An Investigation on the Effects of Powder Warming, Inner Lubrication, and Die Wall Lubrication on the Die Wall Lubricated Warm Compation of Iron Powder

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Abstract

We investigated the mechanism how the high green density can be provided during die lubricated warm compaction (WD). We observed and analyzed the densification processes of iron powders including different contents of an inner lubricant, and measured the lateral pressure at the die wall during WD in comparison with conventional compaction and warm compaction. As a result, the high density in WD was due to not only the particles-deformation enhanced by warming powders but also the particles-rearrangement promoted by reducing an amount of the inner lubricant rather than the die lubrication.

Keywords: **warm compaction, die wall lubrication, pressure propagation, particles-rearrangement, particles-deformation**

1. Introduction

High-density green parts has been taken a notice because of the advantages such that they can provide small sized and high-strength machine parts, and can also reduce the machining cost by introducing green machining technique. Warm compaction (WC) and die lubricated warm compaction (WD) are significant methods to take high-density greens [1-3]. In this work, we measured stress propagation from a lower punch to the die wall through an iron powder during conventional compaction (CC), WC and WD, and considered how warming a powder or the die lubrication influence a densification-mechanism of iron powder.

2. Experimental and Results

Sample powders were, respectively, water atomized iron powders mixed with 0.2mass% (Powder A) and 0.6mass% (Powder B) of a lubricant mixture mainly comprising Lithium stearate with the melting point of 213℃. Each sample powder was pressed by CC, WC or WD as listed in Table1. Fig.1 shows the die set. The die cavity, which was divided into two pieces, had a cylindrical shape with an inner diameter of 25mm. Tube heaters were implanted in the die plate. A heat-resistant load-cell was set up behind one of the die pieces for measuring pressure (lateral pressure) pushing the die wall through a powder in the die cavity. Each sample powder was pressed by following procedure: setting the die set at a 500kN hydraulic a universal testing machine (UH500kNI; ShimadzuCo., Japan), filling the sample powder into the die cavity, and pressing it under the constant stroke speed of 10mm/min until the applied pressure of 686 MPa. Before filling the powder, the sample powder and the die were heated at 115℃ in WC and WD. Additionally, in WD, an amide wax powder was sprayed on the heated die wall using an electrostatic powder spray system. In this system, the applied pressure acts the powder from the lower punch, because the closs-head is fixed, and the lower ram floats at a constant speed in the testing machine. The position of the lower punch, the initial applied pressure P_i at the lower punch and the lateral pressure on the die wall P_s were monitored during pressing.

The densification processes of powder particles were divided into particle-rearrangement process and particle-deformation process using the modified Cooper-Eaton equation, which is an experimental equation of the pressure dependence of a porosity reduction rate [4]. The porosity was estimated from the weight of the powder and the volume of the cavity at p.

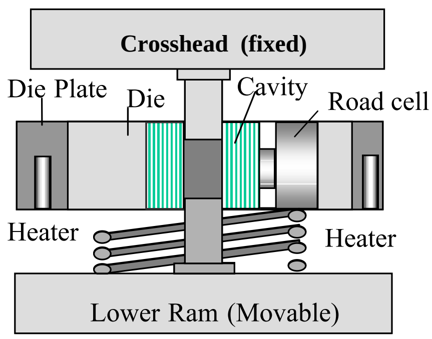

Fig. 1. A frame format of the uniaxial die set.

Table 1 Compacted powder densities and increments in densities during compactions.

Compaction ID	B-CC	B-WC	B-WD	A-WD
D_i (Mg/m^3)	3.25	3.26	3.30	3.26
D_f (Mg/m^3)	7.28	7.39	7.39	7.43
ΔD (Mg/m^3)	4.03	4.14	4.08	4.17
ΔD_1 (Mg/m^3)	1.32	1.38	1.37	1.41
ΔD_2 (Mg/m^3)	2.71	2.76	2.71	2.76

For each compaction, an initial density *Di*, a final green density at 686 MPa D_f, and an increment in the density of powder during compaction ΔD were listed in Table 1. Furthermore, ΔD was separated into the value due to the particles-rearrangement ΔD_1 and that due to the particles-degformation ΔD_2 by the analysis of the porosity reduction rate using the modified Cooker-Eaton equation. In Table 1, the notation of each compacting operation is described as "Powder ID (A/B)-Compaction method (CC/WC/WD)". D_f in A-WD was the highest in these compaction operations. ΔD_2s of the both powders in WC and WD were extremely larger than that in CC. ΔD_1 in A-WD was noticeably large in comparison with those in the other compactions. It follows that the higher density achieved in A-WD can be due to not only the particles-deformation enhanced by the warming powders but also the particles-rearrangement promoted by reducing the amount of the inner lubricant rather than the die lubrication.

Fig.2 shows the relationship between applied pressures and normalized lateral pressure *k*, which was obtained by dividing the lateral pressure by the applied pressure, during each compaction. Above 200 MPa, where the deformation of particles seems to be promoted, *k*s of the both samples in WC and WD were equivarent, and were also higher than that in WC. These results showed that the densification could progress due to the particles-powder deformation by heating powder particles in warm compaction with or without the die lubrication, and that the pressure could be easily propagated by means of the particles- deformation.

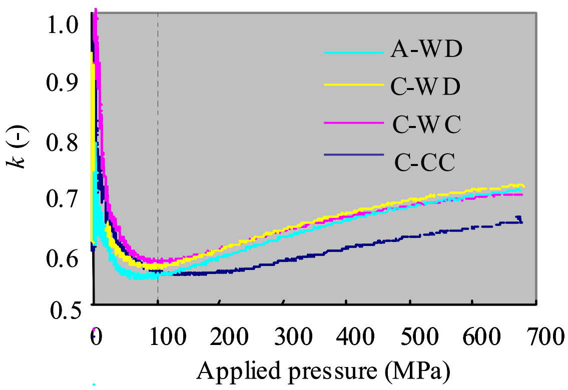

Fig. 2. Normalized lateral pressure *k* vs. applied pressure.

3. Summary

The mechanism of the powder-densification and the pressure propagation through powder particles were investigated during WC providing higher green density compared with CC and WC.

1. The powder-densification was achieved not only by the warming powders but also by reducing an amount of the inner lubricant rather than the die lubrication.
2. The amount of inner lubricant and the die lubrication did not influence the pressure propagation. The particles-deformation of softened powder particles by heating had an important role in the pressure propagation in WD and WC.

4. References

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