Role of Development of Submicro-grained Hardmetal in NEDO National Project "High Precision Micro-components"

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Abstract

High functional micro devices are demanded in a variety of fields. For realising such demands, development of high-precision micro-components installed in the devices are needed. To achieve high-precision in the mold processing of micro-components, the development of mold materials, i.e., the development of WC-Co hardmetal with higher hardness and fracture strength is essential, together with the developments of processing technology of high precision mold and mold-forming technology of high precision micro-components, etc. The role of development of the finer submicro-grained hardmetal in a NEDO national project aiming the integrated development of these all technologies and some results are mainly explained.

Keywords: **NEDO project, submicro-grained hardmetal, integrated development, micro-component, high precision**

1. Introduction

High precision of submicron order is strongly demanded in the processing of micro-components corresponding to the changes in various fields, as schematically shown in **Fig. 1** . To achieve high precision of submicron order in the mold forming, the following are needed.

(1) The precision of mold should be of submicron order.
(2) The wear resistance of mold material should be so high that the high precision of mold is kept during the long use.
(3) The fracture of mold should be avoided during the long use.

Then, a NEDO (New Energy and Industrial Technology Development Organization) national project proposed by JRCM and AIST (National Institute of Advanced Industrial Science and Technology) aims at the integrated developments of mold materials and high precision mold processing technologies through unified promotion of the following three themes.

(I) Development of novel metals with high formability
(II) Development of mold materials and processing technology for high precision mold
(III) Development of high precision mold forming technology for micro-components

In the presentation, the role of development of WC-Co submicro-grained hardmetal as the tool material in the above theme (II) and some results of the project are explained.

2. Role of Development of Submicro-grained Hardmetal

For improving the wear resistance, surface roughness and life of mold for the micro-components, the hardness and fracture strength of WC-Co hardmetal as the mold material should be increased as much as possible, as far as fracture toughness does not become a problem.

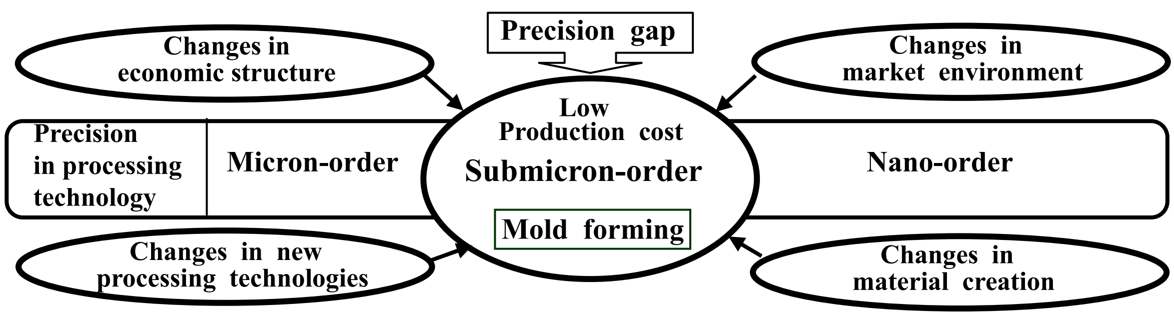

Fig. 1. The need for development of submicron-order mold forming technology that bridges a precision gap between the present micron-order and nano-order technologies [1].

As the hardening or strengthening mechanisms, the following are known in the same way of steels, etc.; (1) solid solution strengthening, (2) precipitation strengthening, (3) work strengthening, (4) martensitic transformation strengthening, (5) matrix grain size refinement strength-ening, (6) decrease in size of micro-structural defects acting as fracture source, (7) orientation of crystal grains, (8) particle dispersion strengthening.

The effect of each factor on the macro hardness (*HV*) and transverse-rupture strength (*TRS*) have been experimentally clarified mainly by the present authors. The results on 10mass%Co alloy are as follows.

(1) Solid solution strengthening [2]

The W solute content in Co binder phase increases from 2% to 9% with decreasing carbon content of hardmetal in the normal phase region free from free-carbon and η phases. The hardness of Co binder phase increases by about 17%. The increment in *HV* and *TRS* caused by the solid solution hardening are about 3% and 7-9%, respectively.

(2) Precipitation strengthening [2]

The W solute in Co binder phase precipitates in the form of Co_3W by annealing at about 1073 K. The hardness of Co binder phase is increased by about 15% at the low carbon content by the precipitation. The increment of *HV*, however, is slight. *TRS* is not increased, but decreased by about 16%.

(3) Work strengthening and (4) martensitic transformation strengthening [2]

The surface layer of hardmetal is work-hardened by grinding. By grinding, $\gamma \rightarrow \varepsilon'$ martensitic transformation also takes place in Co binder phase. Due to these phenomena, *TRS* increases by about 7%. The increment of *HV* is slight.

(5) Matrix grain size refinement strengthening [2]

Co-phase grain size, i.e., the size of domain where the crystallographic orientation is the same, is about 100~1,000 μm. The values are extremely larger than WC grain size of 0.5~6 μm. By decreasing Co grain size, *TRS* is increased by 2%. The increment increases with Co content.

(6) Decrease in size of microstructural defects [2]

TRS of one batch of plural test-pieces fluctuates widely. This is because the fracture always starts from one microstructural defect such as large pore, coarse carbide grain, etc., and the size and amount of the defects are different test-piece by test-piece. By eliminating large pores, *TRS* is increased by about 20%.

(7) Orientation of WC crystal grains [3]

When W+graphite mixed powder is used instead of usual WC powder in the preparation of mixed powder of hardmetal, WC grains becomes plate-like and the grain surface with WC(0001) crystal plane are oriented vertically to powder compaction direction. Due to the orientation, *HV* and *TRS* both are increased by about 6%.

(8) Particle dispersion strengthening [2]

WC-Co hardmetal is a kind of particle dispersion hardened alloy. *HV* increases with decreasing mean free path (*mfp*) of Co binder phase, i.e., with decreasing WC mean grain size and/or Co content. *TRS* also increases with decreasing *mfp* above a critical value and decreases below the critical value. At 10%Co hardmetal free from large pores, *HV* and *TRS* commonly increase by about 15% with decreasing WC mean grain size from 1.2 μm to 0.5 μm [4]. These increments in *HV* as well as *TRS* are the largest among those by varying the above other factors. Thus, the NEDO project aimed the development of finer submicro-grained hardmetal than the present commercial ones (0.5-0.7 μm) as the material of high precision mold.

3. Some Results of Project

(1) Development of nano-sized WC powder [5]

WC mean grain size of hardmetal is determined by the mean particle size and size distribution of raw WC powder and the degree of grain growth during sintering. WC powder of 0.07 μm (70 nm) with narrow size distribution was developed by A.L.M.T. Corp. in the last year.

(2) Development of submicro-grained hardmetal [6]

By using the above nano-sized WC powder, etc., and by selecting grain growth inhibitor and its amount that are considered to be appropriate on the basis of the results by HRTEM and XMA of WC/Co and WC/WC interfaces [7-9], etc., submicro-grained hardmetals of 0.3, 0.2 and 0.1 μm (100 nm) were developed by Fiji Dies Corp..

(3) Increase of punching-mold life [10]

The life of punching-mold for forming ink jet nozzle holes in foil was improved from 450,000 shots to over 1,000,000 shots by decreasing WC mean grain size from 0.5 μm to 0.2 μm. 2,000,000 shots are expected at 0.1 μm.

4. References

1. M. Kiuchi and K. Hayashi: Proc. 16th Int. Plansee Seminar, Vol.2, Plansee AG, Reutte, (2005), 405-417.
2. H. Suzuki and K. Hayashi: Hardmetal and Hard Materials, edited by H. Suzuki, Maruzen Co. (1986), 70-204.
3. S. Kinoshita, T. Saito, M. Kobayashi and K. Hayashi: J. Jpn. Soc. Powder Powder Metallurgy, **47**(2000), 526-533.
4. H. Ike, O. Terada and H. Suzuki: J. Jpn. Soc. Powder Powder Metallurgy, **42**(1995), 517-522.
5. Y. Yamamoto and M. Mizukami: Proc. of 2006 PM World Congress, Pusan, Korea, (2006), C07-04, n.2
6. M. Kawakami, O. Terada and K. Hayashi Proc. of 2006 PM World Congress, Pusan, Korea, (2006), C07-03, n.2.
7-9. M. Kawakami, O. Terada and K. Hayashi: J. Jpn. Soc. Powder Powder Metallurgy, **51**(2004), 576-585.; **53** (2006), 166-171.: Proc. 16th Int. Plansee Seminar, Vol.2, Plansee AG, (2005), 653-667
10. JRCM report: NEDO project "Development Project on Fusion Technology of Material and Mold Forming of High Precision Component" (2005).