
PhD students					
Technical staff	-	3	3	-	100
Other	1	-	1	100	-

Diasfin

Type of position	No. of women	No. of men	Total	% women	% men
Scientific manager	-	1	1	-	100
Scientific team leader / work package manager	-	1	1	-	100
Experienced researcher (> 4 years)	-	2	2	-	100
Early researcher (<= 4 years)					
PhD students					
Technical staff	-	2	2	-	100
Other					

Fraunhofer IPT

Type of position	No. of women	No. of men	Total	% women	% men
Scientific manager					
Scientific team leader / work package manager					
Experienced researcher (> 4 years)	-	1	1	-	100
Early researcher (<= 4 years)					
PhD students					
Technical staff	1	1	2	50	50
Other	1	-	1	100	-

TU Miskolc

Type of position	No. of women	No. of men	Total	% women	% men
Scientific manager	-	2	2	-	100
Scientific team leader / work package manager	-	1	1	-	100
Experienced researcher (> 4 years)	1	5	6	17	83
Early researcher (<= 4 years)	-	1	1	-	100
PhD students	-	2	2	-	100
Technical staff	2	2	4	50	50
Other	1	-	1	100	-

4.3 Appendix 16 – Socio-economic reporting questionnaire

Due to the fact that all consortium members gave the same answers to the questions in this questionnaire, the following table shows the summarised result.

1.1	Do your tasks in the project include socio-economic research activities?	No
1.2	If "Yes", what is the estimated total budget allocation that addresses these activities?	N/A
2.1	Do your tasks in the project include foresight methods	No
2.2	If "Yes", what is the estimated total budget allocation that addresses these activities?	N/A
3.	How many person/months (estimated) are allocated to researchers with a background in social sciences, to perform your tasks for the project?	0