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Computer aided system for selection of parameters for making metallographic microsections

L.A. Dobrzański, M. Gumińska*
Division of Materials Processing Technology, Management and Computer Techniques in Materials Science, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: monika.guminska@polsl.pl

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Analysis and modelling

ABSTRACT

Purpose: The goal of this work was development of the computer aided system for selection of technological parameters for making the metallographic microsections for the microscopic examinations.
Design/methodology/approach: Prolog language – the Artificial Intelligence tool was employed in the project, and the Logic Programming Associate's VisiRule system, which was used for saving the knowledge base - rules pertaining the objects and their relationships. These tools were used to develop the expert system for selection of the recommended technology for the metallographic microsections.
Findings: Knowledge acquisition process was carried out to cover recommendations of manufacturers of the equipment for metallographic microsections. Formulation of the pertinent knowledge in the LPA-Prolog VisiRule tool is presented along with the results of technology instruction sheet presentation.
Research limitations/implications: The expert system for selection of parameters for making the metallographic microsections is currently at the testing and development stage.
Originality/value: Making the metallographic microsections is a time consuming task, sometimes material for examination is scarce, so any system that ensures good quality of microsections is very valuable. The system under development offers the best advice to anybody striving to obtain the best quality of the specimens.
Keywords: Expert systems; Artificial intelligence methods; Preparation of metallographic microsections; Programming in logic

1. Introduction

Microscope metallographic examinations make it possible to determine structural components and defects of metals and their alloys. Apart from discernment of the structural components they also make it possible to determine their amount, dimensions, and distribution, and to some limited extent also identification of phases and analysing changes in the material that occurred, among others, during transformations accompanying diffusion, corrosion, creep, or fatigue processes. The examination results are mainly affected by quality of metallographic microsections. Preparation of samples is composed of several operations: Choosing the sample from the investigated material, its mounting, grinding, polishing, and etching [1, 2]. The consecutive stages of sample preparation are always the same, regardless of the investigated material type, and differences consist only in the appropriate selection of parameters for the particular operations, taking into account properties of the examined materials. The effect of the wrong parameters will be – in the best case – the reparable sample defects, and – in the worst case - the sample will turn out to be useless and the entire process will have to be repeated from acquiring the next sample from the investigated material [2].

Preparation of the metallographic samples is not a complicated process; however, it calls for a considerable expenditure of time and money. Computer aided system for selection of parameters for making the metallographic microsections would be very helpful for the laboratory assistant. Such system would contribute to their correct processing, resulting in cutting the costs and time of the examinations carried out [3, 4].

2. Methodology of sample preparation

Technology of preparation of the metallographic microsections consists of the five main operations. The first step is sample taking for examination from the native material from locations characteristic for service conditions or manufacturing conditions, e.g., from the heat treated locations [1, 3]. The abrasive wet cutting is considered nowadays the best sectioning method, as it introduces the least amount of damage in relation to the time needed to complete the operation [3].

The next operation is mounting in the chemically cured- or thermosetting resins, or in the low-melting metals. Two techniques are used in mounting the samples in resins:

- *cold mounting* - in this method the sample is put into a mould and the following resin types are used in this technology to mount the sample: epoxy, acrylic, polyester.
- *hot compression mounting* - the sample is put into the mounting press, next the resin is added. Finally the sample is processed in the hot compression mounting at elevated temperature and under a high pressure. Two types of hot mounting resins are used: *thermosetting* (duroplastics) – this type of resin cures at elevated temperatures and *thermoplastic* – these resins get soft or even melt at elevated temperatures and harden when cooled again [1, 3, 5].

The third operation of the sample preparation is its mechanical processing. The samples can be processed up to the moment when their perfect finish and the true structure are obtained, or else their preparation process may be halted when their surface quality is sufficient for the selected examination method. Mechanical processing consists of two operations: grinding and polishing.

The initial sample mechanical preparation operation - grinding is carried out at two stages: plane grinding and fine grinding.

Many different types of abrasives are used, depending on a sample material's properties. These may include, e.g., SiC papers commonly employed for plane grinding of soft materials, PG-paper or Al_2O_3 grinding stones are used mostly for ferrous materials; there are also the metal-bonded Diadisc which are employed for harder materials; moreover, the Diadisc or diamond grinding discs are employed for grinding of ceramics or sintered carbides and other hard materials [1,5].

Just like grinding, the next preparation stage - polishing - also is divided into two phases. Successive sample preparation operations have to remove the damage caused by previous stages; polishing achieves that by using the finer abrasive particles:

- *diamond polishing* – diamond is used to make the fastest material removal possible and to ensure best feasible sample plane quality,
- *oxide polishing* – this abrasive material is applicable for the is used for the soft and ductile materials, and also those that need a final polish.

For polishing lubricants must be used. For both stages the consumables to be used depend on the sample material. In case of diamond polishing the right cloth has to be selected, along with the diamond grain size and lubricant type. Cloths with higher resilience and a lubricant with high viscosity are used for final polishing, providing safer processing conditions for the nearly completed sample surface [5].

All operations described above should be best made using the automatic equipment as it will ensure the best possible results saving time and costs incurred.

An important issue is ensuring the stable processing conditions, so that the sample preparation process yields always the same results for the same material. Therefore using consumables of a high standard and uniform quality are of the utmost importance. The parameters controlling the sample preparation quality are the type and amount of abrasive, lubricant, preparation time, rotational speed and direction of the abrasive tool, and load exerted on the samples.

Based on many years' experience of experts in the metallographic investigation area and manufacturers of the laboratory equipment for preparation of microsections the extensive collections were developed of methods and materials recommended for sample preparation from various metals and alloys. All information about technology of sample preparation was the base for development of the knowledge base from this area; next the developed knowledge base was used in the expert system for selection of sample preparation parameters[1, 2, 6].

3. Artificial intelligence tools

Expert systems may be developed using many different tools, starting from the algorithmic programming languages, like Basic, C, C++, next using the artificial intelligence languages, e.g., Prolog, export systems languages – Clips and Flops, up to using the export system shells. The LPA-Prolog system tools - VisiRule in conjunction with Flex – were used for development of the sample preparation expert system because of their ease of merging with the procedures in Prolog, providing flexibility in system development [7-11].

Flex is a powerful expert system software toolkit which – in addition to the conventional rule-based programming - supports also the frame-based reasoning with inheritance, and data-driven procedures. It is fully integrated within the LPA-Prolog logic programming environment, and contains its own English-like Knowledge Specification Language (KSL). The combination of Flex and Prolog featuring together the hybrid expert system toolkit with a powerful artificial programming language provides the versatile expert system development environment. Therefore, this system was selected for the project described in the paper, as one can shape the developed systems freely according to the specific requirements[12-14].

Another LPA-Prolog tool - VisiRule - is a toolkit for creating decision support software by drawing flowcharts only. The VisiRule tool consists of the backward chaining inference engine with the graphical user interface. The product is the automatically generated source code, compiled and ready to run, but which can also be exported and used in a separate program.

LPA-Prolog VisiRule toolkit makes it possible to save rules, generate the relevant code and launching the program, as well as as re-using the generated code in other software modules; therefore, it is a very flexible tool. This tool was used to develop the knowledge base, and at a later stage, another LPA-Prolog software tool – Flex was used to develop the expert system [13-16].

4. Description

The set of rules defined in LPA-Prolog VisiRule constitutes the knowledge base of the system. The rules were created based on the experience and knowledge of experts in sample preparation area and should guide the laboratory assistant quickly to the required solution. The system assists the user in selecting the appropriate parameters for the metallographic samples preparation process, giving him three options to choose from:

- Metalogram developed by Struers[5];
- Sample material;
- Material properties (HV hardness, ductility).

Depending on the option selected after launching the system the user indicates the relevant Metalogram zone, or enters the material properties (hardness and ductility) as prompted by the system, or else enters the investigated material designation. No more information is required by the system to provide the user with the solution. The system operation flow diagram is shown in Fig. 1.

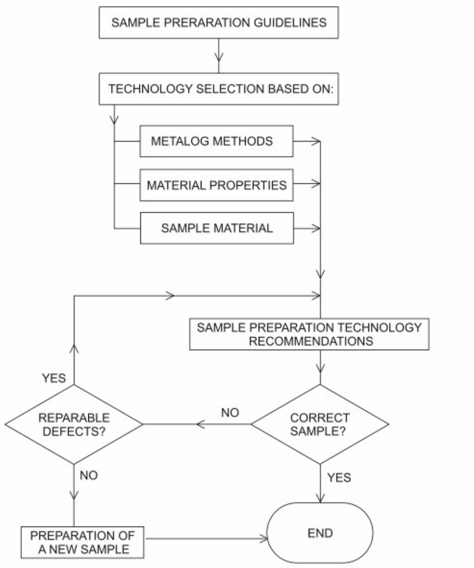

Fig. 1. System operation flow diagram

5. Results

Development of the system commenced with specification of the parameters' selection rules. An exemplary rule may have the following form:

Sic-Paper *if* you have a CuZn alloy *and* CuZn cast

Saving such rules in the LPA-Prolog VisiRule tool consisted in development of decision trees and next the resulting source code was generated.

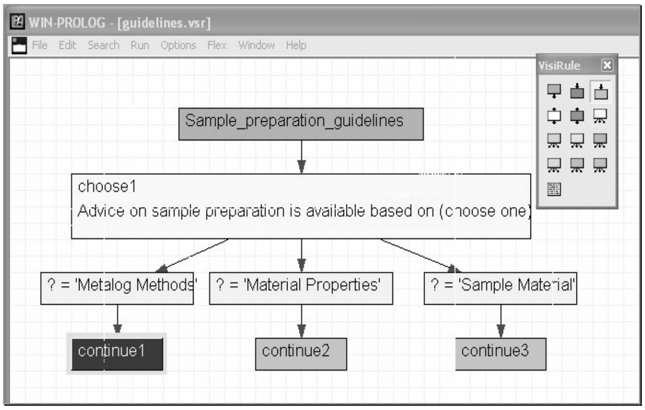

Fig. 2. A part of the VisiRule diagram

The source code is generated after selecting the *Show Code* option in the LPA-Prolog VisiRule menu, the code may be run immediately without the need to leave the development environment. The exemplary generated source code was compiled and launching it opened the dialog window in which the user can enter input data for the investigated material, Fig.3.

LPA-Prolog VisiRule makes it also possible to export the code chunks in the .ksl format and to merge them, as well as to link them to other applications.

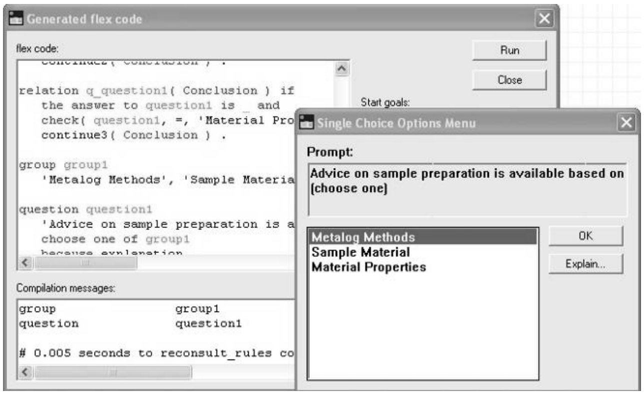

Fig. 3. Fragment of the source code and its resulting dialogue window in the LPA-Prolog VisuRule code development environment

Bitmap is generated after selecting the *Metalog Methods* in which the user can point to the area of interest, and the system looks for all pertinent solutions referring to that diagram zone. An example of the generated Metalogram bitmap is shown in Fig. 4. along with the microsection preparation parameters selection result for the materials belonging to the selected zone B, i.e., Cu, pure - Fig. 5.

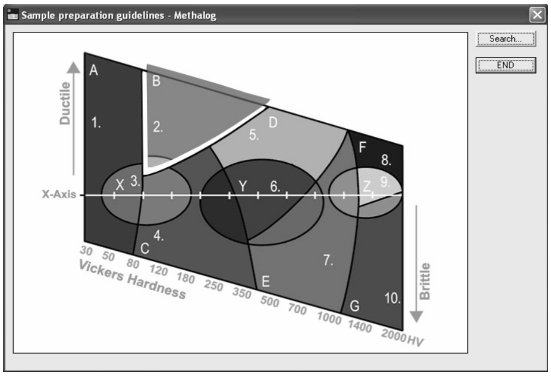

Fig. 4 Metalogram generated with the LPA-Prolog Flex tool [5]

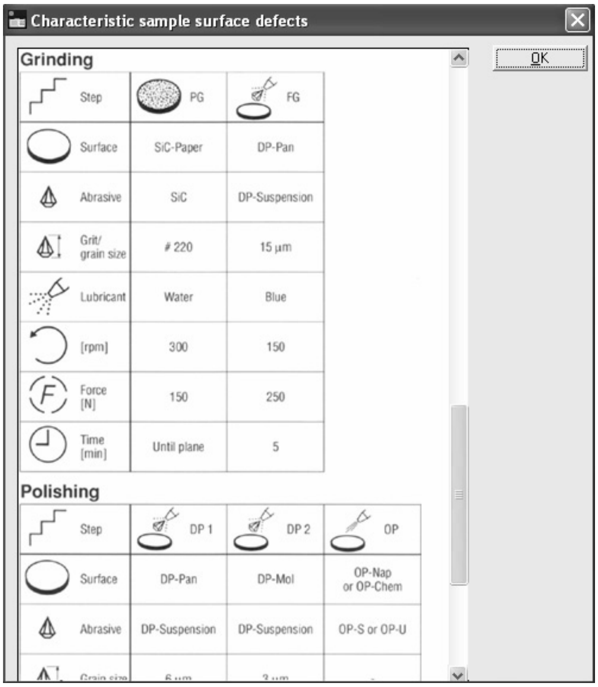

Fig. 5. Microsection preparation technology selected for the Metalogram B zone

6. Conclusions

We have come to the following conclusions analysing the presented project:

- New knowledge base development tool – LPA-Prolog VisiRule together with Flex shell system - offers exciting possibilities in development of expert systems.
- The developed computer metallographic microsections preparation parameters selection system makes it possible to select objectively the correct sample preparation technology.
- Employing the export system for preparation of the metallographic microsections guarantees decrease of the required number of samples made and savings of consumables, along with improvement of the quality of microsections.

Acknowledgements

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