論文 / 著書情報
Article / Book Information

題目(和文)	切削加工を利用した微細結晶粒鉄鋼ストリップ材の製造法
Title(English)	
著者(和文)	永島史悠
Author(English)	Fumihisa Nagashima
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11920号, 授与年月日:2021年3月26日, 学位の種別:課程博士, 審査員:吉野 雅彦,平田 敦,阪口 基己,山﨑 敬久,山本 貴富喜
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11920号, Conferred date:2021/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 系 機械 コース		申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 工学 ）
学生氏名： Student's Name	永島 史悠		指導教員（主）： Academic Supervisor(main)	吉野 雅彦
			指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Ultrafine grained steel has been getting attention because it can be improved its material properties with avoiding additional alloy elements. It has been reported that material properties such as strength, machinability in micro machining and corrosion resistance of austenitic stainless steel are improved by grain refinement. For practical production of ultrafine grained steel, the thermo-mechanical control process is widely used. It is good for mass production because it is a continuous process. However, since the grain refinement mechanism, dynamic transformation and recrystallization, is much affected by chemical components of material, it is required to determine process conditions by experimental data collection. By contrast, severe plastic deformation methods are used to produce ultrafine grained steel. It is able to accumulate large strain in a work material because it does not cause material shape change. However, since repetition of the process is necessary to produce ultrafine grains, its productivity is not high. The author suggested new process to produce ultrafine grained steel by combination of cutting and heat treatment. In this report, the effectiveness of cutting to grain refinement was investigated by comparison with plate rolling. The effect of forming methods on deformed microstructure and static recrystallized microstructure was studied through experiments and numerical simulations. Based on the consideration of those results, the new process to produce ultrafine grained steel strips by cutting and heat treatment was demonstrated with commercial pure iron. In addition, the applicability of the proposed process to an austenitic stainless steel (SUS304) was examined experimentally.

The effect of plastic forming methods on deformation microstructure was investigated by comparing orthogonal cutting and plate rolling. It was obtained that grains were uniformly subdivided into ultrafine grains of 0.2 μm in diameter by cutting but not uniformly subdivided by rolling. During rolling, deformation proceeded differently in grains and it depended on the initial crystal orientation. It was supposed that misorientation inside grains was not generated so much because the slip system activation was restricted by crystal rotation to easily deformed orientation. As a result, grain refinement was not occurred homogeneously by rolling. By contrast, in cutting process, a work material is deformed instantaneously on the shear plane and formed into a chip. Because the thin shear deformation zone passes through crystal grains, grains are deformed uniformly even initial crystal orientations are different. The effect of deformation pattern on slip system activation was studied by numerical simulation based on the crystal plasticity theory. It was found that more slip systems were activated in shear deformation than in plane strain compression. This result indicates that misorientation inside grains which generated by multi slip system activation occurs more in cutting than in rolling. Because that misorientation turns into geometrically necessary dislocations and geometrically necessary boundaries, cutting is more effective process to produce ultrafine grains.

By subjecting those processed specimens to heat treatment, the effect of severe plastic deformation on static recrystallization was studied. It was obtained that uniform and small recrystallized grains were generated in the chip specimens but heterogeneous recrystallized microstructure was generated in the rolled specimens. In the rolled specimens, nucleation rate was seemed to be different in area where grains subdivided into ultrafine grains or large grains remained. Therefore, recrystallization proceeded heterogeneously and recrystallized grain size was varied. By contrast, in the chip specimen, nucleation occurs homogeneously and vehemently through the whole specimen because grains were subdivided into ultrafine grains with large misorientation boundaries. As a result, uniform and small recrystallized grains were generated in the chip specimens. The effect of the deformed microstructure on static recrystallization process was studied by numerical simulation based on the nucleation and grain growth theory. It was supposed that recrystallization rate depended on the ratio of large misorientation area in the deformed microstructure where a lot of nuclei were generated. By using this model, it was suggested that cutting is more useful to produce fine recrystallized grains of 1 μm in diameter than rolling because it is easy to apply large strain.

Based on those considerations, a new process to produce fine-grained steel strips was demonstrated with commercial pure iron. A continuous strip with severe plastic deformation was produced by orthogonal cutting and straighten by skin-pass rolling. After that, the strip was subjected to heat treatment for static recrystallization. The fine recrystallized grains of 1 μm in diameter were successfully produced by the proposed method. The yield stress of that fine-grained strip was improved to twice larger than that of a well annealed specimen. The applicability of the proposed method to SUS304 was also investigated experimentally. It was obtained that austenite still remained after cutting and ultrafine austenitic grains were

generated. After 1000 °C heat treatment, recrystallized grains grew up to 8 μm in diameter, but the hardness was improved 1.5 times larger than the material as received. It was concluded that the proposed method is applicable to produce ultrafine grained stainless steel strips.