INFLUENCE OF EXTERNAL PRESSURE ON STRUCTURAL AND MAGNETIC PROPERTIES OF COBALT

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Abstract: Cobalt powder was pressed into rings and plates with external pressures up to 660 MPa and the phase transformations and ferromagnetic properties as functions of pressure were measured. Half widths of X-ray profiles were analysed and some conclusions about stacking faults and internal strains were drawn.

1. INTRODUCTION

In our earlier examination of the influence of rapid quenching from the liquid on the properties of Co-WC alloys, we were able to increase the carbide content up to 30 wt. pct., i.e. more than twice as much as the metastable solubility obtained by the classical quenching (1). The high microhardness and coercive force of these alloys clearly showed the possible fields of application. However, the explanation of these properties is complex and riquires a special attention to the conditions of quenching, such as the influence of the temperature and the pressure of the quenched components. Also an improvement of the mechanical properties of hard metals may be expected to rise primarily from increasing the hardness of the cobalt phase. The process of consolidation and of the rapid quenching of hard metals itself requires also an explanation of the influence of the external pressure on the physical properties of pure cobalt. Thus, in this work, we started a systematic investigation of structural and physical properties of pure cobalt for different conditions of pressure and temperature. In this paper are given preliminary results of some structural and magnetic investigations.

2. THE COBALT TRANSFORMATIONS

It is known (2) that cobalt appears in two phases: face centered α cubic (f.c.c.) and hexagonal close packed ε(h.c.p.). The allotropic transformation:

$$\alpha\ \text{f.c.c.} \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftarrows}} \varepsilon\ \text{h.c.p.}$$

with the thermodynamic equilibrium at 417°C was found (2). However, an appreciable hysteresis is observed between the heating and cooling transformations (3). When the h.c.p. phase is generated from f.c.c. phase by cooling through the allotropic transformation range, some percentage of the parent f.c.c. phase is always retained.

While the temperature dependence of this phase transformation was examined by many authors, as far as we know no systematic examination of the dependence of the phase transformation on pressure was made. Thus we measured the fractional amount of the mass of each phase, present in samples which were subjected to different forming pressures, using an X-ray method published by M.Sage (4).

The $\alpha \rightleftarrows \varepsilon$ transformation in cobalt was found to be greatly influenced by local strain variations and by grain size. An electronic contribution to the free energy difference may also control the transformation. In order to evaluate the influence of internal strains, grain size and stacking faults on the cobalt transformation we performed the profile analysis of the pressed cobalt.

3. EXPERIMENTAL PROCEDURE

Cobalt powder (99.76 pct.pure) was pressed in to plates (22x12x3 mm^3) with pressures up to 660 MPa at room temperature. Average grain diameter was 1.5 μm. Experimental details of consolidation were published earlier (5). Ringlike samples ($\varnothing_0$=22 mm, $\varnothing_1$=15 mm, d=5 mm), were also pressed in order to make simultaneous measurements of ferromagnetic properties. X-ray powder-pattern peaks were measured with a diffractometer and Cu K_α radiation, monochromated using a bent quartz crystal, which focused it on the entrance slit of the scintillation counter. The radiation was registered using a "Siemens" diffractometer, an oscillation attachment and a scintillation detector. The isochronal annealing procedure in vacuum or inert gas was used for annealing. The coercive fields were measured from the magnetization curves on ringlike samples.

4. RESULTS AND DISCUSSION

As generally known, during reduction of cobalt oxide powder, considerable amount of metastable α-f.c.c. cobalt is retained in the metallic powder which is produced. Structural transformations of so obtained α-cobalt with forming pressure are presented in Fig.1. The f.c.c. phase transforms rapidly to h.c.p. phase at relatively low pressures (up to 20 MPa). At higher pressures transformation is slower, and at the highest pressure at 660 MPa only 17 wt. pct. of f.c.c. cobalt remained.

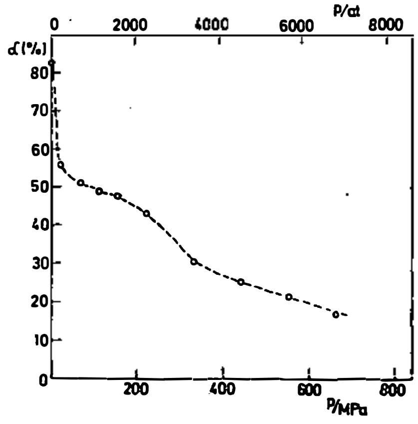

Fig. 1.

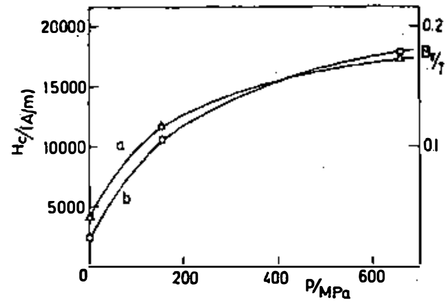

Fig.2.

The rapid initial increase of structural transformation occured in the period when no significant volume distortions of particles yet took place, and should be attributed to the spatial rearangement of the particles. In this stage local contacts of particles were however plastically deformed and cold welded, and it seems that the transformation beginning in the loci at the surface propagated rapidly into interior of particles.

Coercive field H_c (curve a) and remanent magnetization B_r (curve b) as functions of pressure are given in Fig.2. As seen from this figure external pressure strongly influenced the growth of magnetic hardness, which shows that a deaper investigation of internal stresses would be useful.

In Fig.3 (curve a) the phase transformation measured after the process of isochronal annealing (24 hours) of cobalt plate is given. This cobalt plate was previously pressed at 660 MPa. In the same figure (curve b and c) the coercive fields of two ringlike samples (pressed at 155 Pa and non pressed samples) after the process of the isochronal annealing are given.

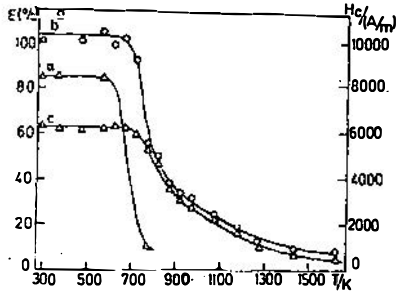

Fig.3.

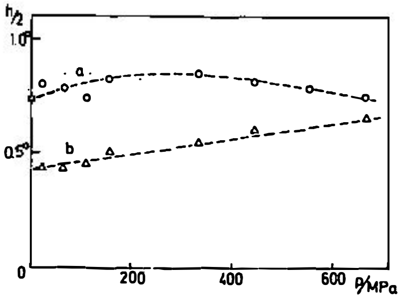

Fig.4.

Temperature of the phase transformation (Fig.3, curve a) and the temperature of drastic decrease of magnetic hardness are in the same interval (723-773 K). In the process of the new phase nucleation internal stresses disappeared and consequently magnetic hardness decreased. Comparing Fig.2 and Fig.3 we may conclude that the mechanism of the temperature transformation is quite different from the mechanism of deformation transformation.

The profile analysis is in progress. On Fig.4 are presented the results of the half-width measurements of our pressed samples. Curve "a" presents the half-widths of the reflexion $10\bar{1}1$ and curve "b" half-widths of the reflexion 200 as the function of the pressure. We suppose that the $10\bar{1}1$ reflexion in curve "a" is mostly influenced by the stacking faults, while the reflex 200 in curve "b" by internal strains. Thus the curve "b" increases linearly with the pressure, while the curve "a" has a maximum, which may be explained with the dominant role of stacking faults at these pressures, and at the higher pressures the internal stresses are dominant. This observation is supported also by the results represented on the Fig.3. So we may deduce that in our samples the appeareance of stacking faults slows down the $\alpha \rightarrow \varepsilon$ transformation. However, detailed computer analysis of profiles, which is in progress, could better explain these assumptions.

5. CONCLUSION

A quantitative dependence of phase transformations of cobalt powder on the pressure is evaluated. The magnetic hardness was found to be greatly influenced by the temperature and the deformation dependent transformations. The presence of stacking faults and internal stresses at different pressures was evaluated. There is an indication that stacking faults influence the f.c.c. to h.c.p. phase transformation.

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