IFERP connecting engineers... developing research

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 5, May 2017

A Study on Surface Properties of Chips Produced by Large-Strain Extrusion Machining

[1]Kunal Arora, [2] Harsh Kansal, [3] Krishna Murari [4] Hitesh Mittal [5] Sumit Kumar
[1], [2],[3],[4],[5] PG Student, Department of Mechanical Engineering, Thapar University, Patiala, Punjab

Abstract: **manufacturing of bulk nano structured are in high demand in today's industry because of recent development and application of advanced materials. Many traditional machining processes were used but none of them have been able to produce complex shapes precisely at low cost. In order to overcome this difficulty Large–strain extrusion machining (LSEM) is introduced. It is basically a fabrication process. It is a single step manufacturing process. It is a method of severe plastic deformation (SPD) which is used particularly for machining bulk nano structured materials. It is a low cost manufacturing technique with advantage of machining and controlling dimensions simultaneously. Different shapes such as foils, sheets and bars of controlled dimensi ons are produced with controlled geometric parameters of the deformation using large strain extrusion machining. The paper reviews all the characteristics of large strain extrusion machining, its background, its developments, effect of various parameters (rake, feed, speed) on mechanical properties of chips, its mechanics, study of chips at microstructure and nano level. Effect of strain, porosity, hardness and other properties on chips have also been studied.**

Index Terms— Bulk, Extrusion, LSEM, Microstructure, Nano..

I. INTRODUCTION

With the rapid development in the fields of aviation, aerospace technology, defense and manufacturing, the use of lightweight alloys like magnesium, titanium alloys possessing high strength and limited ductility, have increased tremendously. With excelle nt mechanical, physical and chemical properties, Nano structured materials are widely used in various fields. The fabrication processes of Nano structured material have gained attention in the recent past. So research and development is being carried out across the globe to develop components using Nano structured materials [1]-[6]. Significant interest has been shown in developing different methods for machining of bulk Nano structured metals and alloys with the objective of exploiting their enhanced mecha nical properties for various applications. For effecting microstructure refinement most the methods used are found to be dependent on severe plastic deformation (SPD). Methods such as equal channel angular extrusion (ECAE), high - pressure torsion (HPT) and more recently, chip formation in machining are found to be particularly effective in imposing large plastic strains in also to low deformation temperatures [7]-[10]. Also multiple passes of deformation are needed to create the large strains, resulting in uncertainties in the estimation and control of the deformation parameters and deformation path. In order to overcome these limitations and study the effects of effective strain, strain rate and temperature one method is the study of chips formation by machi ning [11].

This further leads to the development of large strain machining and large strain extrusion machining. This is because large strain extrusion machining (LSEM) can geometrically controlled chips which can overcome limitation of conventional machining.

II. LARGE STRAIN EXTRUSION MACHINING

A. *Background of LSEM*

A rotary configuration of plain strain machining is used to produce continuous strips process of controlled thickness and by combining machining and extrusion imposed in a single step using a specially designed tool. In this configuration, a LSEM tool moves into a disk -shaped workpiece rotating at a constant cutting speed, V. The tool consists of two components. A bottom section with a sharp cutting edge inclined at a rake angle (α) and a wedge - shaped top section made that acts as a constraining edge. Both sections are of a hard material. The machined material is simultaneously forced through an extrusion die formed by the bottom rake face and the top constraining edge, thereby, effecting dimension and shape control. Undeformed material is continuously fed into the machining zone by advancing the LSEM tool radially into the workpiece at a constant feed rate. This feed is the rate

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 5, May 2017

of radial advance of the tool per revolution of the workpiece machining. Deformation takes place during the tool advance in the shaded region as shown in Fig. 1. In LSEM the thickness of the strip is predetermined in contrast to cutting; furthermore the strip thickness can be larger or smaller with respect to undeformed ch ip thickness. This unique feature offers imposition of different levels of strain that are sufficiently high to induce formation of an UFG microstructure in a single-step deformation process.

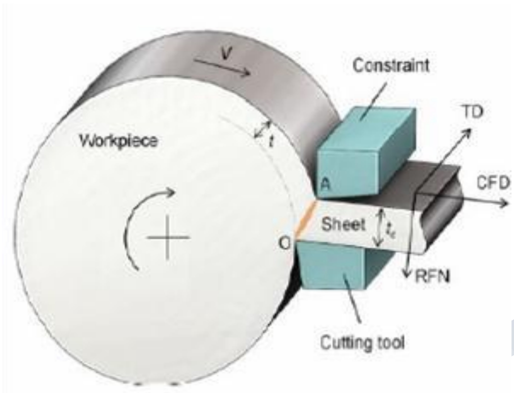

Fig. 1: Schematic of LSEM [15]

B. LSEM Process

In the last few years machining based deformation process has emerged as a feasible alternative to convention severe plastic deformation methods. The Chip formation in machining offers a simple route for the production of nanostructure and UFG materials by the impo sition of large uniform plastic strains in a single pass of a cutting tool. Shear strains in the range 1-15 can be imposed in a variety of materials, [12] including those of moderate to high initial strength, in a single step of deformation. But in machini ng, unlike conventional deformation processing methods, the geometry of the deformation and resulting chip is not determined a priori; hence, there is limited scope for control of shape and dimension of the resulting fine -grained chip material. A modification of the machining process that controls the geometry of deformation would be particularly useful for taking advantage of the simplicity of conventional machining as a method of SPD. This may be realized by constraining the chip flow with a suitable die or tool placed in the vicinity of the cutting edge, thereby maintaining shear strain values on the order of those imposed by machining alone, while introducing control on the shape of the chip. Such a process would be of interest not only for the creation of bulk nanostructure materials but also, for production of wire, sheet and bar with conventional microstructures, as an alternative to deformation processes such as rolling, drawing or extrusion. A method designed for this purpose, as depicted in Fig. 2 which will be called as Large strain extrusion machining (LSEM),a variant of the machining based deformation process which combines microstructure

refinement by large-strain machining, with shape and dimensional control of the chip by extrusion, simultaneously, in a single step deformation process. LSEM is a controlled method of SPD, offering a far greater level of control over deformation parameters than conventional SPD [8].

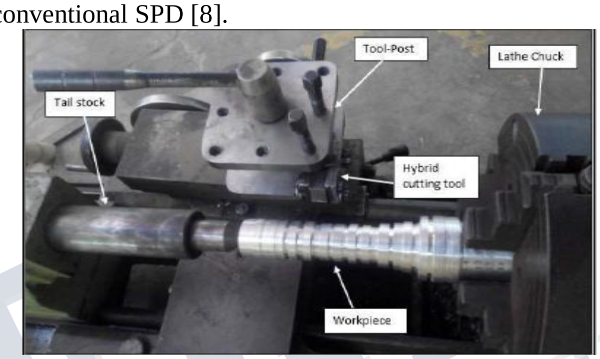

Fig.2: Schematic of experimental set up of LSEM

III.LITERATURE REVIEW

A. Large strain extrusion machining for magnesium alloy

Researchers [1] have investigated the effects of deformation temperature on microstructure and texture evolution machining of Mg-AZ31B magnesium alloy in LSEM. They found that at warm deformation temperatur es (~200°C), cold-worked type microstructures with predominant tilted basal texture were observed. With increase in temperature, grain structure sharply transformed into equiaxed type with predominant in -plane basal texture. This sharp transition was found to be consistent with change in temperature dependent dynamic re crystallization mechanism from continuous to discontinuous type. Investigation [2] the mechanics of LSEM process and its application for deformation processing of bulk Mg alloys, also analyzed the interactive effects of deformation temperature and hydrostatic pressure on sheet formation. At small strain rates microstructure development in single pass SPD was found to be very similar to that observed in multiple pass ECAP. By in situ control o f hydrostatic pressure and temperature in the deformation zone, segmentation in chip formation was suppressed, enabling sheet to be created. Chandrasekar, et al. 2014,[3] have highlighted the capability of producing a variety of continuous bulk forms having controlled microstructures, including crystallographic textures from LSEM process for magnesium alloy . Deformation conditions were set such a way that it was possible to obtain a pre determined crystallographic texture in the continuous bulk form that differs from the crystallographic texture of the solid body. Major controllable parameters were found to be chip thickness ratio (λ), rake angle (α). Chandrasekar, et al. 2015 [4] have demonstrated the application of LSEM for Mg, Ti alloys to produce sheets. They have investigated effects of process parameters on sheet segmentation flow, microstructure, and texture. They found Segmentation and fracture at the larger sheet thicknesses were pronounced in the case of Mg and Ti–6Al–4V, but not with ductile metals, such as Cu and Al. furthermore they concluded the enhanced formability of LSEM sheet have a fine dynamically recrystallized microstructure and shear texture.

B. Large strain extrusion machining for Lead

Researchers [5] have highlighted the character ization of the deformation field in LSEM, and its controllability for deformation processing of bulk material of lead (Pb) in form of sheet using direct measurements with high - resolution optical techniques. After PIV analysis they found for λ< 1, a larger fraction of the undeformed chip thickness region was flowing into the work piece subsurface and a greater spread of the deformation occurs into the subsurface. The deformation field was found to be intense, narrowly confined and controllable.

C.Large strain extrusion machining for copper

Moscoso, et al. 2007, [7] have performed a series of experiments in order to study the enhanced characteristics of nano structured materials and ultra -fine grains (UFG) of copper (Cu) created by LSEM. They found the har dness of nano structured chips was significantly higher than that of the bulk material. With increasing strain the evolution of microstructure refinement and formation of UFG structures were found. They found that, at lower value of strain, elongated UFG microstructure were observed while at moderate values equi-axed UFG was seen, and lastly, at highest strain UFG of 250 nm were produced. Sevier, et al. 2008 [8] have highlighted the development of a finite element method (FEM) procedure for prediction of deformation field parameters for (UFG) materials of Copper and Lead produced by LSEM, and their variation across the thickness of the chip for various chip thickness ratio (λ) were observed. According simulations performed by them they found that the strain produced in the chip, for a given rake angle (α), is entirely controlled by chip thickness ratio (λ). The strain was seen to be uniformly distributed through the chip thickness with a thin primary deformation zone allowing for the application of high str ain rates. Brown, et al. 2009 [11] have have highlighted the interactive effects of deformation field parameters on resulting microstructure of copper material while machining in LSEM process . The microstructure evolution at different deformation rates led to development of following results. The increase in the proportion of high angle boundary misorientation with increasing strain at small deformation rates, which results in the grain refinement in LSEM. At small strain rates microstructure development in single pass SPD was found to be very similar to that observed in multiple pass ECAP. Iglesias, et al. 2007 [12] have highlighted the wear rate behaviour of nanostructure materials like copper (Cu) and commercially pure titanium (Ti) fabricated by LSEM and they were compared with their coarse grain counter parts, and their wear mechanism were also discussed. They found that wear rates of these materials were lower than that of the microstructure materials, the reduction in wear rate for Cu - nano was particularly important under low shear strain value. The adhesive wear mechanism of Ti manifested an abrasive component. Micro structured Cu manifested severe plastic deformation and fracture characteristic of adhesive wear, while nanostructure Cu manifested a milder oxidative wear mode. Deng, et al. 2013 [13] have investigated the effect of constraining tool corner radius (R) on deformation behavior on strain and strain rate, in LSEM deformation processing of copper bulk material into nano structured material of chips. After evaluation of deformation behaviour of experimented chips, it was found that the effective strain increases with an increase in constraining tool corner radius. Furthermore, the effective strain rate decreases with an increase in constraining tool corner radius. Lin et al. 2013 [14] have analyzed the effect of coefficient of friction (μ) on deformation behaviour in LSEM using finite element method (FEM). A series of simulations were conducted using FEM model to obtain distribution of simulated effective strain with different friction coefficients. They found that the level of effective strain increased as the coefficient of friction increased. It was also manifested. At higher value of μ chip faces difficulty to get pushed out and chip gets d eformed more in homogeneously at this point. When cutting length was same the lengths of chip that were detached from workpiece are different at different coefficients of friction. Deng, et al.

2012 [15] have highlighted the application of finite element method (FEM) to investigate mechanism of LSEM process for pure copper material, to understand the advancement of temperature field, effective strain, and strain rate under distinct chip compression ratios. The cutting and thrust forces were also analyzed with respect to time by performing simulation in FEM they found that as λ becomes small, significant

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 5, May 2017

increases in effective strain and thrust force were obtained. Grain refinement of nanostructure materials were attributed for the large strains imposed in the primary deformation zone (PDZ) and the secondary shear zone.

D.Large strain extrusion machining for aluminium alloy

Deng, et al. 2014 [16] have studied the thermal stability of ultra-fine grains of Al alloy fabricated by LSEM. The annealing treatments were performed at different temperatures and for different lengths of time. UFG of Al alloy chips maintained high hardness under 200°C but started losing hardness as temperature increases to 300°C and above. When annealing was done temperature less than 100°C most of the fine grain were replaced by elongated grain there grain sizes increased with significant increase in the aspect ratio as the annealing time increased, when annealing was done at temperature up to 200°C re crystallization occurred, along the grain with growth. Plot illustrating the predicted values of shear strain and hydrostatic pressure as a function of chip thickness ratio is shown in Fig 3. Researchers [17] have studied the porosity level and mechanical properties in strips fabricated fro m casted ingot of aluminum 5052 by employing large strain extrusion machining process. They discovered significant reduction in porosity, due to high shear strain and hydrostatic pressure during extrusion. Also the mechanical behavior from LDH test of strips was found to be ranging within conventionally rolled and annealed strips.

E. Large strain extrusion machining for steel alloy

Study of the mechanical properties of AISI 1020 steel fabricated by LSEM has been done by researchers [18]. Slip line field theory is used for calculating strain. They have discovered significant increase in hardness of steel strips that was about 68% .it was also found that with increase in rake angle and chip thickness ratio strain was found to be increased.

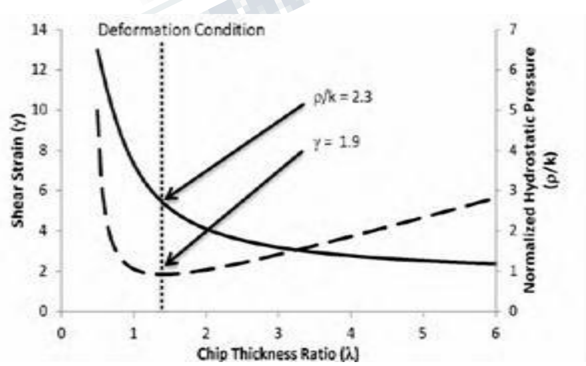

Fig. 3: Plot illustrating the predicted values of shear strain and hydrostatic pressure as a function of chip thickness ratio [16].

IV.CONCLUSION

The effect of rake angle, chip compression ratio or chip thickness ratio, constraining tool corner radius and coefficient of friction on LSEM has been analyzed. Nanostructure UFG strip formations in LSEM were discussed. The result shows that rake angle and chip compression ratio have a significant impact on total shear strain for the strip. The decrease in the rake angle causes effective strain and strain rate to be increased. But smaller the rake angle, the smaller in grain sizes the microstructure was obtained. The decrease in chip thickness ratio will also cause effective strain and strain rate to be increased. But smaller the chip thickness ratio, the smaller in grain sizes the microstructure was obtained. With the constraining tool corner radius or the friction coefficient increases, the strip effective strain, temperature, stress on the strip also increase, which can impact the microstructure and mechanical properties of the strip. The hardness of nanostructure chips was significantly higher than the bu lk material. With increase in shear strain the evolution of microstructure refinement of UFG microstructures was found. The wear rate analysis showcased that the wear rate of nanostructure material are less than micro structured material. Creation of thick sheet from large strain extrusion machining was best achieved using high hydrostatic pressure or large deformation temperature.

REFRENCES

[1] D. Sagapuram, M. Efe, W. Moscoso, S. Chandrasekar and K. P. Trumble, "Deformation temperature effects on microstructure and texture evolution in high strain rate extrusion-machining of Mg-AZ31B", Material Science Forum, pp. 52 -55, May 2011.

[2] M. Efe, W. Moscoso, K. P. Trumble, W. Dale Compton and S. Chandrasekhar: „Mechanics of large strain extrusion machining and application to deformation processing of magnesium alloys", Acta Mater., vol 60, no. 5, pp. 2031–2042, August 2012.

[3] S.Chandrasekhar, K.P Trumble, W. Moscoso, Mert Efe , D. Sangapuram, CJ. Saldana, J.B. Mann ,W.D Crompton, "Large strain extrusion machining processes and bulk produces there from", US Patent no.0017113, 2014.

[4] S. Chandrasekhar, K.P Trumble, W. Moscoso, Mert Efe and D. Sangapuram, "Direct sngle stage processing of light alloys into sheet by hybrid cutting - extrusion", vol 137, pp. 215-217, July 2015.

[5] Y. Guo, M. Efe, W. Moscoso, D. Sagapuram, K. P. Trumble and S. Chandrasekhar, "Deformation field in large-strain extrusion machining and implications for deformation processing", Scr. Mater., vol. 66, no. 5, pp. 235–238, 2012.

[6] H. Kansal, A. Jain and V Grover, "Micro Drilling and Drilling With Nano Materials: A Review", 4th National Conference on Advancements in Simulation & Experimental Techniques in Mechanical Engineering (NCASEme), pp. 45-49, March 2017.

[7] W. Moscoso, M. R. Shankar, J. B. Mann, W. D. Compton and S. Chandrasekhar, "Bulk nano structured materials by large strain extrusion machining", J. Mater. Res., vol. 22, no. 1, pp. 201–205, July 2007.

[8] M. Sevier, H. T. Y. Yang, W. Moscoso and S. Chandrasekhar, "Analysis of severe plastic deformation by large strain extrusion machining", Metall. Mater. Trans. A, vol. 39A, no. 11, pp. 2645–2655, June 2008.

[9] K. Arora, H. Kansal, D. Sharma and K. M. Katara, "Innovation In Design And Analysis Of Ultra - Precision Machine Tool", 4th National Conference on Advancements in Simulation & Experimental Techniques in Mechanical Engineering (NCASEme), pp. 142 -145, March 2017.

[10] A. Jain and H. Kansal, "Green Machining – Machining Of the Future", 4th National Conference on Advancements in Simulation & Experimental Techniques in Mechanical Engineering (NCASEme), pp. 21 -25, March2017.

[11] T. Brown, L. Saldana, C. Murthy, T.G. Mann, J.B. Guo, Y. Allard, L.F. King, A.H. Compton, W.D. Trumble, P. Kevin and S. Chandrasekhar, "A study of the interactive effects of strain, strain rate and temperature in severe plastic deformation of copper", Acta Materialia, vol. 18, no.57, pp. 5491-5500, July 2009.

[12] P. Iglesias, M. D. Bermudez, W. Moscoso, B. C. Rao, M. R.Shankar and S. Chandrasekhar, "Friction and wear of nano structured metals created by large strain extrusion machining", Wear, vol. 263, no. 1, pp. 636 –642, June 2007.

[13] W.J. Deng, P. Lin, and W.Q. Xia, "Effect of constraining tool corner radius on large strain extrusion machining", Materials and Manufacturing Processes, vol. 28, no.10, pp. 1090-1094, 2013.

[14] P. Lin, Z.C. Xie and Q. Li, "Effect of the friction coefficient on large strain extrusion machining", Applied Mechanics and Materials, vol. 273, pp. 138 -142, 2013.

[15] W.J. Deng, P. Lin, Z.C. Xie and Q. Li, "Analysis of Large strain extrusion machining with different chip compression ratios", Journal of Nanomaterials, pp. 1 –12, 2012.

[16] W.J. Deng, Q. Li, B. Li, Z.C. Xie, Y.T. He, Y. Tang and W. Xia, "Thermal stability of ultrafine grained aluminium alloy prepared by large strain extrusion machining", Materials Science and Technology , vol 30, no. 7, pp. 850-859, 2014.

[17] A. Kustas, K. Chaput, S. Chandrasekhar and K. Trumble, "Quality of strip produced by extrusion machining directly from cast 5052 aluminium", 2014.

[18] D. Sagapuram, A.B. Kustas, W.D. Compton, K.P. Tumble and S. Chandrasekhar, "Direct Single - Stage Processing of light weight alloys into sheet by hybrid cutting extrusion", Journal of Manufacturing Science a nd Engineering, vol. 13