Crystal Dependence in Micro Scratching of Carbon Steel - Groove Formation of Cementite and Ferrite Phases -

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In order to produce micromachined parts with a great dimensional accuracy, it is important to clarify the influence of heterogeneity and/or discontinuity of workpiece materials on the micromachining process, because almost all structural materials are composed of heterogeneous and/or homogeneous crystal grains at the micro scale. Experiments where JIS S25C steel had been scratched with a diamond triangular pyramid indenter were conducted under a field emission scanning electron microscope (FE-SEM). The difference of plastic deformation at a groove scratched between a pearlite zone and a proeutectoid ferrite zone was investigated through comparison with the groove scratched of a pearlite zone and a proeutectoid ferrite zone.

Keywords : Pearlite, Ferrite, Cementite, Groove Scratched, FE-SEM, Carbon Steel

1. INTRODUCTION

Many kinds of micro components and devices are machined by using MEMS technologies, which are able to produce micro parts in large quantities, but limited to 2-dimensional structures for silicon. Therefore under such circumstances, it is difficult to machine 3-dimensionally shaped micro parts with great dimensional accuracy[1]. Micro mechanical machining seems to be one of the more promising methods for mass production of complicated 3-dimensional microstructures.

Since the process dimension of micro machining is of the same order of magnitude as the grain sizes of the material phases, the material can no longer be considered to be homogeneous. This study aims to clarify micro machining behavior machined surface quality of carbon steels, which is composed of proeutectoid ferrite and pearlite.

2. EXPERIMENTAL APPARATUS and PROCEDURES

Figure 1 shows the overview of the Micro/Nano tribology testing system. The ultra-precise piezo electric actuating devices are fully controlled by a computer. Scratching experiments used for the system have been done under FE-SEM.

A sample material and a diamond triangular pyramid indenter of which the scratching point measures out at a radius of 20 nm and the three edge angle of 90°, which is used for the purpose of indentation and scratching, are installed under an electron gun. An annealed, polished, and etched S25C steel specimen (0.23 mass %C) is utilized in the experiments, in which the load is controlled at sub mN level. The horizontal speed of the indenter is 100 μm/s. The normal and scratching loads acting on the indenter are measured by strain gage type force sensors, which possess a resolution in the 0.01mN order. The generation processes of an indentation cavity or a groove scratched are examined by means of in situ FE-SEM observations.

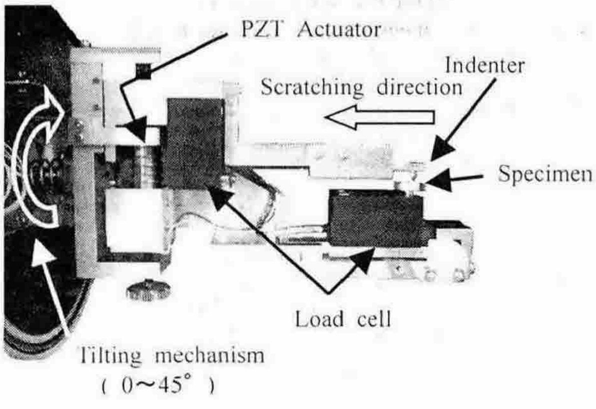

Fig.1 Appearance of Micro/Nano tribology testing system

3.EXPERIMENTAL RESULTS and DISCUSSION

Figure 2 shows FE-SEM image of the groove scratched on the etched S25C at normal load of 3.1 mN from proeutectoid ferrite to pearlite. Since S25C is inhomogeneous at the micro scale, the groove width varies from ferrite to pearlite. Ferrite is a comparatively soft and ductile constituent possessing a tensile strength ranging from 392 to 588 MPa and a hardness values HV of 120. On the other hand, the tensile strength of cementite ranges from 3920 to 5880 MPa and HV ranges from 1200 to 1500 or 10 times greater than that of ferrite[2]. Thus, it is considered that the groove width on pearlite is smaller than that on ferrite because lamellar cementite in pearlite is extremely hard and brittle.

The changes in the normal and scratching load along with the time of scratching S25C is shown in Fig.3. The scratching

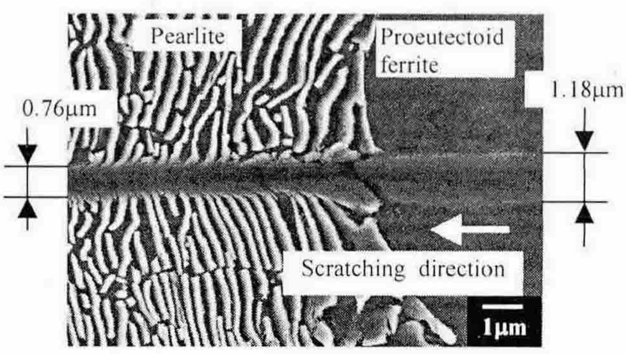

Fig.2 Groove scratched from proeutectoid ferrite to pearlite

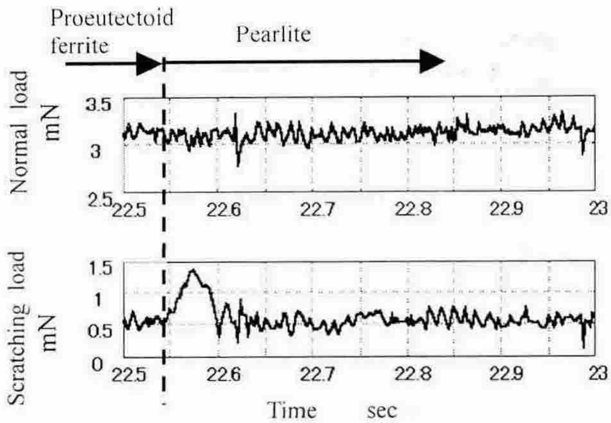

Fig.3. Changes in normal and scratching load

load when the diamond indenter hits pearlite zone temporarily increases from 0.5mN to 1.4mN, and subsequently decreases to 0.5mN. This temporary rise is sometimes observed at the boundary from proeutectoid ferrite zone to pearlite zone.

Figure 4 shows the relation between the groove width and normal load of two zones (proeutectoid ferrite and pearlite). Under the same normal load, the groove width of proeutectoid ferrite zone is 1.1 ～ 3.0 times as large as those of pearlite zone. Figure 5 shows the relation between the scratching load and the normal load. The scratching load of pearlite zone is 1.1 ～ 1.5 times as large as those of proeutectoid ferrite zone under the same normal load. From Figures 4 and 5, it is seen that the groove width of pearlite zone is narrower than the groove width of proeutectoid ferrite zone while the scratching load of pearlite zone is greater than the scratching load of proeutectoid ferrite zone. This phenomenon describes that pearlite contains lamellar cementite, which is 10 times harder and stronger than ferrite.

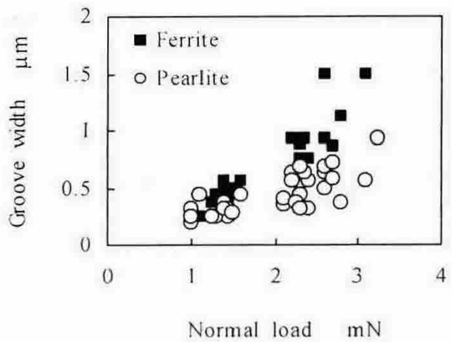

Fig.4 Relation between groove width and normal load

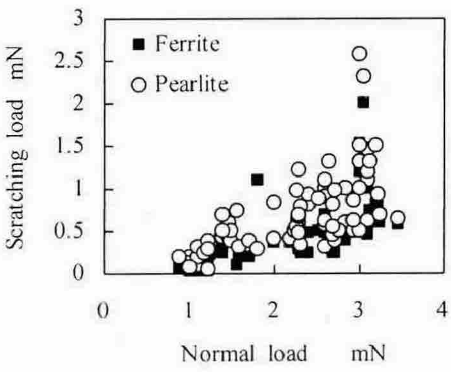

Fig.5 Relation between scratching load and normal load

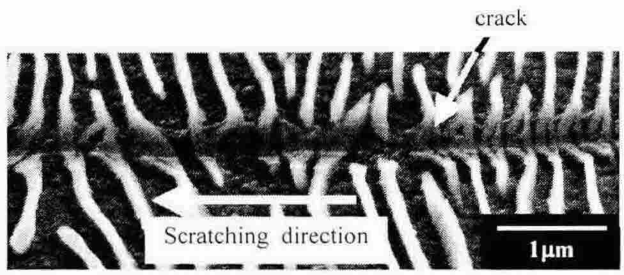

Fig.6 Deformation and fracture of lamellar cementite in groove scratched on pearlite

Figure 6 shows the appearance of a groove scratched on pearlite. The lamellar cementites undergo the elastic deformation and plastic deformation before collapse. Subsequently the lamellar cementites are cracked and broken into several pieces, which are eventually buried into the lamellar ferrite.

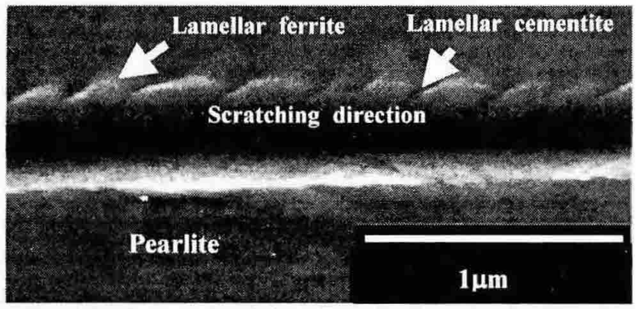

Fig.7 Deformation of lamellar ferrite around side of groove scratched on pearlite

Figure 7 shows that plastic flow occurs in large and concentrates in lamellar ferrite rather than lamellar cementite around the side of a groove scratched on pearlite, when S25C which is polished and not etched, is scratched. Because lamellar cementite is harder and stronger than lameller ferrite, lamellar cementite prevents lamellar ferrite from flowing non-elastically, but resulted in high swell.

4.CONCLUSIONS

The following representative conclusions are obtained:

(1) The groove width of proeutectoid ferrite larger than those of pearlite zone and the scratching load of pearlite zone is larger than those of proeutectoid ferrite zone.

(2) The lamellar cementites in groove scratched on pearlite are cracked and broken into several pieces, which are eventually buried into the lamellar ferrite.

(3) Plastic flow occurs in large and concentrates in lamellar ferrite rather than lamellar cementite around the side of a groove scratched on pearlite.

5.REFERENCES

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