FP6-508378

DeSProCh

Design of a semi-hot process chain

Co-operative research project

Final Activity Report

Period covered: 01.10.2004 to 30.11.2006

Date of preparation: 04.11.2005

Start date of project: 01.10.2004

Duration: 24 month

IPH – Institut für Integrierte Produktion Hannover gGmbH

Revision [0]

This project is supported by funding under the Sixth Framework Programme of the European Union

1. Project execution

Project objectives

Customer’s demands are rising with regard to higher accuracy of manufacturing, surface quality and use of material. It is on the forges to respond to these pressures. Therefore, it is necessary to support the European forging industry by the optimisation of production technologies.
Semi-hot or warm forging is an economical alternative to the conventional forging technology. It offers several advantages that contribute to economic, environmental and social issues. These are reduced energy input, no scale, better surface quality and closer tolerances. It has been successfully used in the production of rotationally symmetric components so far. Components in which one axis is several times longer than the others cannot be manufactured with this process by now.
Main goal of this project is to establish a basis for the set-up of complete, reliable and flexible process chains for the semi-hot forging of long parts. It begins with the feeding of raw material and ends with the output of finished and cooled parts. This will be realized in the supporting SMEs in a process with low production costs and high process quality and will guarantee an optimal use of the project results. The main objectives of the project are to develop a new production process for longitudinal work pieces to increase product and production quality, save on materials and shorten production time. Further objectives are the improvement of working conditions as well as an increase of professional skills and enrichment of operator tasks and a reduction of the environmental impact.

Contractors involved

The consortium of the project comprises 4 SMEs and 2 RTD performers. Within the SMEs there are two forges Kovárna VIVA Zlín, S.C. (Czech Republic) and Omtaş Otomotiv Transmisyon Aksami San. ve Tic. A.ş. (Turkey).
The third SME is a forging and materialography consulting company: METAV S.A. (Romania).The fourth company is specialised in spraying and lubrication equipment technology: BEMERS Sprühtechnik GmbH. The fifth SME is a heating equipment manufacturer: ROBOTERM, spol.s r.o., Chotebor (Czech Republic)
The RTD performers are: COMTES FHT s.r.o and IPH – Institut für Integrierte Produktion Hannover gGmbH.
Each partner participates in work packages he can contribute knowledge and/or can establish guidelines.

Work performed

In the first phase the consortium compiled a specification sheet with the requirements for the finished products and for the process based on existing production technology data and considering the technological and economical requirements.
Based upon two model parts, a steering link consisting of 42CrMoS4 and a connecting rod consisting of C70S6 BY, were chosen. They have characteristics that allow for the demonstration of the advantages of the process, i.e.:

- active surfaces that can be achieved by near-net-shape forging technology,
- a geometry that can not be achieved using cold forming and
- need for good mechanical properties.

This project is supported by funding under the Sixth Framework Programme of the European Union

Forging and process concepts were discussed and a rough outline of feasible approaches was fixed.

The second phase of the project dealt with the development of the pilot product and it's forming steps. The selected forging geometries were adapted to the technology of semi-hot forging and constructed using modern CAD-equipment. Applicable forming sequences for forging were evaluated, verified and optimised using finite-element-analysis for material flow simulation.

To improve the reliability of the simulation results

- cooling curves were measured,
- upsetting tests were performed and the flow curves of the simulation programmes have been adjusted,
- materialographic investigations and sharpy tests have been performed,
- the friction model and values have been adjusted by the use of measurements and plastometer tests and
- the two simulation programmes DEFORM and Forge3 have been compared.

Thus, first results were acquired regarding the necessary number of forming steps, requirements to tools, applicability of materials, process temperatures, critical process time due to cooling of the work piece and necessity and possibilities of heat treatment to obtain good grain structure.

Since the requirements on the process chain are identical for the alternative forming sequences for each product, phase three was already started, where all issues regarding the process are examined. Different tasks deal with the exploration of production strategies and technologies using the results obtained in phase two. Phase three was divided into two parallel tasks: the development and manufacture of the necessary tools and the design and layout of the process chain. The initial tool design has been derived of the gravure geometries defined by the simulations, and of the requirements of the equipment. In parallel, decisions on the necessary equipment for the functions handling, forming machines, heating, monitoring and control and lubrication and cooling were taken. In phase four the whole production line was put into operation and the developed processes were tested and improved in an iterative way. Finally, an experimental plan was set up and the results of the in process measurements and the work piece properties has been documented. The work pieces have been analysed using the following methods:

- Microscopic analysis: microstructure, decarburization, grain size.
- Macro analyze: grain flow.
- Hardness: both microhardness and hardness.
- X-ray diffraction on surfaces.
- Coordinate measuring of geometrical properties.
- Surface roughness with Hommel-testing device.

Together with the in process recorded data and based on statistical methods correlations have been identified and specifications for quality assurance have been derived. In the fifth and last work package all results have been summarised in guidelines for the choice of equipment for warm forging processes and the design of warm forming processes.

This project is supported by funding under the Sixth Framework Programme of the European Union

Discussion of the achieved results

Two representative long flat geometries, a connecting rod and a steering link, were chosen and evaluated regarding their requirements towards a production by warm forging. In an iterative way, a forging sequence has been designed; processes have been simulated and based upon the simulation results the sequences have been adjusted. In parallel, the equipment for the line has been chosen according to the state of the art in warm forging of rotation symmetric work pieces. To increase the reliability of the simulations, the press characteristics have been considered, friction tests have been performed, flow curves have been recorded. Additionally, the simulations were performed in parallel with the simulation software Deform and Forge3.

For the connecting rod a four step warm forging process and for the steering link a three step forging sequence have been developed. Two processes for different components were developed to cover a wide range of geometries of long flat pieces. Because of the different requirements of the geometries towards the forging sequences the two developed processes vary a lot concerning the comprised forging operations. For the steering link several series of tests have been performed and a final experimental plan has been performed for testing the impact of the heating temperature, the incorporated graphite coating, the coating thickness and different combinations of graphite based and graphite free die lubricants. For the connecting rod, only one test series has been performed to validate the developed process.

The material utilisation achieved with the steering link forging process is 86 % which is quite a lot higher than for common hot forging processes, which are in a range of 60-80 %. But this ratio does not include the additional save on material which is caused by lower work piece heights compared to the hot forged work piece. The lower heights are possible because the subsequent machining of the heights is saved. The material utilisation obtained for the connecting rod forging process is about 80 %, which is a good result for a work piece with such a complex material distribution and again this result does not cover the save on material achieved by reduced subsequent machining.

The tolerances achieved in the steering link forging process were IT 10 for the height and length of the pieces and qualities of IT 11 to IT 10 are expected for large batches forged in stable conditions. Compared to the tolerances of IT 16 to IT 12 obtainable by hot forging this constitutes a valuable progress. The surface roughness R_z is below 20 µm as desired and the decarburisation of the work pieces is less than 50 µm deep and does not show an impact on the hardness. Due to this, subsequent shot blasting and machining operations can be saved. No scale formation has been observed during the experiments and no traces of FeO were detected. The micro stricture of the warm forged connecting rods was even finer than for the hot forged pieces and else showed comparable properties and micro structure, so that a warm forging process with integrated heat treatment of the material C70S6BY is possible.

In a cooperative effort, two warm forging processes have been developed, capable of producing existing work piece geometries with reduced energy input due to reduced heating temperatures and with reduced material input due to a higher material utilisation and a save on machining operations. The expertise in the layout and design of warm forging processes has been established in the participating forges, constituting an advantage in the global manufacturing competition.

This project is supported by funding under the Sixth Framework Programme of the European Union

Dissemination of knowledge

Dissemination activities:

- A Project web site (www.desproch.de) has been published, that describes the project and will constantly be updated.
- The Guidelines have been forwarded to the consortium and the EC according to the proposal at the end of the project .
- On-site training, consulting service and technical support have taken place at VIVA with the responsibles of VIVA and OMTAS.
- The project will be promoted and a project description will be provided by the partners to four European associations as follows:
    - Czech forging association: Svaz Kováren ČR (SKCR)
    - Turkish forging association: Dövsader
    - European forging association: Euroforge
    - German forging association: Industrieverband Massivumformung e.V. (IMU)
- Applications for publications will be made to following journals:
    - Journal Kovárenstvi May 2007
    - Schmiedejournal
    - Journal of Materials Processing Technology
    - WGP
- The project have been and will be promoted on the following conferences:
    - FORMING 2007 - September 2007, Podbanské (Slovakia)
    - Kovárenská konference (Conference of the Czech forging association) – May 2007, Nové Město na Moravě (CZ)
    - Sächsische Fachtagung Umformtechnik - Oktober 2007, Freiberg (Germany)
    - Airtec 2006, Conference presentation in October 2006, Frankfurt (Germany)
    - ICMR06, Conference presentation and publication in September 2006, Liverpool (England)
    - TMS 2007, Conference publication and presentation in February 2007, Orlando, Florida (U.S.A.)
- Five Universities have been identified and will be contacted for the possibility to give lectures on the project results. These are:
    - University of Hannover
    - Technical University of Chemnitz - May 2007, Professur Virtuelle Fertigungstechnik (http://www.tu-chemnitz.de/mb/vif)
    - Polytechnical University of Buccarest
    - University of West Bohemia Westböhmische April 2007, Professur Werkstofftechnik und Metallurgie (www.kmm.zcu.cz),

6.

This project is supported by funding under the Sixth Framework Programme of the European Union

Table 1: Overview on Dissemination efforts

Planned/a ctual **Dates**	**Type**	**Type of audience**	**Countries addressed**	**Size of audience**	**Partner responsible /involved**
Since 01.01.05	Project Web site	General public	WW		IPH (all)
ongoing	Promotion in Czech Forging association Svaz Kováren CR	Research and Forging Industry	Czech Rep.		VIVA, Comtes
ongoing	Promotion in Turkish Forging Association: Dövsader	Research and Forging Industry	Turkey		Omtas
ongoing	Promotion in European Forging Association: Euroforge	Research and Forging Industry	EU		IPH (all)
ongoing	Promotion in German Forging Association: Industrieverband Massivumformung	Research and Forging Industry	Germany		IPH
14.01.07	*Guidelines of Best Practice*	*Consortium and EC*	*WW*		*IPH (all)*
2006	*On site training, consulting service and technical support*	*Partner companies*	Czech Rep		*IPH, Comtes*
May 2007	*Publication: Journal Kovárenstvi*	*Research and Forging Industry*	*Czech Rep.*		*Comtes, VIVA*
2007	*Publication: Schmiedejournal*	*Research and Forging Industry*	*Germany*		*IPH*
2007	*Publication: Journal of Materials Processing Technology*	*Research and Forging Industry*	*WW*		*IPH, Comtes*
2007	*Publication: WGP*	*Research*	*WW*		*IPH*
18.10.06	*Airtec06 Conference Presentation*	*Research*	*WW*		*IPH*
06.09.06	ICMR06 Conference Presentation	Research	WW		IPH
26.02.07	TMS 2007 Conference Presentation	Research	WW		IPH
09/2007	FORMING 2007 Conference Presentation	Research	WW		Comtes
2006	Lecture at University of Hannover	Higher Education	Germany		IPH
2006	Lecture at Technical University of Chemnitz	Higher Education	Germany		Comtes
2006	Lecture at Polytechnical University of Buccarest	Higher Education	Romania		IPH, Comtes, Metav
2006	Lecture at University of West Bohemia	Higher Education	Czech Rep.		Comtes

This project is supported by funding under the Sixth Framework Programme of the European Union

Co-ordinator contact details

For further information on the project please contact:

Mr. Achim Schott
IPH – Institut für Integrierte Produktion Hannover gGmbH
Hollerithallee 6
30419 Hannover
Germany
Phone: +49 (511) 27976-331

Or refer to the project website: www.desproch.de.

This project is supported by funding under the Sixth Framework Programme of the European Union