SYNTHESIS REPORT

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CRAFT Proposal No. CR-1082-91

Modern machining technologies and production techniques in the European subcontracting industry.

Brite-EuRam II

Project coordinator: Stichting Samenwerkingsverband
InnovatieCentrum Venlo
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1. Abstract

Under the title of this project 12 Proposers, 6 R&D-Performing organisations and 6 intermediary organisations in the Germany arid the Netherlands worked together on a wide variety of research subjects,
New product development, technology development, control software development, new ways of organizing production and quality management were subjects of the project.

Product development concerned the development of items such as a zero-tolerance gear rack driving assembly, a small and universal milling chips centrifuge linkable to **a** wide variety of machining equipment.

Technology development comprised a high speed milling unit for the machining of aluminum, the forming of high-quality internal screw thread in high-alloy steels, the automated assembling of a rack gear and the mechanical aliqnment of hardened circular saw blades.

A new kind of control software was developed linking a production control system directly to the software used for production preparation.

Production organisation and savings in time and money were the items concerning two Proposers, who actually managed to reorganize and physically regroup their production equipment in such a way, that they realized considerable savings in order lead time, clamping and resetting time and costs.

Finally three companies introduced the concept of quality management in the machining industry.

Most of the results of the research have already been implemented by the Proposers. Some are still working on prototype equipment. Also part of the results are now commercially available to third parties, whereas the remaining results are being made ready for commercialization.

For the Proposers this project is now paying off and they are very satisfied with their participation. Some of them are actually considering further Cooperative Research and will be seeking support by the European Commission in the near future.

Concluding this CRAFT-project it can be said, that for **CRAFT** **as** well as for many other things in life, "the first time is always the hardest." However, it **was** worth the effort.

2. Introduction

Although it was the distinct aim of the initiators of the project to demonstrate the feasibility of the BRITE-EURAM/CRAFT-programme to as many companies in the subcontracting and machining industries as possible, the project itself was based upon real and concrete technical and organisational problems of the Proposers. It was considered vital for the success of the project, that the complex cooperation of so many companies and organisations should be underlined by practical and useful results. Only results of this kind could convince the Proposers to participate and can convince others in the European Union of the importance of Cooperative Research Action For Technology CRAFT.

3. Technical description and results.

3.1 The forming of screw thread in high-alloy steels.

Proposer: Demgen Werkzeugbau GmbH, Schwerte

R&D Performer: WZL-RWTH Aachen
Prof. Dr.-Ing. Dr. h.c.mult. W. König
Dipl.-Ing. M. Fieber

Tapping of screw **thread is usually** one of **the last machining operations a** product has to undergo. Therefore, at that moment any product already represents a considerable value due to previous machining work.
Although the tapping of internal screw thread and the forming of external screw thread are well-known operations in the European subcontracting industry, particularly the tapping of internal screw thread still bears relatively high risks with regard to the quality of the thread and *processing* problems. Especially in the machining of high-alloy steels, Demgen GmbH experiences problems that will also be encountered by many other subcontracting industries.
On one hand, the high-pressure hydraulic application of the product requires strong and flawless screw thread, on the other hand the high-alloy steels used make it especially difficult to control the tapping process.
For these reasons Demgen GmbH was looking for a new and improved method of forming internal screw thread.

This R&D subject comprised fundamental research into materials properties of certain high-alloy steels with respect to the forming of internal screw thread. The research was conducted by the "Laboratorium für Werkzeugmaschinen und Betriebslehre" (WZL) of the RWTH Aachen.
The research subject has been divided into the following steps :

1. Metallographic research on 56 NiCrMoV 7 V
2. Fundamentals of internal screw thread forming and tapping:
   - drilling diameter
     cooling/lubricating fluids
     tool coatings
3. Definition of thread quality
4. Determination of tool lifetime under selected process parameters

Apart from the high-alloy steel selected, the following conditions were defined:

- thread size: M 12 x 1,75
- thread: blind hole
- **thread depth:** 22 mm
- max. **tolerance** on **drilling** diameter: H 10

Tools and apparatus.

Tapping and forming experiments were conducted using ESO tools , Taps were of size M 12 x 1,75 and quality 6H, forming tools were of size M 12 x 1,75 and quality 6HX.

The HSS tools were used in an uncoated version as well as in PVD-coated TiN and TiAlN.

Tests were conducted on a vertical lathing machine type Hurth VF · Drilling reversion and speed were controlled by means of a tapping device.

Material.

The purpose of **this research** subject was to improve the forming of screw thread in high-alloy steels.
The material 56 NiCrMoV 7 V (1.2714) was used **as a good** representative of these high-alloy steels. The material was used in bar-shaped pieces of 60 mm height and 70 mm width. Hardness of the test pieces (Vickers HV30) averaged 375 HV (1255 N/mm^2), standard deviation was 6 HV.

Metallographic tests proved the test pieces to be of good and constant quality and composition.

Test parameters.

The effect of parameter variations on the quality of the screw thread had to be established by considering a large number of parameters . Tool specifications, shear stress and surface quality affect the-resulting screw thread. Torque and axial forces affect the operation itself.
For the determination of optimal parameters a series of short tests of 10 thread holes each were conducted prior to testing tool lifetime and other variables.
Surface quality was documented through electron microscope photographs using 80x enlargement. Quantitative measurement of surface quality could not be used because of the fact that the surface to be evaluated, the internal screw thread, is not readily accessible.

Test results.

As already stated, the first series of short tests were meant to determine the optimum parameters for the forming of internal screw thread in 56 NiCrMoV 7 V.

First tests resulted in the determination of the best diameter for the drilling hole. Based upon this result, further tests were conducted with variations of forming speed, tool coating and cooling/lubricating fluid.

Optimum parameters for screw thread forming in high-alloy steels have been determined. Tool lifetime tests have been conducted. A comparison between the tapping and the forming of internal screw thread in high-alloy steels was made.

3.2 The concept of a milling chips centrifuge.

Proposer: **Metaal Industrie Bergen, Bergen**

R&D Performer: **WZL-RWTH Aachen**
Prof. Dr.-Ing. Dr.-Ing. E.h. M. Weck
Dipl.-Ing. H. Klein

Metaal Industrie Bergen was looking for a reduction of environmental costs of coolants/lubricants through the development of a small and universal chips dryer, adjusted to the capacity of a single working machine and linkable to a machining centre.
The subject comprised the following steps:

1. Expert determination of the package of requirements in which are determined:
   - maximum building space
   - nature of the chips
   - quantity of chips to be processed
   - centrifugal acceleration
   - lifetime of the device and its individual components

2. Elaboration of various concepts for a dryer, resulting in the indication of a range of possible components that meet the requirements.

3. Evaluation of the elaborated concepts.
4. Written documentation of the individual steps.

Concept

Metaal Industrie Bergen and WZL-RWTH Aachen developed a package of requirements. On this basis, six different solutions to the problem were developed and evaluated with respect to technical arid economic aspects.
The resulting solution was further developed with respect to the following aspects:

1. Dryer drum

   The vertical building space between tne chips container and the chips transporter is only 300 mm. The integration of a dryer with a vertical drum axis in this narrow space is not possible. Therefore a drum having a horizontal axis was selected. The drum is open on both the front and the rear side of the axis. Chips are fed to the drum by means of a gutter. The drum is shaped in a conical and parabolic way in order to ensure transport of the chips through the drum in the axial direction. At the end of the drum the dry chips are thrown into a collecting chamber and subsequently dropped into a container. This configuration of the drum enables continuous operation.
   Liquids are collected in the dryer housing and returned to the coolant/lubricant circuit of the machining centre.

2. Drum bearings

   Two alternatives were considered: shaft bearings and circumferential bearings. It was expected that a construction involving a drum shaft might cause plugging of the drum by long chips. Therefore bearings on the circumference of the drum, although definitely larger and more expensive, were given the preference. Due to the conical shape of the drum, one bearings will be 16 inch in diameter, the other will be 12 inch and therefore considerably cheaper.

3. Motor

   The dryer will be equiped with a 380 Volt motor with an integrated emergency brake. The dryer will be operated using only the nominal speed of the motor. Expensive frequency controls are not needed. The emergency brake will be used in case of personal danger or unacceptable unbalance in the drum.
   The motor will be connected to the drum by means of a variable V-belt drive. The V-belt will be connected directly to the drum.

4. Construction

The entire dryer including motor will be hung up in four flexible elements in a steel construction that is open and accessible on three sides, thus enabling the chips container to be put in its place from all three sides.

Masses and forces in/on the equipment, especially when operating with an unbalanced load in the drum, make it **necessary** to give a good deal of attention to the solidity of the construction and the isolation of the entire dryer from the foundation.

Research results.

The concept and the following components have been further detailed and calculated:

- bearings
- bearing covers
- selection of the motor
- V-belt
- V-belt spanner
- dryer housing
- door locks
- unbalance switch
- chips supply gutter
- flexible elements
- construction

Subsequently the results have been documented in detailed drawings and a final report. The Proposer is now implementing the results in a prototype machine,

3.3 The mechanical alignment of circular saw blades with a hardness of 63-65 HRC.

Proposer: **De Kinkelder, Zevenaar**

R&D Performer: **WZL-RWTH Aachen**
Prof. Dr.-Ing. Dr.-Ing. E.h. M. Week
Dipl.-Ing. M. Swoboda

De Kinkelder manufactures circular saw blades for working metal, plastic and steel. The grinding operation as part of the production process causes form changes in the blades, which so far are eliminated manually.
Especially for blades with a hardness of 63-65 HRC, no alternative alignment method is available.

Therefore fundamental research into the cause and the nature of undesirable internal stresses was necessary. Also, the development of **mechanical** alignment would result in a more efficient production and ensure constant quality.

The research subject was divided into the following steps:

1. Basic research into deformation analysis and material behaviour.
2. Making an inventory of processes that might be used.
3. Preparing a concept.
4. Systematic determination of alignment parameters.
5. Development of a prototype.
6. testing and optimization.

Determination of shape deviations.

First tests to determine the deviations in the actual shapes of the saw blades were conducted on circular blades of three different diameters: 250, 275 and 350 mm. Results were evaluated using AutoCAD and reference values given by De Kinkelder.
The following deviations were found:

For 250 mm blades: 0,133 - 0,743 mm,
For 275 mm blades: 0,185 - 0,299 mm.
For 350 mm blades: 0,257 - 0,937 mm.

Selection of a measuring method

After establishing the magnitude of the shape deviations, the conditions for a suitable measuring method could be drawn up.

Also the basic requirements for a mechanical alignment apparatus have been established.
A number of measurement methods were revised:

holographic interferometry
Moiré-process
"Streifenprojektion"
"Lichtschnitt"
laser triangulation

Holographic interferometry did not look promising because of the insufficient data correlation between both pictures and the long processing time for the hologrammes. For the Moiré-process the setbacks were the high-power light source needed and the complicated preparation of test blades.
The remaining methods, though different in their technical and financial demands, seemed feasible.

The final selection of a measuring method was made in cooperation with De Kinkelder.

Materials research on saw blades.

In order to obtain information on the uniformity of the hardness of the **saw** blades, De Kinkelder performed a number of hardness tests, Results showed 65 HRC hardness, practically uniform in radial directions,
Also a series of bending 'tests were performed on saw blades. None of the tests showed a distinct transition from elastic to plastic deformation before rupture. This ruled out plastic deformation techniques as *a* means of aligning the saw blades.

Impact resistance tests were done. These tests brought insight into the forces exerted during manual alignment. Together with calculated theoretical values these data indicated the forces to be used in a mechanical alignment process.

De Kinkelder built a prototype machine for the testing of results obtained by the R&D Performer. This prototype has been changed in the course of the 'work in order to incorporate the growing insights into the subject.

3.4 **Concept development for the automatic assembly of a rack gear.**

Proposer: **Ridder Machinefabriek, Harderwijk**

R&D Performer: **WZL-RWTH Aachen**
Prof. Dr.-Ing. Dr.-Ing. E.h. M. Week
Dipl.-Ing. U. Tüllmann

Ridder Machinefabriek BV **is** producing automatic shadowing devices for greenhouses and packaging machines. Part of the product range is a rack gear used to transform the rotating movement of a shaft into the linear movement of a rack, which is opening the greenhouse's roof windows or moving sun blinds. A number of 100.000 gears are assembled manually each year. Ridder plans to expand, so that the number of gears to assemble may increase up to 200.000 each year. The gear consists of 10 parts:

1 tin frame **as** a housing for all parts
2 guide rollers to fix the rack at the gear
2 riveting bolts **as** shafts for the guide rollers and to hold them in the tin frame
1 gear wheel
2 M8 grub screws, screwed in the gear wheel to connect it with the driving shaft
2 sliding bearing rings to prevent friction and wear between tin frame and gear

Three workers would be occupied assembling those gears. Major savings of personnel costs may be possible by assembling the gears automatically. To judge wether manual or automatic assembly is more economical, it is necessary to know which technical requirements are to be met and which costs are incurred by an automatic assembly plant.
Starting from this point, it was the task of the WZL to develop a concept of an automatic assembly plant for the gear mentioned. To ensure that the chosen concept could be realised, it was to be detailed in form of assembly drawings for the plant and it's subassemblies.
First of all the assembly parts and alternative assembly orders were analysed. As a result it was possible to define an assembly order which meets all requirements of the parts:

- the M8 grub screws are screwed in the gear wheel
- the sliding bearing rings are layed on both sides of the gear wheel.
- the gear wheel and the bearing rings are mounted onto the tin frame .
- the guide rollers are put in the frame and bolted with the rivets.
- the rivets are fixed.

In order to minimise the necessary technical equiqment and the investment costs, different layouts for the assembly plant were investigated. The number of moved and controlled axes in the plant could be reduced by dividing the assembly process in two sections. In the first one rotationally symmetrical parts - i. e. the gear wheel and the two sliding bearing rings - are preassembled, In the second section all operations in connection with the tin frame are done. This is mainly the fitting of the guide rollers and the riveting bolts and the fitting of the preassembled gear-group into the frame.
The great advantage of this solution is that in both sections of the assembly process only one kind of fixture is used. Other'wise each station of the plant would need two fixtures (and handlings) for handling the rotationally symmetrical parts and the tin frame. A further dividing of the process in even more sections was thought over too. Because there are no additional advantages this solution was rejected.

Basing on this scheme the concept was detailed, so that for each problem connected with the assembly a technical solution can be given.
In order to use only one (bought) automatic screwer for the M8 grub screws the preassembly section should be run with the double speed of the second section. By this each gear runs through the preassembly twice, so that both screws can be fixed with one screwing station. This means, that altogether 4 assembly stations for the end assembly steps involving the

frame and 7 stations for the preassembly of the gear wheel group are necessary. If the two M8 grub screws could be just packed with the gear, 3 preassembly stations would be sufficient for the assembly process.
The parts are supplied as bulk material. To single them out and give them an orientation vibratory hopper conveyors are used. The advantage is, that ail parts can not only be singled out by the same facility but can be given to the assembly process with a defined orientation.
Both sections of the assembly should be realized on automatic indexing tables. To hold and support the gear parts in each station of both indexing tables fixing elements for the gear wheel group and the frame were constructed.

The total costs for all bought mechanic and electric parts used in the plant are 180.000 DM. Roughly estimated another 10.000 DM are necessary for the control hardware. Additional costs in estimately the same region would emerge mainly from labour costs for the detailed construction, the manufacturing, the control layout and the assembly and initiation of the plant .

The results of the research work were implemented by the Proposer.

3.5 The development of a zero-tolerance gear rack driving assembly.

Proposer: A. **Mannesmann GmbH und CO,** KG, **Remscheid**

R&D Performer: WZL-RWTH **Aachen**
Prof. Dr.**-Ing. Dr.-Ing. E.h.** M. Week
Dipl.-Ing. A. **Hohle**

A. Mannesmann in Remscheid manufactures high-precision gear rack driving assemblies for tooling machines, robot handling systems and cranes. With regard to the improvement of production efficiency, higher and higher speeds are applied for linear axes driving. A. Mannesmann is looking for further development in this direction, both enabling highest precision and repeatability in high-power drives.

Alternative solutions.

In normal gear rack driving assemblies, a gear wheel is in direct contact with a gear rack. This contact involves certain tolerances. High-precision positioning of a support is therefore impossible. Reversed operation of the assembly introduces yet another tolerance.
Several known methods deal with the elimination of these tolerances , but they all show different disadvantages.

Another **method**, relatively complicated in its construction, consists of a set of two gear wheels placed on a gear rack while maintaining a certain tension between the two wheels. A more cost-efficient alternative to this method is found in the use of three gear wheels in combination with a gear rack.

A. Mannesmann and WZL-RWTH Aachen together set up a package of requirements for the construction of the prefered solution. This package and the computer software available at WZL-RWTH Aachen allows detailed design of the drive assembly.

Results.

The design calculations have been made. Also from the available alternatives a solution for tensioning of the gear wheels has been chosen.
The first prototype has been tested and evaluated with A. Mannesmann. Subsequently further optimization has taken place. A final report and a set of drawings were delivered to the Proposer and to the Coordinator.

3.6 The development of a high-frequency aluminum milling unit.

Proposer: **Mifa Aluminium, Venlo**

R&D Performer: Unisign TACB, Panningen

Mifa Aluminium B.V. is an aluminum processing business that uses extrusion, machining and surface treatment to manufacture high-quality products for the aircraft, fine-mechanical and other industries.
To keep its technological lead in the field of aluminum processing, Mifa is interested in developing a high-frequency milling unit to be combined with its production equipment.

The following aspects had to be considered in the development:

1. Maximum speed in the order of 30,000 rpm.
2. High dynamic stability at both high and low speed.
3. High torque power balance, even at low speed.
4. High precision.

Results.

After setting up the package of requirements, a great deal of attention was given to the thermal and vibrating behaviour of the milling unit. Both research and experiments were conducted. Extensive contacts with Fisher AG, Switzerland, led to concise ideas for the construction of the unit. Fisher AG further assisted in the final development of the milling unit.

Producers of high-frequency speeders were involved in testing and modifying a number of speeders.

Several milling units were tested on a test bench at Unisign and subsequently tested on a production machine at Mifa Aluminium.

In several steps the prototype milling units have been upgraded to meet the requirements set out. Especially the milling speed was increased gradually up to 24,000 rpm in order to understand fully the dynamic behaviour of the milling unit at high speeds. The unit is now commercially available.

3.7 Efficiency improvement in the production process.

Proposer: **Speciaalwerk Venray, Venray**

R&D Performer: **Stork-Demtec B.V., Amersfoort**

Speciaalwerk Venray is a high-quality subcontracting industry supplying to Original Equipment Manufacturers in the aircraft, electronics and other industries.
In order to maintain its competitive edge, the company has to meet the changing demands of its customers through increased efficiency, shorter lead times and higher flexibility.
For large parts of its operation these customer demands involve completely new ways of organizing the work and in fact a different and new lay-out of the production equipment.

The known and foreseen customer demands have been analyzed and a package of requirements has been drawn up:

1. Clamping and setting methods are to be determined for the available tools in order to reduce machine down-time to a minimum.
2. Directives for the NC programmer are to be set up, aiming at a reduction of indirect machining time to a minimum.
3. The production organization has to be adjusted in order to reduce lead times to a minimum, in accordance with the requirements of the ISO 9002 standards.

The project was divided into four steps that are discussed below.

1. Restructuring the production organization.

Four production groups have been defined:
- a turning/milling cell (processing costs dominant)
- plastics machining and assembly (material costs dominant)
- a product range (product dominant)
- a job shop (production technology dominant)

Optimization of the turning/milling cell was chosen as pilot activity. The package of requirements and the responsibilities and duties of the different functions were defined. Duties were described in detail. These descriptions are also used as job instruction tools.
The turning/milling cell was realized. Six production machines, stocking of (final) products and tools, quality control, packaging and NC-programming were placed directly facing each other.
The remaining product groups will be realized at a later date.

2. Reorganization of production preparation and planning.

Production preparation has been adjusted. The preparation for new products was separated from the preparation for repeated orders. Logistical and technical preparation were integrated and are now being done by one and the same work preparatory. Production information for the shop has been simplified and restricted to the really necessary information.

Production planning methods for the different product groups were established and auxiliary means were indicated. At the moment the methods are in a test phase.

3. Establishing of a structured calculation method.

The method followed strongly resembles the one used for the reduction of clamping and resetting times.

4. Reduction of clamping and resetting times.

In accordance with the management of Speciaalwerk Venray, the machines in the turning/milling cell were chosen to serve as a pilot for this action.
A reduction of clamping and resetting times by 50% showed to be realistic through simplification and standardization of cutting and clamping tools. The results of this pilot project were used by Speciaalwerk Venray to reduce clamping and resetting times in the other product groups.

3.8 Efficiency improvement in the production process.

Proposer: Optiwa B.V., Reuver

R&D Performer: Stork-Demtec B.V., Amersfoort

Optiwa is a subcontracting **industry** supplying products in plastics, ferro and non-ferro materials to a large range of customers in the machine, medical, aircraft and aerospace industries. The company produces according to customer specifications and the ISO **9002** standards. Production covers series ranging from 5 to 500 pieces.

Optiwa is presently facing market developments tending towards smaller series and shorter lead times. The decline in size of production series is demonstrated by the decline of the average production time per series over the past years. In 1992 production time per series averaged 18,5 hours, in 1993 it was 12,2 hours and in 1994 the average was a mere 8,7 hours. Meeting these changing market demands cannot be accompanied by rising prices or lower quality, as competition is fierce.
In order to meet market demands, machining, inspection and overall lead times must be reduced. This also holds true for clamping, resetting and transfer times between subsequent machining operations.

Results

For the project at Optiwa the milling machine NCD3 and the production cell BC2 were selected. Results are as follows:

i. For the milling machine NCD3 downtime, caused by clamping and resetting, was reduced by 50%, representing a reduction in order lead time by 11% and a reduction of production cost by 8%.

2. Downtime of the production cell BC2 can be reduced by 73%, representing 8% of order lead time and a reduction of production cost by 22%.

In both cases NC-programming had to be adapted corresponding with a new set of standardized cutting tools. Directions for future programming actions were given.

In the reduction of overall lead times the most important bottlenecks turned out to be the intermediate quality checks and clamping work. In accordance with the ISO 9002 standards the intermediate quality checks could to a large extent be replaced by in-line checks that do not affect lead time.

Outlook

A large share of the products at Optiwa is produced by means of a combination of turning and milling. At the moment these operations take place on different machines and therefore involve a number of transfer, clamping and resetting actions. The producers of milling machines recently developed machines that are in reach of industries like Optiwa and that combine both turning and milling capabilities. In the near future these new developments will enable Optiwa to further reduce production lead times by eliminating the transfer of products from one machine to another.

3.9 Cost reduction by efficiency improvement in SME production.

Proposer: Reef Precisie, Maasbracht

R&D Performer: Exapt Systemtechnik GmbH, Aachen

For the introduction of computerized calculation Reef Precisie was looking for the development of a software linkage between a production control package and a calculation package. This software would enable-the generation of a complete operations plan in which machining times, set-up times, routings, operation sequences and machine settings will be recorded.

Results.

After an extensive search and many discussions with software developing companies, Exapt Systemtechnik GmbH was selected. The actual work started in January 1995 and was completed in the course of the year. The results are now operational at Reef Precisie BV and is paying off. Together Proposer and R&D-Performer are evaluating the market for the software developed.

3.10 Implementing modern supply strategy in machining SME's.

Proposer: **Hecker & Krosch GmbH & Co.KG, Zülpich**
Wigra GmbH, Aachen
Fechner GmbH, Hilden

R&D Performer: **TÜV Rheinland, Aachen**

Modern supply strategy is no longer feasible without Quality Management . More and more, customers demand 1S0 9000 compliance from their suppliers.
For small and medium-sized machining industries there is no specific quality management handbook available at the moment. Therefore it was also the aim of this project to develop such a handbook in a cooperative effort of the three proposers mentioned and TÜV Rheinland.

Although the project started in all three companies simultaneously and progress took place independent from each other, it was the distinct aim of the project to help the Proposers benefit from each other. Therefore the Proposers and TÜV Rheinland have met and discussed their progress and problems at regular intervals.

Two of the Proposers have completed the work in such a way, that they are now 1S0 9000 certified suppliers. The third Proposer is still working towards certification.

'The Quality Management Handbooks of the two certified companies will serve as examples for the machining industry in Europe.

4. Conclusions

All of the research subjects in this project have yielded at least the results that were expected.

A high-speed milling unit for the machining of aluminum was developed. A zero-tolerance gear rack driving assembly was developed. Forming of high-quality internal screw thread in high-alloy steels is now operational. A prototype of a universal milling chips centrifuge is being tested. The manual assembly of a rack gear has been mechanized. Novel software for production control was developed and introduced and is commercially available. Method and equipment for the mechanical alignment of hardened circular saw blades were developed and tested. Production systems of machining industries were redesigned, regrouped and reorganized in order to save time and money. Specific quality management handbooks for small and medium-sized machining companies were developed and introduced.

The project as such was far from a typical CRAFT-project. The large number of Proposers, the variety of research subjects, the cooperation with no less than 6 R&D-Performers and. the involvement of 6 intermediary organizations made this project far more complicated than a normal CRAFT-project. Nevertheless, the results have proven it to be a good and justified project.

5. Acknowledgements

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Project title:"Modern machining technologies and production techniques in the European subcontracting industry."

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On behalf of the Proposers the Contractor wishes to express his gratitude to the following persons and organizations for their help, their understanding and their cooperation in a project that **was of** an exceptionally complex nature,

The European Commission, for enabling and supporting this unusual project under the CRAFT-Programme. Without the financial support of the Commission this project would ***not*** have been feasible. With this support a number of very interesting developments in the machining industry -were obtained.

Mr. F. Sgarbi, DG XII, who was the Scientific Officer on behalf of the European Commission and who was the first person to be confronted with our more or less succesful efforts to report the progress of the project correctly.

Prof. Dr. - Ing. P. Dietz, who was appointed as Project Technical Adviser and who was valuable to us as a counselor with respect to the execution of the various research topics. He particularly warned us to closely supervise the work done by universities in order to keep it from growing scientifically “malignant”.

Dipl.-Ing. D. Lung and Dr.-Ing. T. Steinert from WZL-RWTH Aachen, who ensured that the research topics handled by their university institutes almost ran like clockwork, and who made sure that the warning expressed by Prof. Dietz did not become a reality.

Mr. Bartz, now retired, and **Mrs. S. Hartmeyer** from WZL-RWTH, who were very considerate with respect to our periodic payments.

Dipl.-Ing. K. **Böttcher** from TÜV Rheinland, who handled a subject as difficult as **quality** management in the machining industry with all the talents of a diplomat.

All the other R&D-Performers and representatives from Handwerkskammern and InnovatieCentra who together made this project work so well after all. Without their effort we would not have made it.

6. References

All of the research subjects have been documented in reports, detailed drawings and the like. These are of a confidential nature and are the property of the Proposers.
Information on individual subjects and Proposers' names and addresses can be obtained through the Coordinator:

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Information on the project can also be found in the CORDIS Databank of the European Commission.
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