Commentary

Examples of Compaction by CNC Press

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Abstract

In recent years, powder compacting presses utilizing a hydraulic servo mechanism (hereinafter, CNC press) have gained increasing popularity, and it has now become possible to compact shapes with which net-shape compaction by the powder metallurgy process had been impossible in the past. This report introduces the compacting method using the CNC press, including distinctive products which have been mass produced to date or are under study for mass production.

Keywords: CNC press, multistage compaction, horizontal groove compaction

1. Introduction

At present, the mainstream technologies in the powder compacting presses used in powder metallurgy are the mechanical crank press and the hydraulic press. In the press motion in these devices, the upper die applies pressure to the surface of the powder, and the lower die acts as a result of this motion. In other words, the lower die functions in a passive operating state. In recent years, systems utilizing pneumatic or hydraulic pressure controlled by a computer program have been introduced in mechanical and hydraulic presses in order to enable more active operation of the die. However, because many of these operations are set using the crank angle as an operational standard, operation is not linear, which gives rise to a variety of problems. For example, it is difficult to perform transfer of the raw material powder accurately, which is indispensable when compacting products with complex shapes, and defects such as compacting cracks and local deficiencies in density occur.

The respective powder metallurgy makers have introduced proprietary die set designs and other measures to solve these problems, but compacting is still impossible with some product specifications.

The CNC press, which has been developed and marketed in recent years, is a revolutionary powder compacting press enabling press operations that can solve many of the aforementioned problems, and has greatly expanded the range of shapes which can be compacted. As the press mechanism, NC control of the die position by a linear scale is possible, and hydraulic technology has been adopted in many operating systems. The following two points may be mentioned as representative features.(1) Proper transfer of the raw material powder is possible, securing homogeneous green compact density.

(2) Displacement of the die position so as to cancel differences in elastic deformation is possible in order prevent compacting cracks which occur due to differences in elastic deformation during pressing with segmented dies.

Thanks to these features, it is now possible to press products with top dies having a high step difference, which had been impossible with conventional powder compacting presses.

This report introduces examples of compaction of products which make the maximum use of the distinctive features of the CNC press.

2. Problems and comparison of features of conventional presses and CNC press

First, the following presents examples of problems during compacting with conventional presses and the response to those problems.

As problems with the conventional press specification, Fig. 1 shows the raw material filling and pressing condition in compacting the powder of a product when the step in the product being pressed by the top die is “large.” As a problem in compacting the above-mentioned specification, because it is difficult to secure complete powder transfer in the stepped part being pressed by the top die, local deficiencies in compaction density occur.

Furthermore, in the A part, because the raw material powder is transferred without pressing by the upper 2 punch and lower 2 punch, pressing is necessary after transfer.

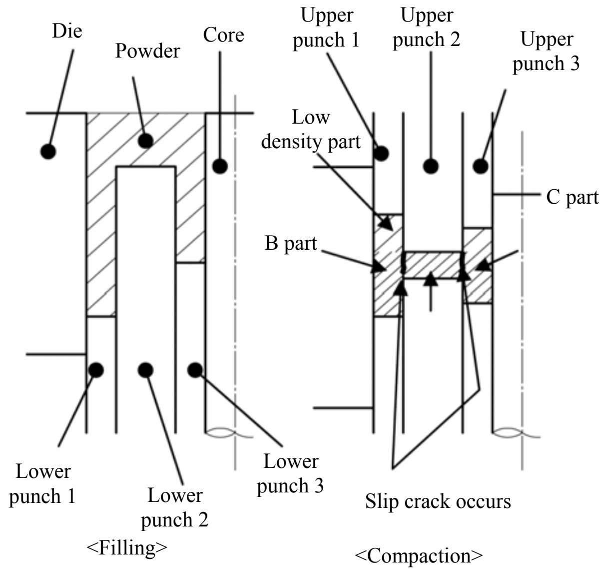

Fig.1 Problem of conventional press specification.

However, because synchronized control of the upper and lower punches is difficult with the conventional press, the A part is normally pressed first, causing differences in the timing of pressing with the B and C parts. This results in a fault-shaped compacting crack called a “slip crack.”

Fig. 2 shows an example of the compacting process with the CNC press. After the raw material powder is filled, the respective punches transfer the powder in the ideal pre-pressing condition without compression of the powder. Because pressing is achieved after this process, simultaneous timing of pressing by all dies is possible and a uniform density is realized. The CNC press has a die position coordinate displacement function, as shown by the “Ejection” step in Fig. 2. Utilizing this function, it is possible to prevent ejection cracks in green compacts due to differences in die elastic deformation during pressing.

Due to these features, net shape and near-net shape compacting of shapes that had been impossible to compact with the conventional powder presses are now possible, contributing to a large reduction in machining allowances. From this viewpoint, the CNC press can also be considered a resource saving powder compacting press. Based on these advantages, wider application is expected in the future.

3. Examples of complex shapes produced by CNC press

3.1 Examples of pressing of segmented multi-step die/high step shape product

3.1.1 Outline of product specification

Fig. 3 shows the configuration of a product with a high step shape. Net shape pressing of this product shape was possible by using the CNC press. The product specification includes gear teeth around the outer diameter, which are used to drive a timing belt, and a flange which functions as a belt guide. As a distinctive feature, the specification shows a maximum step difference of 30mm from the top die side relative to a total length of 42mm, or a step ratio of approximately 71%.

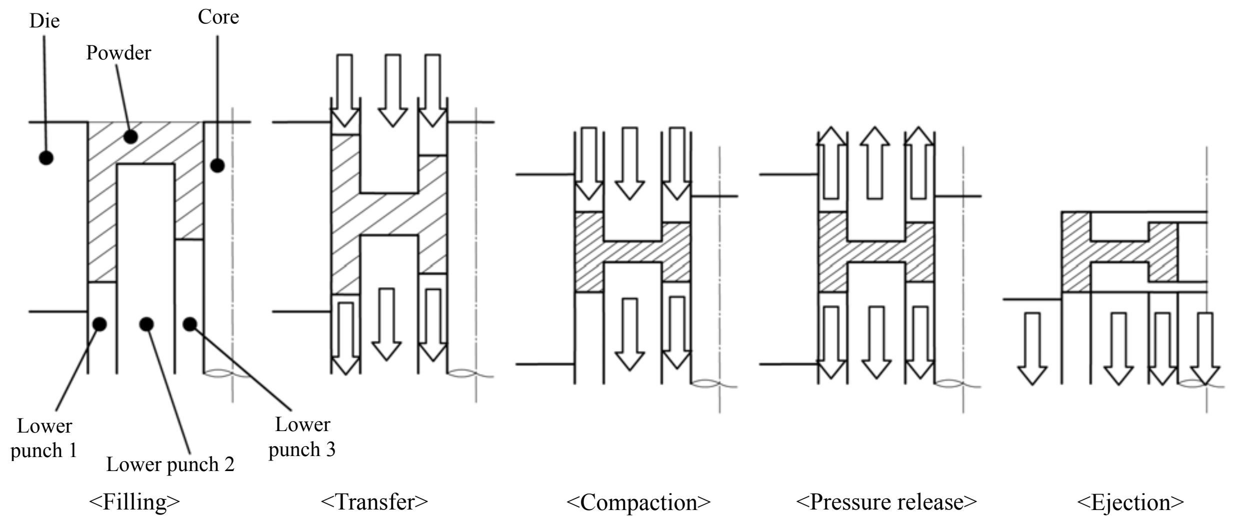

Fig.2 Compacting process of CNC press.

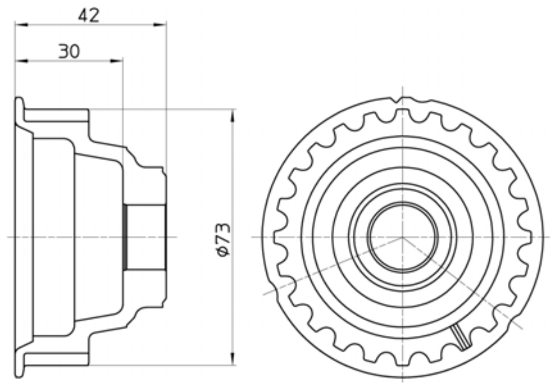

Fig.3 Product figure.

3.1.2 Problems due to compaction with conventional press

The problems which arise in compacting this product with a conventional mechanical or hydraulic press are shown in Fig. 4.

When the step difference of the part pressed by the top die is large, as in this product (30mm), raw material powder transfer is necessary. In some cases, die sets designed with a mechanical transfer mechanism are applied to conventional presses. However, even with this measure, it is difficult to perform transfer without pressing the raw material powder with the top and bottom dies. In performing raw material powder transfer, the timing of operation of the top and bottom die, which consist of opposing segments, the amount of die movement, and the die speed must all be consistent with two dies When these conditions are not materialized, pressing of the powder begins before material powder transfer. As a result, the timing of pressing by the segmented dies is not simultaneous, and this results in slip cracks. With the die mechanism shown in Fig. 4, in fact, there are also problems in the ejection of the green compact, etc., and problems also even occur when powder transfer can be performed perfectly.

3.1.3 Possible compacting shapes with conventional presses and problems

Based on the above discussion, the shapes which can be compacted with conventional presses have the specification shown in Fig. 5. In particular, it is only considered possible to press shapes with a step on the order of 10mm from the top die side. Therefore, when actually manufacturing products, it is necessary to machine the part shown by the hatched lines in Fig. 5. This increases production costs.

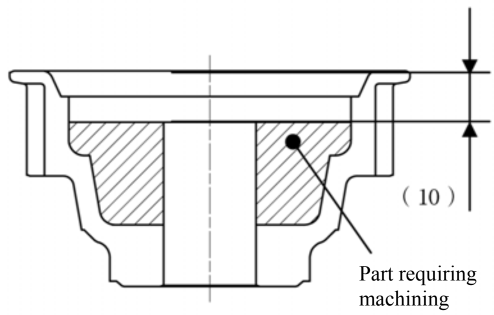

Fig.5 Product from compacted with conventional.

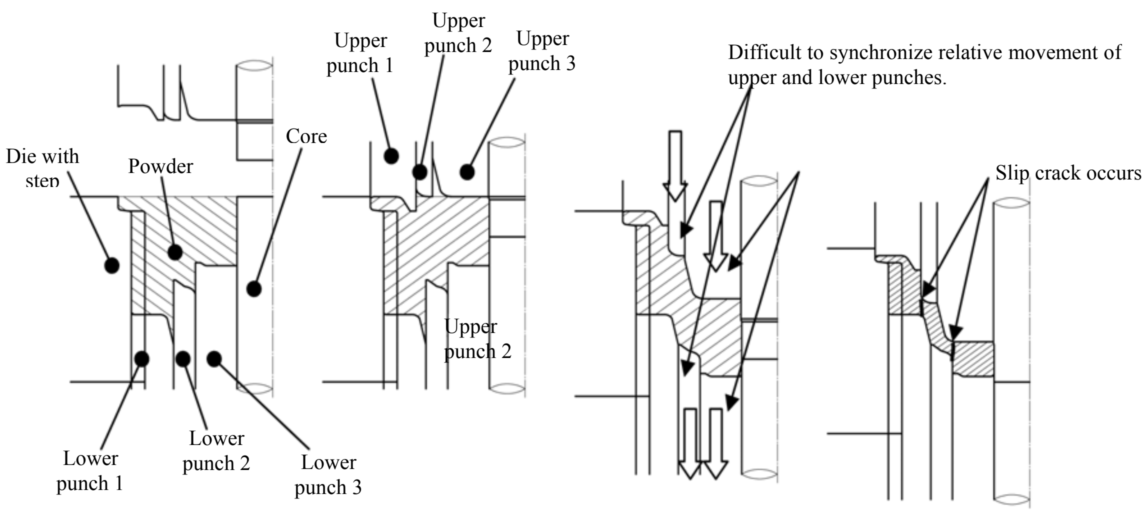

Fig.4 Problem of compacting by using conventional press.

3.1.4 Compacting using CNC press

Fig. 6 shows a cross-sectional photograph of a product manufactured using a CNC press. Fig. 7 shows the compacting process for the same product. After the powder is filled, the powder is transferred without pressing, and pressing is then achieved. As features of the compaction of this product, because the lower 3 punch is a fixed punch and is set to the ejection standard, when the powder is transferred, the amount of powder which is to be pressed by each punch is secured by moving the die, upper 1 and 2 punches, and lower 2 and 3 punches upward. After a desktop study, these press operating conditions were established by a thorough examination of all press operating conditions, beginning with powder transfer conditions, during trial operation using a die. As a result, net shape compaction of this product has become possible. The product is produced by a process comprising pressing, sintering, and repressing (second compaction), and turning and other machining are not performed.

Fig.6 Cross section of product.

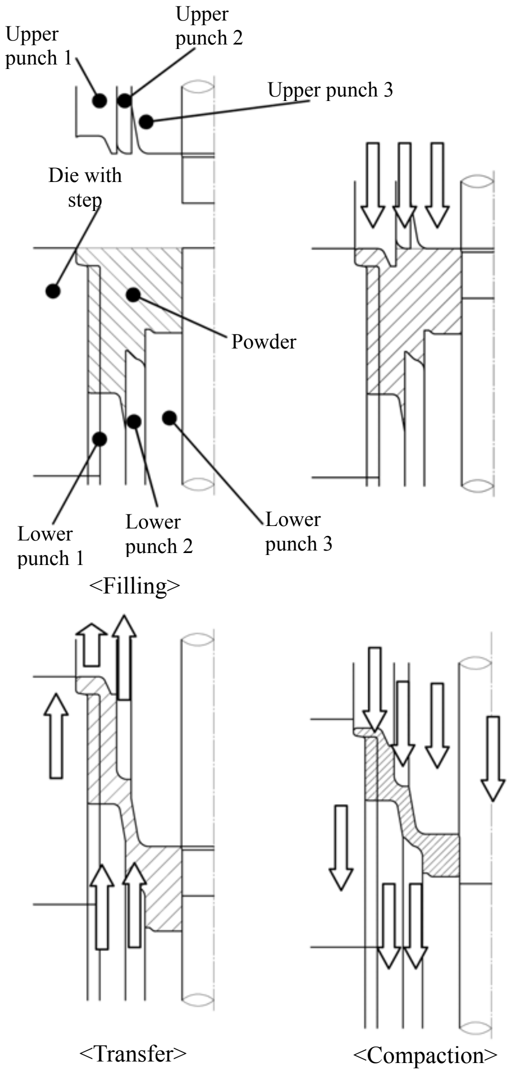

Fig.7 Compacting conditioning by using CNC press.

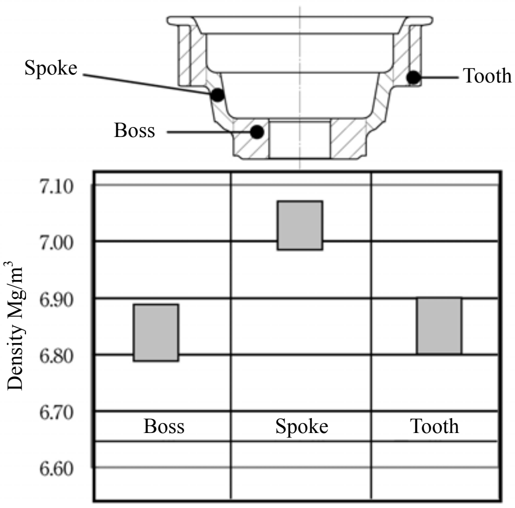

Fig.8 Result of density distribution.

3.1.5 Results of evaluation of density distribution

Fig. 8 shows the results of a measurement of density distribution. The standard deviation σ shows little deviation, with values in the respective parts of boss part = 0.015, spoke part = 0.010, and tooth part = 0.013.

3.2 Example of compacting multi-step/complex shapes

Next, an example of a multi-step/complex shaped product will be introduced. Fig. 9 shows the product specification, and Fig. 10 shows the appearance of the product.

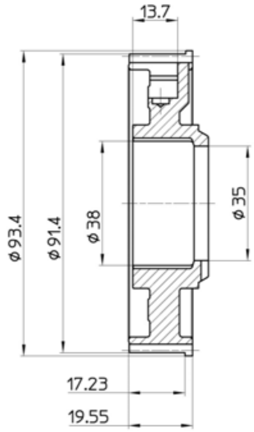

Fig.10 Product appearance.

Fig.9 Product specification.

With this product, the die mechanism was complex, comprising a stepped die, stepped core, 3 lower steps, and 3 upper steps. However, the compacting design and compacting conditions were established, and a product with an outer spline part density of 7.0Mg/m^3 was mass-produced using Fe-Cu-Ni-Mo material.

3.3 Example of compacting of product with horizontal groove shape

This section presents an example in which a product having a horizontal groove shape was compacted using a CNC press.

3.3.1 Outline of product specification and problems in conventional compacting method

Fig. 11 shows the product specification. As features of this product, the shape includes a side groove 6mm in width, and the thickness of the material around the groove is thin, at 0.5mm. Assuming compacting of this product by the conventional compacting method, the part with the 12° slope would have an undercut shape, as shown in Fig. 12, which means that compacting would be impossible.

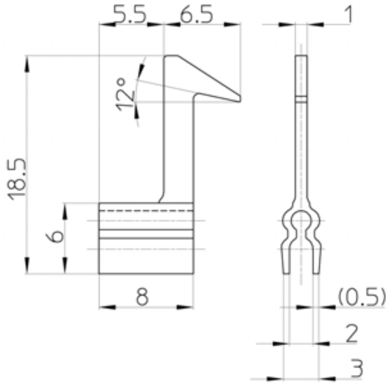

Fig.11 Product specification.

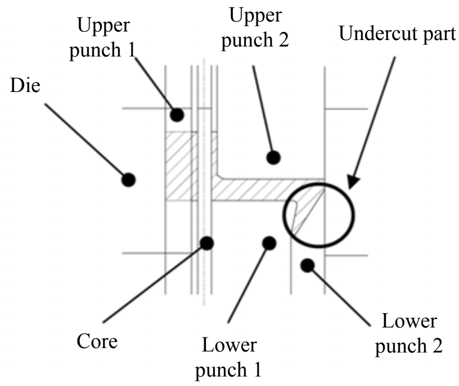

Fig.12 Compacting method by conventional press.

3.3.2 Side groove compacting method using CNC press, and problems and response when applied to product

In order to perform net shape pressing of this product, a method of compacting the side groove is necessary. Therefore, application of a “side groove compacting mechanism,” which is added to the CNC press, was studied. Fig. 13 shows a model of the basic side groove compacting process in the CNC press. The process sequence of the compacting process from powder filling to ejection of the green compact is as follows.

(1) Powder filling is divided into two stages; in the first stage, the powder necessary for compacting the bottom of the side groove is filled.

(2) The punch which presses the side groove compacting part is operated. After this operation, the powder necessary for compacting the top part of the side groove is filled.

(3) Pressing/compacting is performed with the top and bottom dies.

(4) The dies used previously to compact the side groove are retracted first. Following this, the die is

lowered and the green compact is ejected.

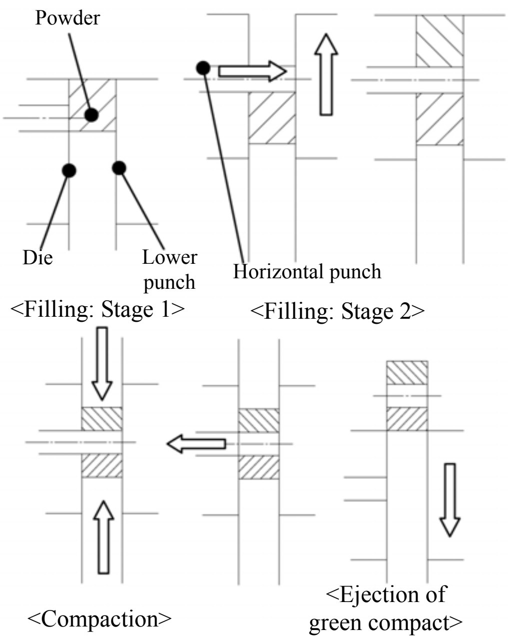

Fig.13 Compacting process of side groove with CNC.

Compacting of the side groove is possible by the CNC press operation method described above. However, the following problem is assumed in compacting the side groove of this product. The problem assumed during compaction of this product is shown in Fig. 14.

Because the groove specification is not a shape which is enclosed by a surrounding part, there is considered to be a possibility of breakage of the green compact due to resistance during ejection from the die. To solve the problem of breakage of the green compact during ejection, a specification was adopted in which the strength of the green compact is secured by compacting 2 parts continuously, and then cutting the parts after sintering, as shown in Fig. 15.

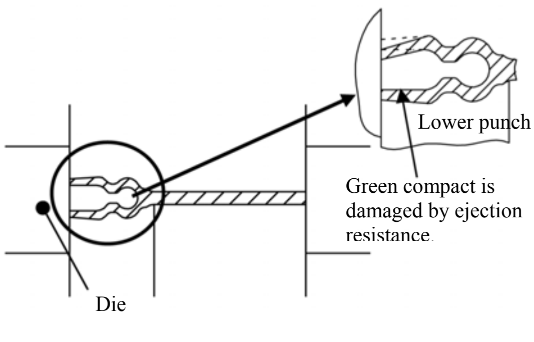

Fig.14 Problem of compacting side groove with CNC.

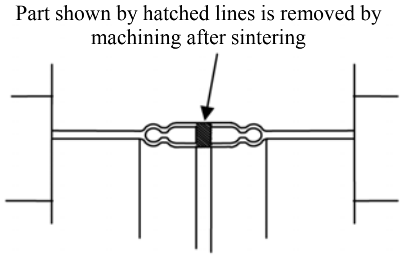

Fig.15 Countermeasure of breakage at compacting.

3.3.3 Problems in trial compacting and countermeasures

Trial compacting was performed using a die under the specifications shown in Fig. 15. However, as a result, shape damage occurred. This is thought to be due to ejection resistance between the opening of the groove and the die. It can also be said that the thin thickness (0.5mm) of the material was a factor contributing to shape damage.

Based on the above, the compacting conditions were reviewed as a countermeasure for shape damage. Fig. 16 shows the condition of compacting after improvement of the compacting conditions.

The sequence of the compacting process was as follows. This is a large change from the compacting process sequence as originally planned.

(1) Filling of the powder is performed. (The necessary amount is filled in one step.)

(2) First pressing is performed to a degree that does not achieve the final compact density.

(3) The raw material powder is transported outside the compacting die by the groove compacting punch, and final pressing is performed.

(4) The powder which was transported outside the compacting die is returned again to inside the compact.

(5) The returned powder is ejected together with the green compact, serving as a “support” against the ejection resistance of the groove part.

The problem of shape damage was solved by reviewing the compacting operation method and conditions, as described above.

Fig. 17 shows a product which was compacted by the improved method.

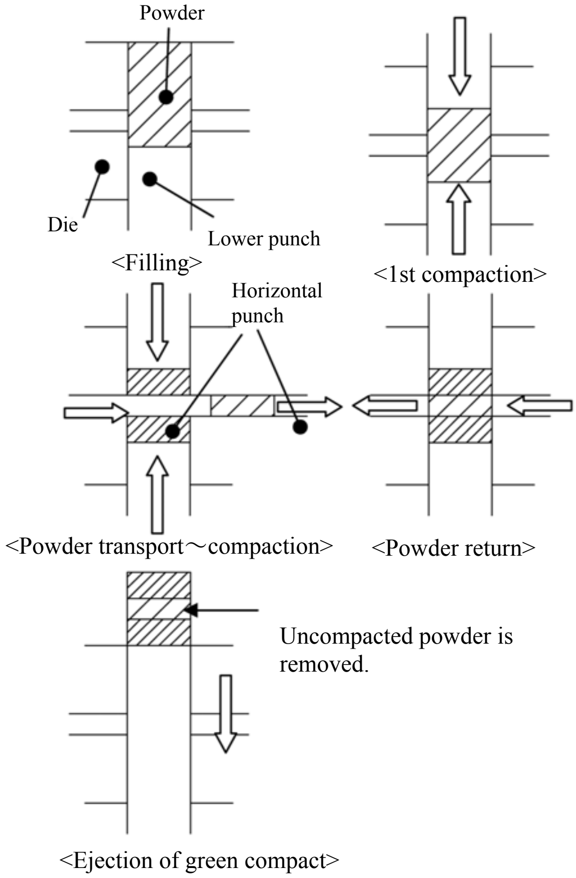

Fig.16 Compacting process with improved condition.

Fig.17 Appearance of product with side groove.

4. Conclusions

Using the CNC press, net shape compacting of products which had been difficult to produce with the conventional hydraulic and mechanical press methods has become possible. Because this technology makes it possible to supply powder metallurgy products at lower cost, it can be said that the CNC press is a powder compacting press that will make an important contribution to the development of powder metallurgy products in the future.


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