EUROPEAN COOPERATION IN THE FIELD OF SCIENTIFIC AND TECHNICAL RESEARCH - COST

COST 526

Automatic Process Optimization in Materials Technology
(APOMAT)

Title:

Optimisation of fatigue Resistance of cold Forging Tools by considering Damage Mechanisms at Micro Scale

Keywords:
Low-cycle fatigue, cold forging, finite element method, sensitivity analysis, optimisation

Organization/Company:
C3M d.o.o.
Centre for Computational Continuum Mechanics
p.p. 431, SI-1102 Ljubljana,
Slovenia

Project leader: **Dr. Igor Gresovnik**
Tel.: **+386 1 2000 444, +386 1 2000 442**
Fax: **+386 1 2000 440**
E-mail: **igor.gresovnik@c3m.si**

1. Duration / run time of the project
4 years

2. Overall cost
120 kEURO (subject to availability of funding)

3. Funding situation
Partially own funds.
The company will also apply for funding at governmental institutions in Republic of Slovenia

4. Project partners indicated to participate
NTF – University of Ljubljana, Slovenia

5. Project partners to be found
Our objective is to collaborate with material scientists in modelling of low cycle fatigue, numerical analysts in sensitivity analyses and optimisation as well as with industrial partners.

6. Short description of the material process to be optimized
Cold forging processes can be used for the production of net-shape components such as shafts and gears with quality class reaching IT 5-6 which requires tools with extreme tolerances up to IT 3-4. Such precise dies are difficult to produce and very expensive. Due to extreme process loads they are exposed to high risks related to fatigue failure. Therefore the success of high volume production depends strongly on the capability of optimising forming processes in order to improve fatigue resistance of the tool.

7. Material(s) involved:
Cold working tool steels, powder metallurgical high speed steels

8. Optimization potential of the process or process step
Expectations for service life of heavily loaded tools in cold forging are 10^3-10^4 forming cycles. Industrial experience shows that appropriate modifications of the technology can lead to improvements in die life by a factor of ten or even more which indicates a high potential for economising the production.

9. Specified material properties to be achieved
Resistance of die inserts to low cycle fatigue will be improved and risks related to formation of cracks will be reduced.

10. Process parameters to be optimized
Mechanisms contributing to fatigue failure can be minimised by appropriate selection of materials, design of forging sequence and prestressing of tools.

11. Material laws including material dependent coefficients

Elasto-plastic constitutive laws with isotropic and kinematic hardening coupled with damage. The models will be applied at microscale to take into account interactions between carbides and martensitic-austenitic steel matrix.

12. Simulator

ELFEN - A finite element system for implicit and explicit analyses of 2D and 3D problems by considering large strain and deformation theory, elasto-plastic constitutive relations, thermomechanical coupling, frictional contact between deformable bodies, etc. The simulator includes a sensitivity analysis module. The system is being developed by Rockfield Software, Swansea, U.K. C3M will enhance the simulator to take into account the damage phenomena that occur at microscale. This will enable more elaborated evaluations of objective functions and sensitivity terms.

13. Optimizer

A programme shell “Inverse” for solving optimization and inverse problems developed by C3M Ljubljana, Slovenia, will be used. The shell enables good flexibility for solving a wide variety of problems with different physical background, in different computing environments, and with different simulation programmes.

14. Competence / activities of proposer:

The proposer is a developer of a general optimisation shell “Inverse” and has extensive experience in solving optimisation and inverse problems in the field of forming processes. C3M is a commercial company acting in the field of numerical modelling in continuum mechanics, modelling in material science, and optimisation of forming technologies. The company collaborates with a number of industrial enterprises and therefore possesses a good overview of industrial demands. On the other hand, the company has been involved in many research projects within the scope of FIFTH FRAMEWORK PROGRAMME, BRITE/EURAM, COST, COPERNICUS and EUREKA.

15. International state of the art and references

The programming packages to control optimisation procedures are relatively well developed [1]. However, they require the sensitivity of the process to be evaluated with respect to design parameters. Since forming processes are non-linear and path dependent, the evaluation of sensitivities often represents the most critical part of the optimisation procedure. Although considerable efforts have been spent in recent years to apply direct differentiation and adjoint methods in sensitivity analysis [2,3] of forming operations there are still many unresolved issues and applications to large scale industrial problems are still very rare. In addition to algorithmic and computing problems related to process optimisation there are severe problems in defining appropriate objective functions. In this project we will investigate the applicability of fatigue criteria [4,5] for the definition of objective functions in optimisation of service life of cold forging tools.

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[4] Pedersen T.O.: Cyclic plasticity and low cycle fatigue in tool materials. Ph.D. Thesis. DCAMM, Report No. S 82, November 1998

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