THE ACTION OF AC MAGNETIC FIELD ON COLD FORMING PROCESS AND COMPARISON OF FLOW STRESS CURVES

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MECHANISMUS PŮSOBENÍ STŘÍDAVÉHO MAGNETICKÉHO POLE NA PLASTICKOU DEFORMACI OCELI A SROVNÁNÍ KŘIVEK PŘETVÁRNÝCH ODPORŮ

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Abstrakt

Výroba strojních součástí tvářením za studena sebou nese kromě řady předností, jako například vysoká přesnost zhotovených výrobků, zlepšení mechanických vlastností, i některé nedostatky související s čerpáním zásoby plasticity. Práce se zabývá vlivem střídavého magnetického pole na plastickou deformaci oceli za studena se rovněž zabývá změnami souboru přetvárných odporů a s dopadem do využitelné zásoby plasticity vlivem změn magnetického pole. Střídavé magnetické pole je aplikováno v průběhu plastické deformace.

Abstract

Cold forming of steel components brings many advantages, like high accuracy of products and improvement of mechanical properties, but this technology also brings problems with exhausting of plasticity. This work deals with influence of AC magnetic field on cold forming process in terms of changes of flow stress and the store of plasticity in consequence of magnetic field performance. AC magnetic field is aplicated with running plastic deformation.

Key words: magnetic domains, magnetostriction, electromagnetic volume power, change of the magnetic flux density in time, increase of the natural strain until fracture, decline of flow stress

1. Introduction

Cold forming of steel components brings many advantages, like high accuracy of products and improvement of mechanical properties, high productivity, in comparison of cutting operation, but cold forming also brings problems with exhausting of plasticity. Store of plasticity is very important in case that the component is loaded with elastic - plastic stress. If the component is made with cold forming, then a hardening is present. Set of the flow stress has an increase. Value of the set of the flow stress influences tool-working life. Changes of flow stress - the hardening is made with an increment of the deviation of the lattice.

This work deals with influence of AC magnetic field on cold forming process in terms of changes of flow stress and the store of plasticity in consequence of magnetic field performance. The store of plasticity is represented with natural strain until fracture. AC magnetic field is aplicated with running plastic deformation.

Material of the workpiece is annealed steel 23MnB4. Microstructure is composed with ferrite and spherical pearlite, see Fig.1. Chemical structure is described in Table 1.

Table 1 Chemical structure

Workpieces were tested with torsion test until a fracture. At the same time a magnetic field worked on the workpiece. Permeability of the steel 23MnB4 was determined from measurement of magnetic amplitude characterisation. Frequency of AC magnetic field was determined in consideration of skin effect [1], so that magnetic flux density went through all the cut of the sample. In time of the torsion test the number of the turns was measured, the torsion moment, a current flowing in a reel, and a temperature of the sample in a time of the fracture was measured too. Decline of flow stress and increase of store of plasticity have been observed in the time of torsion test. Microstructure was conserved [2].

a) b)

Fig1 Microstructure: a) the lengthwise cut, b) the transverse cut (corroded with Nital)

2. The action of AC magnetic field on cold forming process of the steel

If the cold forming process is made in the AC magnetic field, then many physical processes are in progress. The substance of the physical processes is the change of all sorts of energy. These changes are related with the change of structure of magnetic domains and the change of the vector of magnetic flux density in time. The physical processes are divided in consideration of reply of the macroscopic set of the elements.

- **The physical processes which are possible described with the dynamic hysteresis curve**

The changes of the magnetic domains are made with cyclic magnetization processes. The changes of the energy of the magnetic crystallographic anisotropy and changes of energy of the wall of the magnetic domains are produced with a displacement of the wall of the magnetic domains [3]. There are changes of the changeable energy and changes of the magnetoelastic energy, which is an answer on the mechanical stress and causes magnetic anisotropy on dislocations [4].

The description using the dynamic hysteresis curve divides losses into a histeresis losses and a losses of eddy currents [5]. The hysteresis losses depends on first power of the frequency and the losses of the eddy curents depends on second power of the frequency, see equation (1):

(1)

z	-	total losses which are produced with AC magnetize.
z_h	-	the hysteresis losses
z_v	-	the losses of the eddy currents
f	-	the frequency

An area of the dynamic hysteresis curve corresponds to the total losses. The total losses are determined from the measured dynamic hysteresis curves.

♦ The relation between the magnetostriction strain and vector of magnetic field intensity

Relation between magnetostriction and vector intensity of the magnetic field is in Fig.2. The λ is a relation extension in Fig.3. Equation (2) is accepted for a cubic crystal. The α_1 α_2 α_3 are directional cosines and λ_{100} λ_{111} are magnetostrictions in different crystallographic directions.

(2)

Fig.2 Relation between magnetostriction and vector intensity of the magnetic field

Equation (3) is accepted for mechanical stress resulting from the magnetostriction The ***E*** is the Young's modulus.

(3)

♦ The physical processes connected with the change of the vector of magnetic flux density in time.

Consequently of the change of the vector of magnetic flux density in time is created an electric field [5,6].

(4)

This electric field produce eddy currents. In the workpiece with conductivity χ is the density of the eddy currents indicated with ***J*** [7].

(5)

Interaction between electric flux density and magnetic flux density produce an electromagnetic volume power [8], which appears in the tested workpiece see Fig.3.

(6)

Fig.3 Electromagnetic volume power in the tested workpiece

3. Results of the experiment

Workpieces were tested with torsion test. Three types of the flow stress curves were measured see Fig.4:

Flow stress curve is measured with the magnetic field.

Flow stress curve is measured without the magnetic field.

Flow stress curve is influenced by the temperature

Flow stress curves were approximated by Hollomon function. Yield stress, constant strength and magnitude of the natural strain until fracture were compared see Tab.2.

Fig.4 The flow stress curves

Table 2 Comparing of the yield stress, hardening constant and magnitude of the natural strain until fracture and the temperature in time of the fracture

Increase of the plasticity is represented by decline of yield stress and by increase of the natural strain until fracture.

If we compare the increase of this deformation, from the set of data, measured with the magnetic field and the set which was influenced by the temperature, then the set influenced by the magnetic field has increase 5,5 % of the natural strain until fracture.

Described decline of flow stress which is represented by constant strength, and increase magnitude of deformation until the fracture of workpiece are caused by changes of all sorts of energy, which are related with the change of magnetic domains structure.

An engineering analysis based on finite element method (the systems QForm were used) provides information about the course of circumferential stress (Fig.5) in the formed semi-product of the socket screw. There is a considerable lower tensile stress in a screw head influenced with AC magnetic field. The tensile stress has unfavourable influence on the quality of the product.

Creating a magnetic anisotropy in deviation of the lattice is one of characteristic features of cold forming process of steel in Ac magnetic field. This process is characterised by oscillation of dislocations as a result of magnetostriction. The process is at the same time characterised by the electric field in consequence of change of magnetic flux density vector. The electromagnetic volume power resulting from relation between electric flux density and magnetic flux density is present in the tested workpiece. The process is further characterised by the mechanical stress resulting from the magnetostriction.

Fig.5 Circumferential stress: a) without AC magnet. field, b) with AC magnet field

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