Producing Nanocrystalline Materials by Machining

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Abstract: According to our previous idea, metal chips are one of the major waste stream components of machining. But surprising finding from recent research at Purdue University shows metal chip are valuable nanocrystalline materials. This paper reviews recent discovery which represents a much cheaper way to produce nanocrystalline materials by machining with similar properties to those produced using traditional approaches. The characteristics of the deformation zones in machining are analyzed. A comparison between machining approach and traditional severe plastic deformation approach in producing nanostructure nanostructured materials was made.

Key words: chip recycling; metal chip; nanocrystalline materials; machining
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It is well established that severe plastic deformation can have essential effects on the microstructure and material properties. For example, microstructure refinement and the forming of cells, sub-grains and fragments take place during torsion straining under high pressure and equal channel angular extrusion and it can lead to remarkable improvement in mechanical properties. Severe plastic deformation techniques have been successfully used for fabrication of nanostructures in various bulk metallic materials.

In recent years, an important discovery have been made by the researchers at Purdue University that metal chips produced in the machining of a material entirely or primarily made up of nanocrystals and they could be more valuable weight-for-weight than the material from which the part is being machined[1-2]. A potential alternative processes have been suggested to create nanocrystalline materials by machining[1]. During the machining process, up to 15 percent of workpiece material by weight is lost, resulting in tons of metal chips. Traditionally, these chips can often be melted down, reformed and reused. However, during the recycling of the metal chips a lot of the metal is lost as a result of oxidation, the costs of labor and energy as well as the expenditure on environmental protection impose heavy financial burdens on machining operations. Nowadays, the machined chips would be no longer taken as machining wastes but valuable nanocrystalline particles for the production high performance nanostructured bulk materials[1].

1 Deformation behavior of material during machining

In machining operations, the values of strain, strain rate and temperature in the various shear zones are much higher than in traditional severe plastic deformation operations. The calculated strain rates up to $d\varepsilon/dt = 10^6\ s^{-1}$ based on the measurement of the shear bands in chips[3]. In this area the total strain can increase up to $\varepsilon = 13$ and the temperature is estimated to rise up to 0.9 of the melting temperature. As a comparison, the values in single stage of severe plastic deformation process test are $\varepsilon = 2$, $d\varepsilon/dt = 10\ s^{-1}$[4]. Eq(1) show the shear strain experienced by workpiece material flowing through the primary shear zone in continuous chip formation. In order to better visualize shear strain ε, the results of calculations using Eq. (1) illustrated

$$\varepsilon = \frac{\zeta^2 - 2\zeta\sin\gamma_0 + 1}{\zeta\cos\gamma_0} \tag{1}$$

in Fig.1 for different rake angles. It can be observed that machining can cause very large strains in the chip. Shear strains greater than 4.0 are very commonplace. The shear strain depends on a large extent of the rake angle γ_0. By choosing appropriate machining parameters combinations, a very larger shear strain (> 10) can be obtained. Furthermore, in practical machining operation, the shear is usually not planar, the friction

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at the tool-chip interface will influence the deformation and the strain will exceed the calculated values.

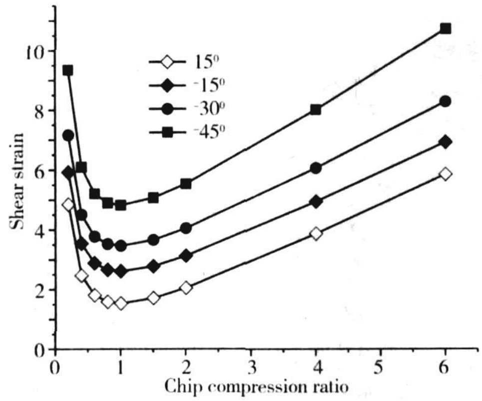

Fig. 1 Shear strain in machining

TEM micrograph of microstructures of the machined copper chips shows that most grains had an equiaxed shape with diameters approximately equal to the widths of the elongated cells. The sizes of the subgrains ranged between 100 and 300 nm, with a mean diameter of about 200 nm. It can be concluded that the machined chip is kind of ultra-fine grained/nanostructured and machining can be taken as a new king of severe plastic deformation method to produce ultra-fine grained/nanostructured materials.

2 Machining vs. severe plastic deformation

For both of the approaches, the materials are subjected to the imposition of very large strains and remarkable grain refinements are obtained. It is more significant to choose them to carry on the comparison. Severe plastic deformation belongs to "top-down" approach in which existing coarse-grained materials are processed to produce substantial grain refinement and a nanostructure[5-6]. Nanostructured materials produced by severe plastic deformation are 100% dense, contamination-free, and sufficiently large for use in real commercial structural applications. However, machining partly belongs to the "bottom-up" approach to some extend. In order to produce bulk forms from nanostructured chips derived from the machining, the chip was initially converted into particulate using attrition milling, and then using powder extrusion to build nanocrystalline bulk. A fundamental understanding of consolidation and densification processes will be further studied before widespread use of nanocrystalline chips. Machining are suitable producing nanocrystalline chips of almost any alloys and metals. Severe plastic deformation is inability to induce large strains in very strong materials, such as tool steels, hardened steel and nickel-based superalloys[5-6].

Machining process is easier to control than severe plastic deformation. Because chip formation is a machining operation whose parameters can be precisely controlled, it means that the desired nanocrystalline chips can be accurately and repeatably obtained for the given alloys and metals. Furthermore, the machining operation can be adjusted to produce chips of various grain sizes and shapes for use in a variety of application. In addition, An important benefit would be providing the possibility of reusing the enormous quantities of chips produced in manufacturing operations in high value products. there isn't any negative impact on the article being machined. Nanocrystalline chips can be produced as a useful byproduct. Hence designing potentially cost efficient and environmentally friendly products with better performance is possibility.

3 Conclusion

This paper reviews recent findings which represents a process to forming nanocrystalline materials in a wide variety of metals and alloys by machining. The characteristics of the deformation zones in machining are analyzed. A comparison between machining approach and traditional severe plastic deformation approach in producing nanostructure nanostructured materials was made. While correlation between the machining conditions, the important variables of the temperature and deformation field, microstructure characteristics and mechanical properties of the metal chips would be further studied.

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切削大塑性变形制备纳米材料

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摘 要：长期以来，切屑都被看成是金属切削过程中产生的废物。最新研究表明在一定切削条件下形成的切屑几乎全部为纳米结构材料。首先分析了切削加工中材料的塑性变形特征，然后将切削大塑性变形制备纳米结构材料工艺与其他传统的剧烈塑性变形工艺进行比较，发现切削法具有工艺简单，价格低廉，生产效率高，对高强度材料同样适用等优点，同时还可以减少切屑回收过程对环境造成的污染。

关键词：切屑回收；金属切屑；纳米材料；切削
中图分类号：TG501

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直接缩聚法合成淀粉接枝可降解聚酯和聚酯酰胺及其表征

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摘 要：以可溶性淀粉、乳酸、乙醇酸和己内酰胺为原料在氯化亚锡催化下直接缩聚制备得到了淀粉接枝乳酸-乙醇酸共聚物及淀粉接枝乳酸-乙醇酸-己内酰胺共聚物。用核磁共振 (NMR)、差热 (DSC) 及热重 (TG) 分析分别对产物的结构和热性能进行了表征。

关键词：生物可降解；淀粉；接枝；直接缩聚
中图分类号：O631.1; O633.14

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