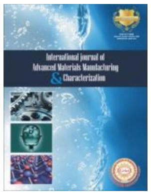

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A Review on Severe Plastic Deformation

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A B S T R A C T

In the recent years much attention has been paid to the development of ultra-fine grained and nanostructured materials due to their superior properties. Several severe plastic deformation (SPD) techniques have emerged in the recent years for producing ultra fine grained materials in bulk metals and alloys. Among the various SPD techniques proposed most of the methods are intended for processing bulk materials; very few methods like Equal-channel angular pressing (ECAP),High pressure torsion (HPT)technique **,**constrained groove pressing (CGP) and repetitive corrugation and straightening (RCS) are capable of processing sheet materials. The requirement of stringent surface preparation the propensity of cracking due to de-lamination of accumulative roll bonded layersand formation of edge cracks limits the application of ARB processed sheets. Meanwhile in RCS process elongation of sheets causes strain inhomogeneity. The recently invented CGP process sans above mentioned problems is considered method for producing fine grained sheet materials for structural applications .A further defining feature of SPD techniques is that the preservation of shape is achieved due to special tool geometries which prevent the free flow of material and thereby produce a significant hydrostatic pressure. The presence of a high hydrostatic pressure, in combination with large shear strains, is essential for producing high densities of crystal lattice defects, particularly dislocations, which can result in a significant refining of the grains

Introduction

Severe plastic deformation (SPD) is a generic term describing a group of metal working techniques involving very large strains which are imposed without introducing any significant changes in the overall dimensions of the specimen or work-piece. A further defining feature of SPD techniques is that the preservation of shape is achieved due to special tool geometries which prevent the free flow of material and thereby produce a significant hydrostatic pressure. The presence of a high hydrostatic pressure, in combination with large shear strains, is essential for producing high densities of crystal lattice defects, particularly dislocations, which can result in a significant refining of the grains.

Plastic deformation is a process is which enough stress is placed on metal or plastic to cause the object to change its size or shape in a way that is not reversible. In other words, the changes are permanent; even when the stress is removed, the material will not go back to its original shape. Sometimes referred to simply as plasticity, this type of deformation can take be conducted under controlled circumstances [1]

Both the deformation of plastic and the deformation of metals involve changes to the makeup of the material itself. For example, metals that undergo this process of plastic deformation experience a condition known as dislocation. As stress of some type is exerted on the metal, the material reaches a point known as the yield strength. When this point is achieved, the pattern of the molecules that make up the metal begin to shift. The end result is that the molecules realign in a pattern that is shaped by the exterior stress placed on the object. As the dimensions of the work-piece practically do not change in an SPD operation, the process may be applied repeatedly to impose exceptionally high strains. Optimization of routes and regimes of SPD can eventually introduce an extremely fine microstructure into the processed material which will extend, reasonably homogeneously, throughout the bulk. A distinctive feature of these ultrafine-grained materials is that they contain a high fraction of grain boundaries having high angles of misorientation. SPD process is currently defined as any method of metal forming under an extensive hydrostatic pressure that may be used to impose a very high strain on a bulk solid without the introduction of any

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significant change in the overall dimensions of the sample and having the ability to produce exceptional grain refinement[2].

Based on the extensive research conducted to date, applications of SPD techniques are now starting to emerge for use in manufacturing industries and several commercial products such as sputtering targets, fasteners and dental im-plants, are already available. An up-scaling of the SPD processes, which are already proven viable at the laboratory scale, and the development of continuous processing techniques will further allow for the development of large-scale applications. The compaction of powders through SPD processing is also an additional area of opportunity for utilization in large-scale manufacturing. SPD methods are used to convert coarse grain metals and alloys into ultrafine grained (UFG) materials. Obtained UFG materials then possess improved mechanical and physical properties which destine them for a wide commercial use[3]. The main aim of SPD processing is extreme grain refinement and the ensuing strengthening of the processed material. There is no longer any doubt that this is achievable with most malleable and even with many hard-to-deform materials

Types of Severe plastic deformation

Equal-channel angular pressing

The process of equal-channel angular pressing (ECAP), also known as equal-channel angular extrusion Equal channel angular pressing (ECAP) developed by Segal et al.is an effective tool to impose large plastic strains.ECAP is based on simple shear taking place in a thin layer at the crossing plane of the equal channels[4]. The process has attracted considerable interest as a method to refine microstructure by deformation processing. ECAP process involves simple shear deformation that is achieved by pressing the work piece through a die containing two channels of equal cross-section that meet at a predetermined angle .Deformation occurs in the immediate vicinity of the plane lying at the intersection of two channels. The effective strain imposed on the work piece increases with decreasing channel angle (/). An important advantage of ECAP process is that a large amount of simple shear deformation can be imposed in single or multiple processing steps without changing the cross-section of the work piece. In spite of its invention in the early 1980s, the process is yet confined to the laboratory due to problems associated with die design.Very few have extruded difficult-to-work materials like titanium alloys, magnesium alloys and have succeeded to a certain extent. Even in laboratory scaleprocessing, problems arise when different materials are deformedwith a same ECAP die set. ECAP is envisioned as a primary metal working process; therefore an ECAP die should be able to process a wide variety of materials successfully. In order to overcome this bottleneck, the effect of various parameters such as corner angle friction strain hardening rate, back pressure

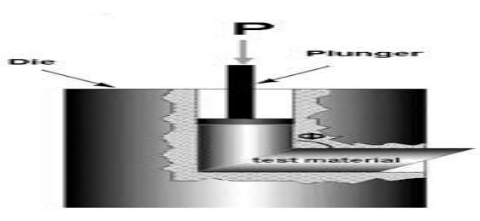


Fig 1:Equal-channel angular pressing

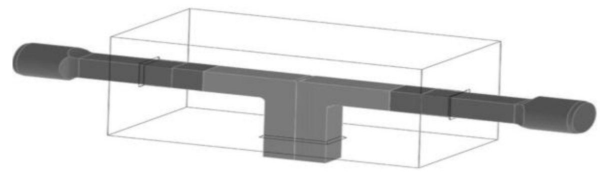


Fig 2: ECAP with converging billets

ECAP with converging billets

The new ECAP system uses two substantially equal square or rectangular input channels converging into a single output channel, which is twice as wide as the input channels so that it can accept two converging billets. The contact surface between converging billets plays the same role as a movable bottom wall in the output channel of classical ECAP as show in fig 2. It reduces friction and the process force. This effect is achieved without using a complex die with movable parts[5]. Instead, two punches are used to push two billets synchronously from the opposite sides. The system doubles productivity compared to the case of processing a single billet. Show comp-arison of classical ECAP of a single billet (without moving die walls) and ECAP with two converging billets in terms of strain distribution Friction coefficient in both processes is the same and equal m¼0.1. Strain appears to be similar, except the bottom part of the billet, where it is smaller for ECAP with converging billets as in Fig2 . This is related to the fact that, in the absence of friction on the bottom part of the billet, the die corner at the channel

Intersection is filled less; the same effect would be observed in ECAP with a movable bottom wall. A remedy might be back pressure, which improves filling of the die and makes strain distribution more homogeneous. ECAP with two converging

Billets reduce friction in the output channel, which leads to a lower value of the maximum process force.

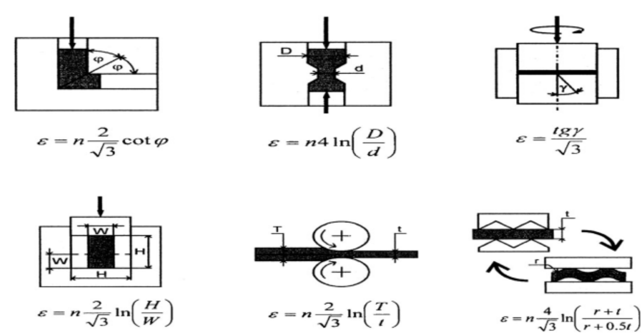


Fig 3 Different effective in Severe plastic deformation

Constrained groove pressing

In CGP the sheet material is subjected to repetitive shear deformation under the plane strain conditions by alternately pressing between asymmetrically grooved and flat dies as in the fig4. The CGP die assembly essentially consists of two asymmetric grooved dies for corrugating the sheet and two flat dies for flattening the corrugated sheet. The asymmetric grooved die consists of equally spaced groove and the distance between the grooves is maintained as the thickness of the sheet to be processed. The groove angle (h) is maintained at 45 to obtain maximum uniform shear strain during CGP processing. The entire die assembly is constrained at both ends to ensure plain strain deformation condition. A single pass of CGP involves two stages of alternating corrugation and flattening of sheets. During first stage the sheet is corrugated between asymmetric grooved dies imparting shear deformation in the inclined regions followed by flattening between flat dies. At the end of first stage total effective plastic strain of is introduced in the double hatched regions whereas adjacent white regions in are left undeformed. Before the start of second stage, the sheet is rotated by 180 along the thickness axis or the asymmetric grooved die is shifted horizontally Equivalent to the groove width so that the undeformed flat regions obtained in the first stage is subjected to shear deformation in the second stage. During second stage, similar to first stage the sheets are corrugated and flattened thereby imparting effective strain of 1.16 homogenously throughout the sheet material. By repeating the process continuously large amount of plastic strain can be imparted to the material without appreciable dimensional changes, thereby achieving fine grained structures and superior mechanical properties[6].

Even though many earlier investigations have been reported on processing of pure FCC metalsby CGP technique, pure nickel sheet is processed by this technique for the first time in the present work.

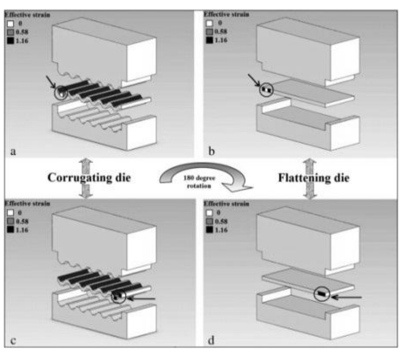


Fig 4: Constrained groove pressing

The room temperature tensile behaviour of the nickel sheets processed up to three passes of CGP is investigated. The influence of severe plastic deformation on the plastic flow behaviour of nickel is described by evaluating the applicability of different constitutive equations in the uniform deformation range. The strain hardening behaviour is examined by Kocks–Mecking plot. Additionally the dislocation density evolution in severe plastically deformed nickel sheets is examined using Kocks one variable phenomenological model.

High pressure torsion (HPT) Technique

High pressure torsion (HPT) refers to processing that evolved from Bridgman's anvils involves a combination of high (GPa range) pressure with torsional straining as shown in fig 5. Today this technique is appreciated by many researchers as the one that allows the most efficient grain refinement. A handicap of the method is that only small coin-shaped samples, typically 10–15 mm in diameter and 1 mm in thickness, can be processed. The readers are referred to a comprehensive review on the subject for details. Because of size restrictions, the samples manufactured by HPT are used primarily for research purposes. An important issue for many SPD processing schemes, including HPT, is the non-uniformity of deformation[7]. For instance, during HPT straining, the shear strain at the rotation axis should be zero, increasing linearly in the radial direction if the geometry of the work piece does not change. This means that the material near the rotation axis of the sample should stay undeformed. This is not supported by numerous micro-structural observations and micro hardness measurements showing a reasonably uniform distribution of grain dimensions and micro-hardness, provided the compressive pressure and the number of revolutions of the anvil are sufficiently large. Vorhauer and Pippan explained this discrepancy by the fact that it is virtually impossible to realize an ideal HPT deformation due to the misalignment of the axes of the anvils.

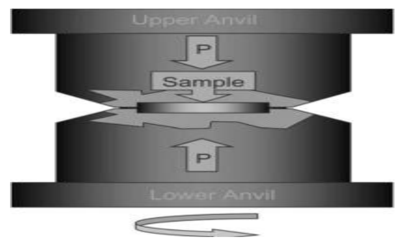


Fig5. High technique pressure

Alternatively, the development of a reasonably uniform strain and homogeneous microstructure was explained in terms of gradient plasticity theory coupled with the micro structurally based constitutive modeling .This model will be addressed in the following section. Axial in homogeneities observed in an HPT-processed Zr3Al intermetallic were associated with softening effects related to nanostructuring.

Twist extrusion

The principle of TE process is pressing a billet through a die with a profile consisting of two prism sections separated by a twist section as shown in the fig6, where extremely large shear deformation produces. The twist feature contributes to format the pronounced dislocation cell structure at the submicron scale . TE has been aroused the considerable attention for the advantages of relative lower extrusion load and shearing strain accumulation nature. Recently, some investigation of TE technology in succession, e.g. kinematics of metal flow , computational study of TE process , summary on features of TE , and mass experimental study on different materials processed by TE (Al, Cu, Ti, and their alloys; powders of different composition). Systematic investigations of material properties and deformation characteristic are still needed to establish a basic foundation for TE technology.TE technology is one of the most promising SPD methods for fabricating UFG materials in industrial commercialization. However,the non-symmetric nature of the process limits its application to only rectangular sections . Since industrial raw materials are basically round-section shape, the limits of TE process would increase the complex process design, e.g. the manufacture of dies and equipment .

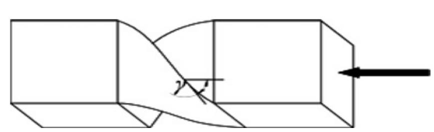


Fig 6.Twist extrusion

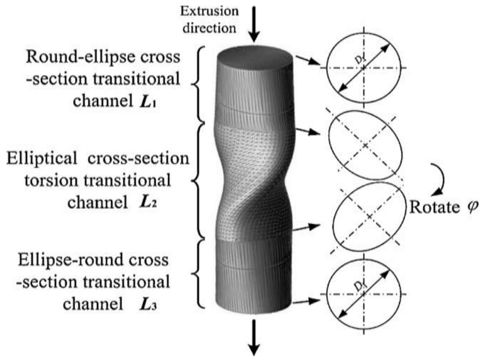
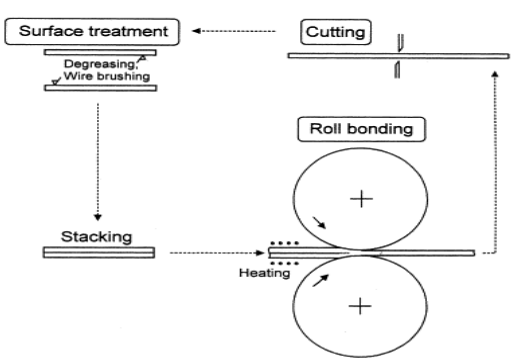


Fig 7.Twist extrusion of a prismatic billet

IT is another variant of a simple shear deformation process that was introduced by Beygelzimer et al. some ten years ago [8-10]. Under TE processing, a prismatic billet is extruded through a "twist die". While the advantage of the process is its high up scaling capacity, it suffers from essentially the same generic problem as the HPT: deformation is non-uniform, being smallest near the extrusion axis. Investigation by Orlovet al. [11] showed that this technique is slightly less effective in producing UFG structure than ECAP or HPT.

Accumulative Roll Bonding (ARB)

A key issue of the research is the investigation of Accumulative Roll Bonding in combination with other processes like Roll Bonding and Differential Speed Rolling. Accumulative Roll Bonding (ARB) was first published by Saito in 1999. It combines joint plastic deformation with severe plastic deformation. Two sheets are brushed on one side, each. These are placed together, facing each other and bonded together by roll bonding with a thickness reduction of 50 percent as shown in the fig 8 . As cold welding takes place during rolling a new sheet is produced. After rolling the sheet is divided in the transverse direction into two parts with the same geometry as the two initial sheets. By repeating this cycle, a large plastic deformation is inserted into the metal. The applicability of ARB has been studied for various metallic elements and alloys like steel, copper, aluminium and technically important aluminium alloys. The development of texture, micro-structure and mechanical properties has been studied mainly for aluminium alloys [12]. By utilising ARB laminar material composites can be produced by combinations of different materials. In addition intermetallic phases can be generated. This in principle also holds for compounds such as _-AlTi, which are important high temperature materials but are hard to roll to sheets



Therefore,it is advisable to roll the more easy formable metallic materials to sheets and start the reaction of the elemental foils into intermetallic phases subsequently. The limiting factor of the reaction of titanium and aluminium to TiAl is the inter diffusion. By ARB the thickness of the individual layers can be reduced below the length which is affected by diffusion in a reasonable short time. In addition diffusion is accelerated due to the gain in free volume, the large volume fraction of grain boundaries and the high number of vacancies caused by severe plastic deformation.

A solid, light and tough material can be created by combining layers of a solid material such as titanium and a soft material such as aluminum. A commonly known example for a composite like this is the seashell. The main aim of this project is to investigate the parameters of the production of Al-Ti-layered materials. Because of the fact that the intermetallic phases are not desirable in order to maintain the ductility the possibility to separate the titanium and aluminum layers by niobium

Conclusion

A comprehensive theory of the trans-formation of the dislocation cell structure into a new grain structure with a large proportion of high-angle grain boundaries
needs to be developed. Such a theory should provide insights in the mechanisms and governing factors that determine the smallest achievable grain size.
It probabilistic theory able to predict grain size and mis-orientation angle distributions and their variation with strain for different deformation paths.
Basis for simulations of the post-SPD performance of the processed material under service conditions. Understanding
the nature of dislocation–grain boundary interactions for small grain size systems and the role of grain boundaries as sinks and sources of dislocations is a particularly interesting goal of research
SPD techniques to modify various physical or physicochemical properties of function-al materials. Work hardening is fairly low in ECAP-processed material. This is possibly due to the difficulty of storing additional dislocations or there distribution of stored dislocations during straining, that is not seen for annealed, well recovered materials.
ECAP with converging billets is a new original process, which reduces friction between die and billet by introducing another symmetrical billet processed at the same time in a way, which makes both billets converge in the output channel of the die. This leads to forming force reduction and avoidance of material Pick up on the die surface.

Reference:

1.Bert Verlinden "severe plastic deformation of metals"Association of Metallurgical Engineers Serbia and Montenegro Scientific paper
AME UDC:669.01:620.174/.175=20

2. Y.Estrin, A. Vinogradov "Extreme grain refinement by severe plastic deformation: A wealth of challenging science"Acta Materialia 61 (2013) 782–817.

3.J. Zrnik, s. v. Dobatkin, i. Mamuzi "Processing of metals by severe plastic deformation (spd)–structure and mechanical properties respond" ISSN 0543-5846METABK 47(3) 211-216 (2008)UDC – UDK 669.14418:539.37:620.17=111.

4. G. Angella, B. Esfandiar Jahromi, M. Vedani "Tensile behaviour and strain hardening characteristics of constrained groove rolling of silver in the severe plastic deformation regime"

5. A. Rosochowski, L. Olejnik, J. Richert , M. Rosochowska , M. Richert
"Equal channel angular pressing with converging billets—Experiment"Materials Science & Engineering A 560 (2013) 358–364.

6. S.S. Satheesh Kumar,T. Raghu Mater Sci Eng "Process and charaterization of nickel sheets by Constrained groove pressing " 2009;519:105.

7 Mousumi Das ,Goutam Das, Mainak Ghosh , Matthias Wegner , V. Rajnikant,
S. GhoshChowdhury." Microstructures and mechanical properties of HPT processed 6063 Al alloy" T.K. Pal Materials Science & Engineering A 558 (2012) 525–532

8. Beygelzimer YY, Varyukhin VN, Synkov SG, Sapronov AN, Synkov VG. Phys Technol High Press 1999;9:109.

9. Beygelzimer Y, Orlov D, Varyukhin V. In: Zhu YT, Langdon TG, Mishra RS, Semiatin SL, Saran MJ, Lowe TC, editors. 2002 TMS

10.Beygelzimer YY, Orlov DV. "High pressure effects in chemistry''. BiolMater Sci 2002;208-2:311.

11. Orlov D, Beygelzimer Y, Synkov S, Varyukhin V, Tsuji N, Horita Z. annual meeting and exhibition. Seattle, WA: TMS; 2002. p. 297.

12. S.S. Satheesh Kumar,T. Raghu "A comparison between equal channel angular pressing and asymmetric rolling material and design '' page32 (2011) 4650–4657