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Densification Mechanism of Warm Compaction for Iron-based Powder Materials

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Abstract

An apparatus measuring changes of various forces directly and continuously was developed by a way of direct touch between powders and transmitting force component, which can be used to study forces state of powders during warm compaction. Using the apparatus, warm compaction processes of iron-based powder materials containing different lubricants at different temperatures were studied. Results show that densification of the iron-based powder materials can be divided into four stages, in which powder movement changes from robustness to weakness, while its degree of plastic deformation changes from weakness to robustness.

Keywords: warm compaction; densification mechanism; iron-based powder material; powder metallurgy

1. Introduction

Warm compaction is one of the most creative technologies in the area of powder metallurgy since 1990's [1, 2]. Densification of warm compaction is affected by many factors, and current research about warm compaction generally limits in powders formula, lubricants types and lubrication patterns of die wall [3]. Recently, point measurement method is mainly adopted to investigate powder compaction process, and subsequent curve is fitted by data points. This method, however, cannot describe true compaction process [4, 5]. In order to investigate forces state inside powder metallurgy parts during warm compaction process, especially distribution of side force, an apparatus measuring changes of various forces directly and dynamically was designed by a way of direct touch between powders and transmitting force component.

2. Experimental Materials and Method

Water atomized iron powder was selected as object of study because iron-based materials have extensive application. 98.7wt.% iron power and 0.6wt.% colloid graphite were dry blended with 0.7wt.% lubricant EBS, polytetrafluoroethylene, stearic acid barium and zinc, respectively. The different types of blended powders were compacted into Φ30mm×30mm cylindrical compacts at different temperatures using the designed apparatus, as shown in Fig. 1

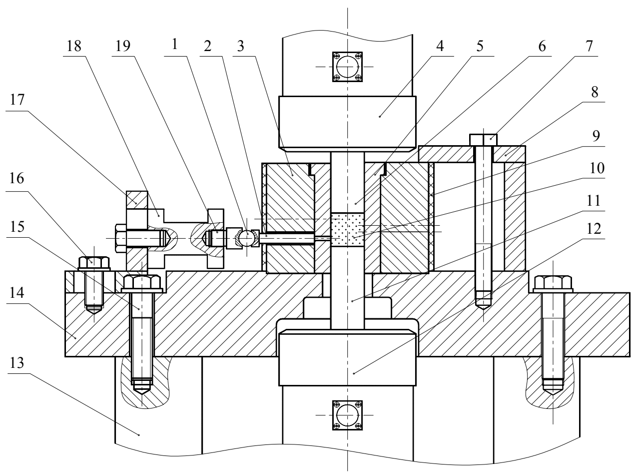

Fig. 1. Experimental apparatus for measuring forces in powder compaction process.

1-Steel ball; 2-Carrier rod; 3-External die bolster; 4-Upper sensor; 5-Inside die; 6-Upper punch; 7-Binding bolt M16; 8-Compression block; 9-Heater plate; 10-Powder; 11-bottom punch; 12-Lower sensor; 13-Cushion block of die plate; 14-Die plate; 15-Binding bolt M20; 16-Bolt M16; 17-Support plate; 18-Side force sensor; 19-Shore

3. Results and Discussion

According to the results of dynamic compaction curves, pressure dependence of warm compaction density can be divided into four stages, as seen in Fig. 2.

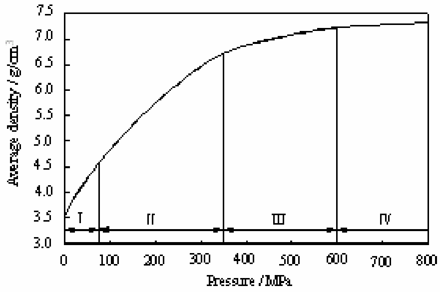

Fig. 2. Typical warm compaction curve (final pressure is 800MPa).

In stage I, which is from the start of compaction to compaction pressure about 75MPa, and lasts about 1.75s as shown in Fig. 3, movement of powder particles is mainly of no friction or little friction. Bridge conjunctions between powder particles are destroyed by very small pressure from upper punch, and powder particles move and fill into pores. Furthermore, the movement distance of powder particles is relative far, while increase amplitude of compact density with compaction pressure is also relative big.

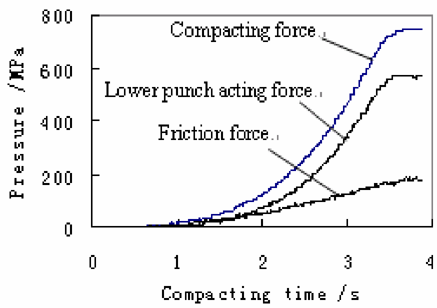

Fig. 3. Curves of pressure changes with compaction time

In stage II, which is in the pressure range from 75MPa to around 350MPa and in the time range from 1.75s to about 2.78s, densification mechanism is mainly of friction movement of powder particles, together with little elastic-plastic deformation. When compaction pressure is above 75MPa, compaction curve is straight line with big rake ratio or curve with big curvature radius, and densification is characteristic of regular friction movement of powder particles. Compaction density and pressure increase by exponent with the increase of compaction time. Near the end of the stage II, owing to that density of powder exceeds its tap density, contact of powder particles is characteristic of slightly raised point. And elastic-plastic deformation occurs in slightly raised area with the increase of compaction pressure, which makes powder particles densification with features of movement and elastic deformation.

In stage III, which is within the pressure range from 350MPa to about 600MPa and in the time range from 2.78s to about 3.25s, densification is combination mechanism of powder particles movement and plastic deformation induced by abrasion. Elastic deformation of powder particles changes form robustness to weakness, yet their plastic deformation changes form weakness to robustness. Part of compaction pressure is contributed to movement of powder particles, another part of compaction pressure is dedicated to overcoming the friction between powder particles and die wall, and other part of compaction pressure is contributed to inside friction of powder particles. With the increase of compaction pressure, average side force of die wall is from dramatic increase state to gently knee point, which is the terminal point of the stage III.

In stage IV, which is in the pressure range over 600MPa and in the time range above 3.25s, densification is caused by metal plastic deformation. The compaction curve is a curve with smaller rake ratio or straight line. When compaction pressure is about 700MPa, effective compaction pressure exerted on powder surpasses its critical yield stress, which will cause big plastic deformation of powder. Under compaction pressure, underneath pores makes downward movement of powders possible. In addition to consumption of inside and outside friction, powder particles are homogenously forced around, which cannot cause plastic deformation of powder particles and fill into others pores. Lubricants make transverse movement of powder particles possible, which leads to increase of side force of underneath powder particles. When compaction pressure is around 800MPa, compact density can be over 98% of free pore density. If compaction pressure further increases, compact density cannot continue to increase.

4. Summary

Through measuring forces state of iron-based powder materials dynamically and continuously, it can be concluded that movement of powder particles changes from robustness to weakness in warm compaction process, while degree of plastic deformation changes from weakness to robustness. Density of warm compacted materials experiences four stages with compaction pressure, which are defined into different pressure range.

5. References

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