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„New Trends“

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Grain boundary engineering beyond adjusting special CSL boundaries – is SPD-processing a way to go?

Gerhard WILDE

Institute of Materials Physics, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany
matphysik@uni-muenster.de

Abstract

Ultrafine grained and nanocrystalline materials have been shown to possess properties that are modified from their polycrystalline counterparts. At the same time, processing of sufficient quantities and also the stability of the fine grained microstructrue, once obtained, against detrimental coarsening have been long-standing issues. Within the past decade, severe plastic deformation (SPD) has often been applied for refining the microstructure of polycrystalline materials down to the ultrafine grained - or even the nanocrystalline range, yielding bulk materials that are mostly free from porosity or contaminations of the internal interfaces. Underlying the often spectacular property enhancement after SPD processing, mostly with respect to the mechanical properties, which forms the basis for a wide range of potential applications, are modifications of the local structures in addition to the drastic increase of the volume fraction of grain boundaries. Yet, along with the enhancement of mechanical properties, several important questions arise e.g. concerning the accommodation of external stresses if dislocation-based processes are not longer dominant at small grain sizes. One question concerns so-called “non-equilibrium” grain boundaries that have been postulated to form during severe deformation. These boundaries should possess enhanced excess free energy densities, enhanced residual microstrain and enhanced atomic mobility along the boundary plane and are supposed to present the microstructure element that underlies the property enhancement.

As described above, grain boundaries and particularly grain boundaries with structures that are modified by the interaction with large number densities of lattice dislocations as well as triple junctions of several grain boundaries are important elements of fine-scaled microstructures. Their presence, their structure and particularly their strain state is of importance for the stability, the mechanical performance and also the grain-boundary diffusion and grain-boundary-diffusion-related properties of ultrafine grained or nanocrystalline materials obtained through severe deformation processing. Thus, this contribution focuses on the experimental determination of local strain fields in severely deformed metallic materials with high spatial resolution and on their relationship with macroscopic properties such as grain-boundary self-diffusion and hardness. In addition, recent results indicate that rotational gradients are likely to occur as a result of the severe deformation process at already refined grain sizes. Results from microstructure investigations as well as from thermal analysis indicate that the kinetic stability against coarsening and grain growth might be enhanced for materials that include these types of structural defects. Additionally, some first results on severely deformed, multifunctional alloys will be discussed which might show the direction towards ultrafine grained materials with high electrical conductivity, high mechanical strength, good ductility and high stability against coarsening.

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Semi-solid processing of aluminum alloy 7075 with Sc and Zr additions

Jan DUTKIEWICZ, Łukas ROGAL

Institute of Metallurgy and Materials Science of the Polish Academy of Sciences, 25 Reymonta St., 30-059 Krakow,Poland

Abstrakt

A necessary condition for thixoforming (semi-solid processing) it is a fine globular microstructure in a semi-solid range. It has been obtained for 7075 aluminium alloy by addition of modifier sucgh as scandium and zirconium. The microstructure of the feedstock for the thixoforming process consisted of homogeneously distributed globular grains of solid solution (average grain size 23 μm) surrounded by eutectic precipitates. Differential Scanning Calorimetry (DSC) analysis has established the solidus and liquidus temperatures for heating and cooling at rates of 4°C and 15°C per minute respectively. Additionally, the liquid phase fraction was determined below the liquidus temperature. The thixoforming process was carried out at 632°C which gave about 25% of liquid phase in accordance with DSC analysis. The microstructure of thethixoformed part consisted of globular grains surrounded by precipitates of secondary phase. The average hardness of thixo-formed parts was 105 HV_5 and the tensile strength 300,3 MPa. T6 heat treatment was performed: supersaturation at 450ºC for (i) 30 min and (ii) 10 hours. In both cases the ageing time was set as 18 hours at 120ºC. The measured average grain size was 30,5 μm and 32 μm, respectively. Transmission Electron Microscopy enabled the identification of precipitates of the metastable dispersoids of $L1_2$ – Al_3 (Zr, Sc) and - η' ($MgZn_2$) phases in the alloy after the thixoforming and T6 treatment. Both heat treatments led to improvement of hardness up to 184 HV_5 and 198 HV_5, while the average tensile strength increased up to 482 MPa and 498MPa, respectively. The measurements of rheological properties of 7075Al alloy with Sc and Zr additions in the semi-solid range was performed in cooperation with Aachen University, using the Searle system indicated an increase of particle size and its spheroidization leading to an observable decrease of viscosity during isothermal shearing. Ashear rate jump experiment showed that with increasing shear rate the viscosity rapidly falls. The aim of this study is characterization of the thixo-formed components made of 7075 with Sc and Zr as well as determination of the influence of Sc and Zr on the rheological properties of the 7075 aluminum alloy in the semi-solid state.

Keywords

7075 alloy with Sc and Zr, thixoforming, semi-solid processing, rheology, DSC,grain refinement.

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The process of alternate extrusion and multi-axial compression – possibility of ultrafine-grained structures producing

Marcin KNAPIŃSKI, Henryk DYJA, Anna KAWAŁEK, Marcin KWAPISZ

Czestochowa University of Technology, Faculty of Materials Processing technology and Applied Physics, Armii Krajowej 19,PL 42-201 Czestochowa, Poland,knap@wip.pcz.pl

Abstract

Ultrafine-grain structure can be achieved by using large plastic deformation in the process of materials forming. The basis of this method is a possibility of obtaining a rearrangement of dislocations introduced by strain, which leads to a very strong effect on grain refining. At the Institute of Metals Forming and Safety Engineering in Czestochowa University of Technology, a new method of combined with alternate extrusion and multi-axial compression was proposed.

In order to develop the methodology of this process, a large number of numerical studies, physical modelling using the simulator GLEEBLE 3800 and metallurgical laboratory testes using vertical press Hydrapress PWH-250R were performed. All testes were made for three kinds of aluminium. The numerical studies allowed to determine the optimal shape of the punch and the matrix, The proper shape of designed dies allows to obtain the good quality of material after extrusion and next, after compression original, cylindrical shape of processed material without folds on the side-surface. The physical simulations of large deformation of materials were performed using the module MaxStrain of GLEEBLE 3800 system. These testes allowed to determine the nature of microstructures changes depending on the single-hit strain, strain rate and total strain. The numerical study and physical modelling allowed to design and make the tools, which were used to perform laboratory testes on a vertical press. Thanks to obtained results it can be state, that a combination of extrusion and multi-axial compression is possible accumulation of strain, which causes a decrease in average grain size and thus increase the strength properties.

Keywords

Large deformation of material, alternate extrusion and compression, ultrafine-grain structure, aluminium alloys.

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Effect of initial structure modification on UFG structure modification of low carbon steel

[a]Jozef ZRNÍK, [b] Sergey V. DOBATKIN, [c] George RAAB, [a] Libor KRAUS

[a] *COMTES FHT Inc., Průmyslova 995, 33441 Dobřany, Czech Republic, jzrnik@comtesfht.cz*

[b] *Baikov Institute of Metallurgy & Materials Science, RAS, Moscow, Russia, dobatkin@ultra.imet.ac.ru*

[c] *Institute of Physics of Advanced Materials, UFA, Russia, G.I. Raab@mail.rb.ru*

Abstract

Ultrafine grained structures prepared by severe plastic deformation are receiving increasing attention in the technical community in the last years. The term “ultrafine grain structure” is referring to nanostructure with grain size of less than 100 nm and submicrocrystalline structure is referring to refined grains having size between 100 and 1000 nm. The fabrication of bulk materials with ultrafine grain sizes has attracted a great deal of attention over the past two decades due to the materials’ enhanced properties. In recent years, it has become a worldwide effort to develop a manufacturing process to obtain ultrafine grain structures in steels.

The paper focuses on the severe plastic deformation (SPD) of low carbon (LC) steel AISI 1010 (ČSN 12014) performed at increased temperature. The grain refinement of ferrite structure is monitored and described with respect to different initial structure of steel modified by solutioning and thermomechanical (TM) treatment prior severe plastic deformation. The refinement of coarse initial ferrite structure with grain size of 30 - 50 μm resulted from solutioning was then conducted in two steps. Preliminary structure refinement of coarse ferrite structure has been achieved due to multistep open die forging process and quite uniform ferrite structure with grain size of the order of 5 μm was received. In the second step grain refinement of steel structure was accomplished during warm Equal Channel Angular Pressing (ECAP φ= 120°) at 300°C, introducing the effective strain in range of ε_{ef} = 2.6 - 4. The change of microstructure in dependence of effective strain was evaluated by SEM and TEM study of thin foils. The high straining of steel resulted in extensive deformation of ferrite grains and formation of mixture of submicron grain structure in deformed banded structure with dense dislocation network and with a prevalence of subgrains. The dynamic polygonization process, due ECAP increase temperature, modified the submicrocrystalline structure formation. Thereafter only indistinctive difference in structure refinement was observed, considering the different initial steel structure. Deformation behaviour in condition of tensile strain was characterized bystrength increasedfollowed by consequentsoftening. For all states of steel, there was not observed uniform work hardening effect.

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Numericalsimulation and experimental validation of creation of residual stresses in nano - structured AS-21 alloys

Tibor DONIČ, Zoran PELAGIĆ, Peter PASTOREK

ZU – University of Žilina, Univerzitná 1,010 26 Žilina, Slovak Republic, tibor.donic@gmail.com

Abstract

Nowadays alloys are more and more applied in all industrial fields like aerospace, automotive, electric industry etc. One of the most used types of alloys are Magnesium based alloys (Mg-alloys). Their mechanical properties allow them to create parts that have low weight at high strength. The hexagonal close-packed (h.c.p.) structure allows the material such properties. One of the most interesting types of Mg-alloys is the magnesium-aluminum-siluminum alloy or AS-21. The most used technique of creation of these types of alloys is powder metallurgy. The main advantage of this technique is that no complex mechanical or chemical processes are needed, and you can create various shapes. The presented paper focuses on creation of residual stresses in these types of alloys. First the creation technique of these materials is presented. Then the finite element simulation of residual stresses in the testing specimen and its experimental verification on a testing stand are made. The testing stand consists of two discs made from 100Cr6 steel - "bearing steel" and a cylindrically-shaped test specimen. This specimen is between these discs subjected to contact loading. The resulting residual stresses created by micro-plastic deformation are measured for each time step. At the end the comparison of results obtained numerically and experimental are presented.

Keywords

Contact, residual stress, Magnesium alloys, powder metalurgy.

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Mechanical Characterization of Nanomaterials with the Use of Mini – samples

Jan DŽUGAN, Pavel KONOPÍK, Radek PROCHÁZKA

COMTES FHT a.s., Průmyslová 995, 334 41 Dobřany, Czech Republic, jan.dzugan@comtesfht.cz

Abstract

A wide range of currently produced bulk nanomaterials are produced by severe plastic deformation (SPD) technologies. Common SPD methods are Equal Channel Angular Pressing (ECAP), High Torsion Pressure (HPT) and Constrain Groove Pressing CGP. Typically, small volumes of nonastructured materials are obtained. Thus if mechanical properties of materials investigated are to be evaluated, special techniques using miniature samples have to be applied. The small punch test (SPT) method is an innovative technique applicable in cases when limited amount of the experimental material is available. Another possibility are micro-tensile samples from the same material volume as SPT. This kind of tests maintains minimal material requirements, while the same loading mode of samples as in the case of standard tensile tests is kept. With the use of Digital Image Correlation systems for micro tensile samples measurement, additional information on material behaviour can be obtained. By modification of the active part geometry providing wide range of stress strain conditions, even miniature tensile samples can be used for ductile damage parameters determination and thus provide deeper insight into nanomaterials behaviour.

Keywords

Nano-material, small punch test, mini-tensile test, digital image correlation.

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Microstructure and martensitic transformation in Ti-based alloys subjected to severe grain refinement

Wojciech MAZIARZ, Paweł CZAJA

Institute of Metallurgy and Materials Science Polish Academy of Sciences, Reymonta Str. 25, 30-059 Kraków, Poland, w.maziarz@imim.pl

Abstract

Materials characterized by ultrafine and nanocrystalline microstructure show significantly different mechanical and structural properties as compared to those featuring coarser grain. This is well demonstrated in the case of Ni-Ti shape memory alloys (SMA), which fuse excellent mechanical properties with unique shape memory behavior and superelasticity. It has been shown that severe structure refinement of these alloys has an effect on the sequence of martensitic phase transformations and in consequence it may impact the thermo mechanical properties related to their shape memory behavior. It may also lead to a variety of outstanding mechanical properties including high strength coupled with an improved elongation capacity. Moreover it has been found that the self accommodation of martensitic plates is strongly dependent on the grain size. Ultrafine crystalline Ni-Ti SMA may be obtained by devitrification of an intermediate amorphous phase generated by high pressure torsion (HPT). HPT apart from equal channel angular pressing (ECAP) is one of the most commonly used methods of severe plastic deformation (SPD), which is employed to perform such an ultrafine and nano structuring. Other SPD modes such as cold rolling may also be implemented. In principle the SPD entails subjecting bulk materials to a large plastic deformation at relatively low homologous temperatures. At the same time cracks propagation and growth is hindered by a large pressure build up imposed on the material by the geometrical constraints of the straining devices such as dies and anvils, which in result prevents mechanical failure. The chief advantage of SPD is that it produces large samples, which are fully dense and may be manufactured from high purity precursors. This paper reviews recent progress in the area of Ti-based SPD structured materials. Some examples of β–Ti shape memory alloys deformed by cold rolling are also presented as a prospective route.

Keywords

Microstructure, nanocrystals, martensitic transformation, shape memory alloys, SPD, TEM.

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Research Opportunities in COMTES FHT a.s.

Michal ZEMKO

COMTES FHT a.s., Průmyslová 995, CZ 334 41 Dobřany, Czech Republic, michal.zemko@comtesfht.cz

Abstract

COMTES FHT realised large investments in year 2012 to strengthen its position among the top regional research organisations acting in the field of metal research. The new investments cover a wide range of applications starting with (1) big metallurgy technologies and standard sample size mechanical testing, continuing with (2) micro sample size preparation and testing equipment and ending with (3) equipment for production of nano-sized bulk metallic materials.

The biggest investments are as follows: a vacuum melting and casting furnace up to 50l of liquid metal; a universal fast hydraulic press up to 2500 t; a two-high and four-high configurable rolling mill with many heating and cooling options. A set of tools for Conform to enhance an efficiency of grain refinement was designed and manufactured for the existing Conform S315i machine. To allow the numerical modelling of all investigated processes new licences of JMatPro, DEFORM, MSC Marc, Patran, Dytran and XFlow were purchased.

Mechanical testing laboratory was equipped by ZWICK Z 250 testing system with laser extensometer; MTS multiaxial testing system; Aramis digital image correlation (DIC) system consisting of two digital cameras and software; discharge sampling equipment for miniature samples testing.

New investments were accompanied by significant increase of staff members. Altogether 65 staff members worked at COMTES FHT a.s. at the end of year 2012.

Keywords

Melting and casting furnace, hydraulic press, rolling mill, JMatPro, DEFORM, multiaxial testing, DIC, micro tensile test.

INVESTMENTS IN EDUCATION DEVELOPMENT

R&D of centrifugal casting technology of intermetallic compounds for industrial applications

Karel MALANÍK, David KAŇÁK

VÚHŽ a.s., Dobrá 240, CZ 739 51 Dobrá, Czech Republic, malanik@vuhz.cz, kanakd@vuhz.cz

Abstract

Inter-metallic alloys form an extensive class of materials, which is highly interesting from the perspective of their application in demanding environments, namely in the areas with high temperatures and high pressures under action of oxidation atmosphere. Big interest in these materials is caused by unique combination of their properties, such as high tensile strength at high temperatures, good resistance to oxidation and corrosion accompanied by their comparatively low density. Materials for use at high temperatures and pressures are primarily intended for components of energy and chemical equipments. Due to the application potential of these advanced materials, it was decided to start new project in VÚHŽ a.s. The aim of our project is verified centrifugal casting technology of intermetallic compounds based on Ni in operating conditions of foundry VÚHŽ a.s. This project is realized in cooperation with VSB-Technical University of Ostrava and builds on previous results of research activities in this field at this institution. It is a comprehensive solution to increase the efficiency of research and development and accelerate the transfer of results into the application sphere, increasing the intensity and effectiveness of cooperation in research and development between industrial companies and research organizations. Implementation of this project will increase the quantity and quality of knowledge, applied research and experimental development of advanced technologies and materials that are applicable in the form of innovation in several sectors (metallurgy, energetics, etc.), thereby contributing to the production of goods and services with higher added value.

Keywords

Intermetallics, intermetallic compounds, centrifugal casting, melting, testing of material properties, technology processes optimizing.

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New types of magnesium alloys for ECAP processing

Stanislav RUSZ, Lubomir ČÍŽEK, Jan KEDROŇ, Stanislav TYLŠAR, Michal SALAJKA

VŠB – Technical University of Ostrava, 17. listopadu 15,708 33 Ostrava – Poruba, Czech Republic, stanislav.rusz@vsb.cz

Abstract

The technology ECAP – Equal Channel Angular Pressing, belongs to technologies of accelerated development and represents top items of severe plastic deformation methods to reach ultra-fine granularity structure. This concerns specifically forming of non-ferrous metals and their alloys. This technology was therefore applied namely for aluminium alloys. The achievement of the desired structure depends primarily on the tool geometry, number of passes through the die, magnitude and strain rate, temperature of processing and lubrication mode. In this article a new type of magnesium alloys for ECAP processing are presented.

Magnesium alloys AZ31, WE45 and Mg-Zr supplied in the form of bars with dimensions Ø 50 – 600 mm length, prepared by hot extrusion and/or with heat treatment T4 application, were used as an experimental material. HT - T4 condition: pre-heating 375 °C/3 hours + 415 °C/18 hours / water or air cooling. Samples with dimensions 15 × 15 × 55 mm for ECAP processing were used.

This paper describes namely on ECAP technology investigations that have been oriented on overall objectives of acquiring new knowledge concerning strengthening, influence of stress conditions, mechanical properties and microstructure of magnesium alloys given above. Measurement of Vickers hardness for determination of mechanical properties and methods of light microscopy for the study of microstructures were used.

Keywords

Severe plastic deformation, ECAP process, heat treatment, magnesium alloys, mechanical properties, structure.

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Experimental possibilities of SPD investigation in age-hardening aluminium alloys

Vladivoj OČENÁŠEK

SVÚM a.s., Podnikatelská 565, 190 11 Prague 9 – Běchovice, Czech Republic, ocenasek@svum.cz

Abstract

In comparison with non-age-hardening aluminium alloys, the investigation of the SPD effect on structure and properties of age-hardening aluminium alloys requires a quite specific approach to carrying out experiments. When the experiments aim at reaching optimum properties (it does not mean always the maximum ones), the relations between as received - and final structure, heat treatment (solution annealing, natural ageing, artificial ageing) and deformation applied leading to an ultra-fine-grained structure shall be taken in consideration. The paper deals with the possibilities which respect these demands and lead to the better utilizing of properties of aluminium age-hardening alloys. The effect of various technological parameters on the course of experiments is analysed. Examples of SPD experiments, that are substantially meaningless and of experiments showing that an optimum hardening effect can be reached owing to the interaction of a plastic deformation and precipitation hardening, are given.

Keywords

Severe plastic deformation, age-hardening aluminium alloys, heat treatment, microstructure.

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Modelling of Grain Refinement in Steels by Thermomechanical Treatment in Torsion Plastometer

[a] Josef BOŘUTA, [b] Tomáš KUBINA

[a] *MATERIÁLOVÝ A METALURGICKÝ VÝZKUM s.r.o., Pohraniční 693/31, 706 02 Ostrava-Vítkovice, Czech Republic*

[b] *COMTES FHT a.s., Průmyslová 995, 334 41 Dobřany, Czech Republic, tomas.kubina@comtesfht.cz*

Abstract

The paper presents comments on methods of and the current state in achieving ultrafine microstructures in steels. It also offers literature references on the so-called nanosteels. An analysis is presented of fundamental plastometer tests and simulators from the viewpoint of stress states and with regard to achieving maximum strains. A comparison has been made between their characteristics and stress states encountered in present-day forming processes. The focus of the paper is simulation conducted in SETARAM plastometer. The SETARAM plastometer used in the experiments has been modified recently. The changes concerned predominantly its temperature measurement and control devices. The lower limit of its operating temperatures was reduced to approximately 400 °C.

Various types of sheet rolling simulations conducted in the plastometer are demonstrated. In the field of basic research into materials plasticity, approaches to evaluating continuous torsion tests to fracture are presented. In terms of interrupted tests, the importance of the anisotropic interrupted test as a source of information for research is touched upon. In particular, demonstration is given of the potential for finding transformation temperatures governed by deformation in the 1.0583 steel grade.

A physical simulation procedure involving strain-induced ferritic transformation has been designed on the basis of results of tests. Mechanical properties were measured using specimens upon the simulation. Microstructures resulting from the thermomechanical simulation are discussed.

Keywords

Grain refinement, torsion plastometer, physical simulation, thermomechanicaltreatment.

INVESTMENTS IN EDUCATION DEVELOPMENT

Using of nanomaterial at industrial profession

Marcel KLOS

VŠB – Technical University of Ostrava, 17. listopadu 15, 708 33 Ostrava – Poruba, Czech Republic, mklos@visteon.com

Abstract

Development automotive industry and incidences activity of global depression thesis in latterly of new demand on search savings in used material.

In terms of development state economies fall European currency versus dollar happen in global automotive industry to fall or shift activities depending on positive result of seals.

In global economies in latterlythings are drawing of sales in destination e.g. China and India. For preservation positive economic growth happen to limitation productions and development make of smaller needs to technological innovation. Necessary ismake use of currently capacity of industrial production.

At latterlyof suppliers to automotive industry must by develop activities for decreasing of the total salary of the product. The suppliers make of cost savingin staff qualification, limitation of technological develop and investment.Obviously these aspects have of the effects non-competitive efficiencyand inability of implementation of new materials to serial productions, which bringing of no small investment in modernization ofproduction process and increasing of product quality.

Strategically is necessary be on the look for new industries for exercise of nanomaterials, that are not dependent of economies stagnation.

Keywords

Economies stagnation, development, nanomaterials, automotive industry, serial production.

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Use of instrumentation of the Department of Materials Technology of the SilesianUniversity of Technology in Katowiceat the preparation of joint projects in the field of SPD technologies within the project"Nanoteam VŠB – TU Ostrava"

[a] Lubomír ČÍŽEK, [b] Eugeniusz HADASIK

[a] *VŠB – Technical University of Ostrava, 17. listopadu 15, 708 33 Ostrava – Poruba, Czech Republic, lubomir.cizek@vsb.cz*

[b] *Silesian University of Technology, ul. Krasinskiego 8, 40-019 Katowice, Poland, eugeniusz.hadasik@polsl.pl*

Abstract

Since the beginning of the XXI we see a recurring significant interest in magnesium alloys and their applications in the automotive and aerospace industries. The automotive industry is interested in them primarily in connection with possible reduction of weight and of fuel consumption. The aerospace industry uses these alloys for the fuselage of aircrafts and for components in the cockpit. New areas of use of Mg alloys are opened to us by new production technologies and their enhancements, such as:

- Processing of new alloys
- New technologies for production of by foundry processes
- Enhancement of forming technologies with use of the SPD method
- Production of new coatings ensuring protection of materials against corrosion

The report of the European Commission MAG TECH 1 (2004) "Magnesium alloys and processing technologies for lightweight transport applications" refers to the necessity of intensification of research and development works on magnesium alloys and of their subsequent applications, especially in the area of the entire transport.

The following is expected:

- Development of foundry technologies
- Intensive development of forming technologies

International collaboration in these areas, especially between universities and research institutes, is of great importance. The Department of Materials Technology of the SilesianUniversity of Technology in Katowice, Poland, in addition to its other activities, collaborates closely with the Department of Mechanical Technology, at the Faculty of Mechanical Engineering of the VSB-TU Ostrava, Czech Republic.

The working site is equipped with the following basic devices:

- Hydraulic press with the max. forming force of 150 t
- Proprietary equipment for the process of forward extrusion
- Chamber furnace CARBOLITE CWF13/13.

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Evaluation of sheet-metal strainby embossed circular grids

Radek ČADA

VŠB – Technical University of Ostrava, 17. listopadu 15, 708 33 Ostrava-Poruba, Czech Republic, radek.cada@vsb.cz

Abstract

Contribution concerns the method of deformation networks in range of sheet-metal forming. Principle of this method consist in creation of deformation network at sheet-metal blank before forming and evaluation of its deformation at any moment or after forming operation in forming tool.

A special apparatus for embossing of circular grids on sheets with continuous regulation of embossing force was constructed. With this apparatus accurate, clear and permanent circles can be applied to the sheet simply, very quickly, without the use of a power source. The apparatus has small dimensions and so it is portable, its cost is low.

At drawing of intricate shape stampings from steel deep-drawing sheets the using of impression depths between 0.05 mm and 0.06 mm proved true, which guarantee minimum sheet-metal influence by deformation in places of impressions with contemporaneous good legibility even after great plastic deformation of material.

Keywords

Deformation network, sheet-metal, circular grid, embossing, strain, forming.

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New opportunities in the support of R & D projects in the nanotechnology field

Libor KRAUS

COMTES FHT a.s., Průmyslová 995, 334 41 Dobřany, Czech Republic, libor.kraus@comtesfht.cz

Abstract

This paper contains presentation of options in the support of R&D projects in the programmes of financial support in the Czech Republic and in the international programmes. The paper summarizes opportunities of both fundamental as well as applied research and development, and compares opportunities of grants and the probability of accepting proposed projects in terms of success rates of accepted proposals. The paper includes the conditions of projects in international programmes in terms of consortia size and a number of international partners as well.

Keywords

R&D projects, international programmes, financial support.

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INVESTMENTS IN EDUCATION DEVELOPMENT

Accumulative Roll Bonding

Zbyšek NOVÝ

COMTES FHT a.s., Průmyslová 995, 334 41 Dobřany, Czech Republic, zbysek.novy@comtesfht.cz

Abstract

ARB is a process by which metal bands with a prepared surface are put to each other, such made sandwiches are rolled at room or higher temperature by fifty-percent draft and potentially subsequently thermally processed. The process is repeated several times. During rolling bands joining occurs, as well as putting deformation into metallic material. After the rolling removal a rolled semi-product is being annealed in some cases, then it is split into two halves, these are put together after surface treatment again and further rolling follows.

Due to multiple process repetition it is possible to achieve a very high degree of accumulation of strain in the material. When the process is properly set up deformation material refinement after extreme strain occurs. Heavily elongated texture grains are divided into small subgrains and in favorable cases into small grains with large angular mutual orientation. Thus microstructure refinement occurs as well as texture changes, these changes can come to gaining ultrafine microstructure or even nanostructure. The process can be suitably supported by intermediate operation annealing, which should decrease dislocation density, but also change the nature of the angle grain interface, textures character, and in some cases, it should activate recrystallization. In specific cases, the microstructure is being hardened during annealing.

ARB process can be realized also by rolling sequences at increased temperature, followed by potential annealing and then rolling at room temperature and possible subsequent annealing. Material parameters are usually monitored during the whole process and after its completion. Grain size and subgrain, angular boundaries between the grains, the type of texture, dislocation density, mechanical properties are frequently evaluated. The homogeneity of microstructure on the thickness of the band and character of the connection of bands that were rolled together is very significant.

Keywords

ARB process, grain size, band rolling, microstructure, nanostructure.

INVESTMENTS IN EDUCATION DEVELOPMENT

Mechanical properties of UFG magnesium alloys

Pavel LUKÁČ

Charles University, Dept of Physics of Materials, Ke Karlovu 5, 12 116 Praha 2, Czech Republic,lukac@met.mff.cuni.cz

Abstract

Severe plastic deformation (SPD) technique may produce an ultrafine grained (UFG) microstructure of metallic materials, which leads to a significant improvement of the materials. The results of investigations show that grain refinement is also of significance for magnesium alloys to obtain enhanced properties. Magnesium alloys prepared by equal angel channel processing (ECAP) were deformed at various temperatures. It has been found that reducing grain size leads to a large increase in the strength of ultrafine grained magnesium alloys deformed at room temperature in comparison to that of coarse grained ones. The strength of ultrafine grained magnesium alloys decreases rapidly with increasing test temperature. At higher temperatures the strength of ultrafine grained magnesium alloys may be lower than that of coarse grained ones. On the other hand, the overall ductility prior to failure of ultrafine grained magnesium alloys deformed at room temperature is higher than that of coarse grained ones. The ductility of ultrafine grained Mg alloys increases with increasing test temperature. In some cases, the superplastic deformation behaviour may be observed. It should be noted that the processing route of ECAP is one parameter that can effectively influence the mechanical properties of materials.

This paper presents a very brief review describing mechanical properties of ultrafine grained magnesium alloys

Keywords

SPD, grain refinement, mechanical properties, magnesium alloys.