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Finite Element Method application for modelling of mechanical properties

L.A. Dobrzański, A. Śliwa*, T. Tański
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: agata.sliwa@polsl.pl

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ABSTRACT

Purpose: A numerical model was developed in order to predict the hardness for casting the magnesium alloys MCMgAl12Zn1, MCMgAl6Zn1, MCMgAl3Zn1 and MCMgAl9Zn1.

Design/methodology/approach: Computer simulation of hardness was carried out with the help of finite element method in ANSYS environment, and the experimental values of hardness were determined basing on the Rockwell method.

Findings: The presented model meets the initial criteria, which gives ground to the assumption about its usability for determining the hardness in casting the magnesium alloys MCMgAl12Zn1, MCMgAl6Zn1, MCMgAl3Zn1 and MCMgAl9Zn1, employing the finite element method using the ANSYS program. The computer simulation results correlate with the experimental results.

Research limitations/implications: Presently the computer simulation is very popular and it is based on the finite element method, which allows to better understand the interdependence between parameters of process and choosing optimal solution.

Originality/value: The possibility of application faster and faster calculation machines and coming into being many software make possible the creation of more precise models and more adequate ones to reality.

Keywords: Computational materials science; Finite Element Method; Magnesium alloys

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ENGINEERING MATERIALS PROPERTIES

1. Introduction

At the contemporary stage of the development of the engineering thought, and the product technology itself, material engineering has entered the period of new possibilities of designing and manufacturing of elements, introducing new methods of melting, casting, forming, and heat treatment of the casting materials, finding wider and wider applications in many industry branches. Therefore the development of engineering aims at designs optimizing, reducing dimensions, weight, and extending the life of devices as well as improving their reliability [1-3].

Contemporary materials should possess high mechanical properties, physical and chemical, as well as technological ones, to ensure long and reliable use.

The above mentioned requirements and expectations regarding the contemporary materials are met by the non-ferrous metals alloys used nowadays, including the magnesium alloys. Magnesium alloys and their derivatives, characterize of low

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density (1.5-1.8 g/cm^3) and high strength in relation to their weight [1,4].

Knowledge of the relaxation properties of metal materials at elevated temperatures is necessary for the verification of susceptibility of castings to the creation of defects during the production and forming processes [1,5]. Temperature limits of materials where highest tension values are generated may be detected with tensile tests under high temperatures.

The finite element method is currently commonly used in such branches of science, like: mechanics, biomechanics, mechatronics, materials engineering, and thermodynamics [6-12]. All types of simulations shorten the design process and give the possibility to investigate the particular factors on the entire model. This is often impossible to achieve in real conditions or not justified economically. The finite element method makes it possible to understand the relationships among various parameters better and makes it possible to select the optimum solution Applying of this method contains many fields of contemporary industry and also modern technologies are supported by using of computers [13-14]. MES system can be treated as one of program belonging to CAD/CAM/CAE group, which contain complex supporting of designing tools cycle, beginning with constructing up to realization of manufacture processes [15-18].

The paper shows a model enabling the user to evaluate hardness in the examined specimens without doing experimental researches. The comparative analysis was carried out of the results of computer simulation of hardness with the experimental results.

2. Numerical simulation model

For simulations of deformation during hardness test by Rockwell method was used ANSYS program. Taking into consideration that real model is symmetric and model made in Ansys is ¼ of real model. By keeping proper edge conditions in symmetric plane such a simplication does not influence simulation's results whereas in considerable degree reduces time of carried out calculations by program. Initial loading was 98.1N and than total loading which was 588N.

Materials data used during simulation for casting the magnesium alloys:

- Modulus of Elasticity – E=50.1 GPa,
- Poissons Ratio - ν= 0.3,
- Tensile Strength, Yield – Re=20 MPa,
- Tensile Strength, Ultimate– R_m=90 MPa,
- Elongation at Break – A_5%=6%.

Physical model consists of:

- Steel globule,
- Native material of casting the magnesium alloys MCMgAl12Zn1, MCMgAl6Zn1, MCMgAl3Zn1 and MCMgAl9Zn1.

Analytical model consists of:

- Solid, that is undeformable and is represented by steel globule,
- Contact, that presents interaction between steel globule and native materials,
- Native material of casting the magnesium alloys MCMgAl12Zn1, MCMgAl6Zn1, MCMgAl3Zn1 and MCMgAl9Zn1.

The solid which presents steel globule was simulated as undeformable solid using MESH 200 element. This element is only a mesh and is not subjected to any calculations..

Material selection for native material should insure the ability to deformation and initial stresses. That's why it was used SOLD 95 element. This element is used to three- dimensional modeling of solid structures. It is defined by twenty knots which each has three translational degrees of freedom (UX, UY, UZ) and materials properties (Modulus of Elasticity, Poissons Ratio, thickness, thermal condition factor). Automaticly the element takes global coordinate system.

Element CONTA 174 was used in order to define contact between steel globule and native material. This element is located on the surface of the solid and id defined by eight knots.

Work scheme:

- real model was created,
- put mesh of finite elements ,
- put edge conditions,
- made contact surfach,
- loaded power to model,
- made calculations.

Figure 1 presents three- dimensional view of calculated model with put finite element mesh on it.

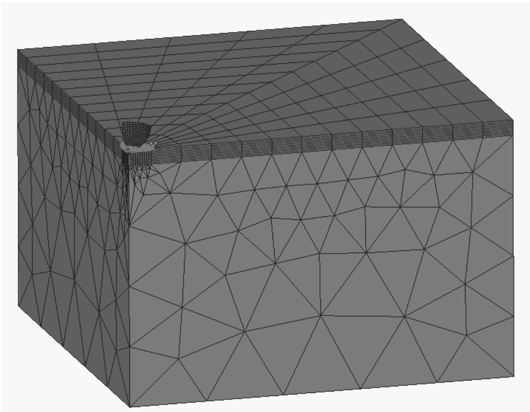

Fig. 1. Three-dimensional view of calculated model together with steel globule and put finite element mesh

3. Results

In order to avoid mistakes in calculations variable quantity of finite elements were used. In places where were expected higher deformation gradients the mesh is more thickened than in places in which deformation should have similar value. Figures 2-5 presents obtained results of numerical analysis using finite elements method gathered as maps of deformation and stresses distribution with loading and after loading in casting the magnesium alloys MCMgAl6Zn1.

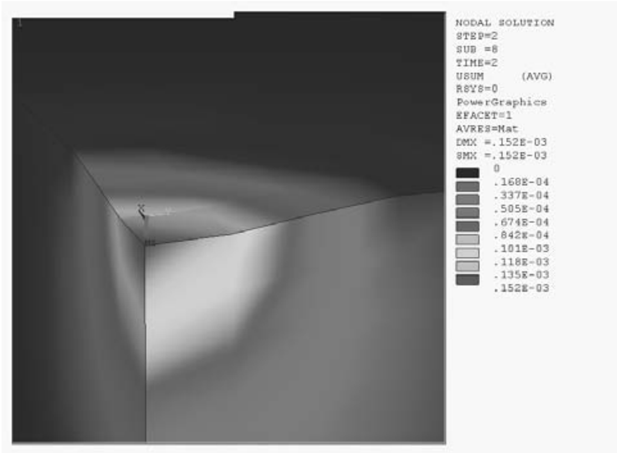

Fig. 2. State of deformed material with loading

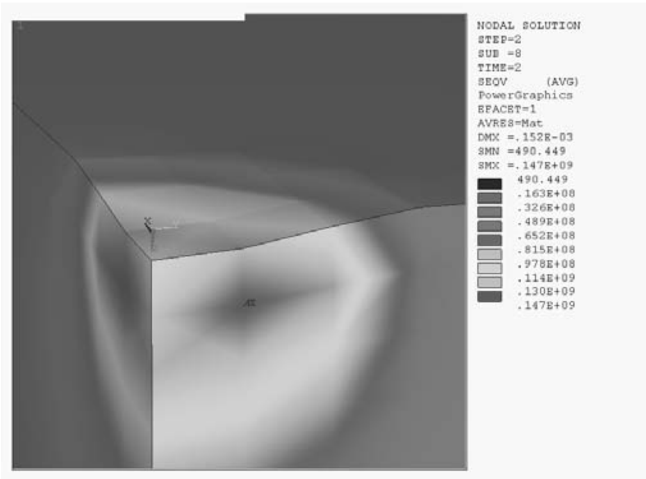

Fig. 3. Distribution of stresses with loading

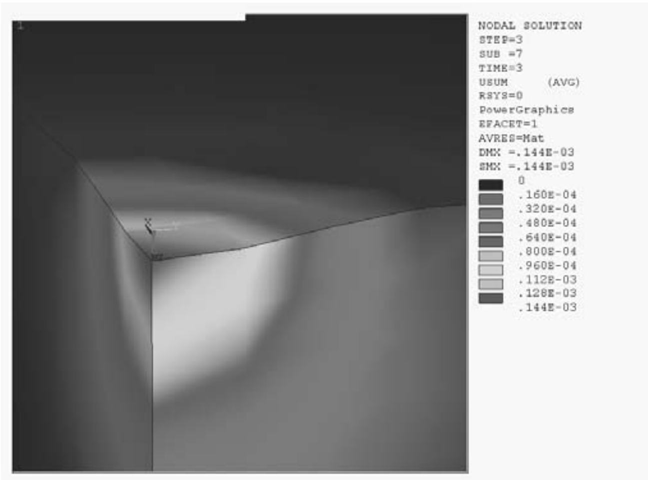

Fig. 4. State of deformed material after loading

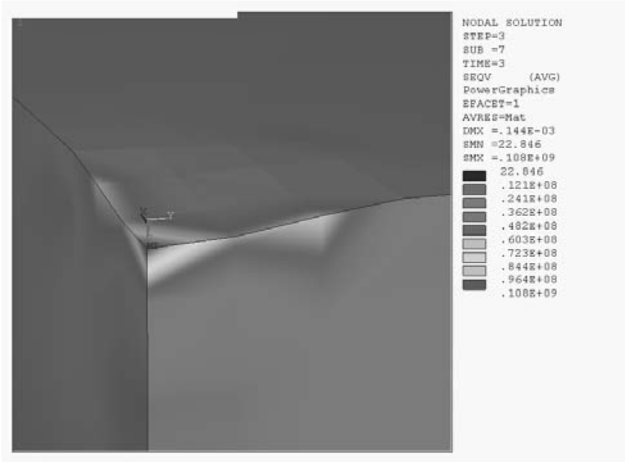

Fig. 5. Distribution of stresses after loading

On the basis of obtained simulation results it was possible to calculate theoretical hardness, which results correlate with results which were obtained by experiment (Table1).

Table 1.
Comparison of hardness results obtained by the use of computer simulations method and experimental Rockwell hardness tests for analysed alloys

	Alloys MCMgAl12Zn1	
	As-cast	after aging
Rockwell hardness tests	75.380	94.600
Computer simulations	74.2	102.3
	Alloys MCMgAl9Zn1	
Rockwell hardness tests	65.680	75.140
Computer simulations	62.5	76.8
	Alloys MCMgAl6Zn1	
Rockwell hardness tests	51.940	53.200
Computer iymulations	54.3	58.4
	Alloys MCMgAl3Zn1	
Rockwell hardness tests	30.640	31.500
Computer simulations	32.6	36.8

4. Conclusions

Finite element method is the perfect tool to solving engineering task and making simulation which is cheaper than carry out laboratory research, considerably reduce time of solving problem and gives reliable results.

Comparing the results of calculated hardness by Rockwell method in casting the magnesium alloys MCMgAl12Zn1, MCMgAl6Zn1, MCMgAl3Zn1 and MCMgAl9Zn1 and worked out model in paper using finite elements method presents full adequate of this model with experimental data.

Having precisely data concerning native material properties it is possible to precisely determine hardness by Rockwell method and also the distribution of stresses and deformations in this material.

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