

COST 526
Automatic Process Optimization in Materials Technology
(APOMAT)

Title:

Formulation of objective Functions for estimating fatigue Damage of Cold Forging Tool Steels at Microscale

Keywords: Cyclic plasticity, damage, microscale modelling, tool steels, cold forging

Organization/Company:
Faculty of Natural Sciences and Engineering,
University of Ljubljana
Askerceva 12
SI-1001 Ljubljana
Slovenia

Project leader: **Dr. Tomaz Rodic**
Tel.: **+386 1 470 45 00**
Fax: **+386 1 470 45 60**
E-mail: tomaz.rodic@uni-lj.si

1. Duration / run time of the project

4 years (2001-2005)

2. Overall cost

90 kEURO (subject to availability of funding)

3. Funding situation

Will apply for at MINISTRY OF EDUCATION, SCIENCE AND SPORT, Republic of Slovenia

4. Project partners indicated to participate

C3M – Centre for Computational Continuum Mechanics, 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 industrial partners.

6. Short description of the material process to be optimized

The tooling systems applied in near-net-shape and high volume production of cold forging components are repetitively subjected to very high loads. Despite of high strength materials and prestressing applied to the tooling systems, these loads often cause local plastic deformation of tools. Even though the plastic deformations caused by each forming cycle are relatively small, they accumulate during the production and can eventually lead to the initiation of a fatigue crack. Once the fatigue crack is initiated, it can grow and cause failure of tooling system.

The mechanisms governing the damage evolution are not fully understood at present and therefore it is difficult to formulate objective functions for optimisation of service life of tooling systems. In this project the interactions between carbides and in the martensitic-austenitic steel matrix will be considered in order to analyze amplitudes in the stress strain fields at microscale during cyclic loading.

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 economizing the production.

9. Specified material properties to be achieved

Higher resistance of die inserts to low cycle fatigue.

10. Process parameters to be optimized

Arrangement of carbides in the martensitic-austenitic steel matrix as well as properties of the metal matrix composite will be varied in order to minimize damage accumulation at microscale.

11. Material laws including material dependent coefficients

Metal matrix composite consisting of elastic particles (carbides) embedded in an elasto-plastic steel matrix. The martensitic-austenitic steel matrix will be modeled with isotropic and kinematic hardening coupled with damage.

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 program 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 programs.

14. Competence / activities of proposer:

NTF has expertise in numerical modelling in material science which includes direct simulations as well as inverse analyses and optimisation of forming processes. The research activities include sensitivity analyses, constitutive modelling of materials, development of algorithms for solving frictional contact problems, prediction of microstructural changes, thermal and mechanical fatigue, tool surface wear, etc. NTF has experience in participation in international programs within the scope of ALIS, ALAMED, BRITE/EURAM, COPERNICUS, PECO-HCM and TEMPUS initiatives.

15. International state of the art and references

Phenomena governing fatigue damage of cold forging tool steel materials are not fully understood at present and still require considerable fundamental research. Therefore the phenomenological models remain the most frequently used approach for engineering applications. For example, the Coffin-Manson relationship that describes the experimentally observed influence of plastic strain amplitude on fatigue life [1] is often applied. Alternatively, energy methods can be used to relate plastic work in a material to its fatigue life. To apply these approaches it is necessary to describe stress strain response of tool steel materials under cyclic loading which involves Baushinger effect, cyclic hardening or softening, ratcheting and mean stress relaxation. For this purpose relatively complex plasticity models [2] must be applied. These models can be coupled with continuum damage theories [3,4]. On the other hand, the stress strain response predicted by the cyclic plasticity models can be analyzed (or even coupled) with microscale models [5] to provide a more detailed insight to the evolution of damage. In this project the objective functions for optimisation of fatigue life of tooling systems will be formulated in such a way that results of micromechanical analyses will be taken into account.

[1] S. Suresh: Fatigue of Materials, Cambridge University Press. (1991)

[2] J. Lemaitre, J.L. Chaboche: Mechanics of Materials, Cambridge University Press. (1990)

[3] P. Brondsted & P. Skov-Hansen: Fatigue properties of high strength materials used in cold forging tools, Proceedings of the 30th Plenary Meeting of the International Cold Forging Group, Den Bosch, (1997)

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

[4] T. Rodic, J. Korelc, M. Dutko, A. Pristovsek, R. Kunc and M. Hänsel: Cyclic Plasticity and Damage of Cold Forging Tool for Production of Automotive Shift Fork. The Third International Conference on Industrial Tools, Rogaska Slatina, 331-334 (2001)

[5] F.G. Rammerstorfer, A.F. Plankensteiner, F.D. Fischer, T. Antretter: Hierarchical Models for Simulating the Mechanical Behaviour of Heterogeneous Materials: An Approach to High Speed Tool Steel, Mat. Sci. Engng., A259 (1999) p73