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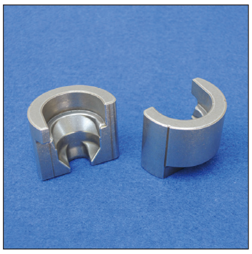

# Sintering of Parking Support Parts Utilizing the High Shape Flexibility Offered by Powder Metallurgy

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Powder metallurgy involves compressing powder in a mold and sintering it to strengthen compact parts. Through innovative mold designs, near-net-shape*¹ compacts that closely resemble the final product can be achieved. Parking support parts are found in various vehicle types, including hybrids and electric cars as well as gasoline cars, and are crucial components used in parking lock systems to prevent wheel rotation during parking, with diverse shapes. We successfully developed parking support parts utilizing the shape flexibility of powder metallurgy, contributing to the growth of the sintering market. Our development includes examples like adjusting density balance by removing excess powder, compacting two different shapes, creating horizontal grooves, and integrating multiple components. Additionally, the use of partial laser hardening has enabled precise production while promoting environmentally friendly manufacturing practices.

Keywords: powder metallurgy, parking support, shape flexibility

## 1. Introduction

Sintered parts are manufactured using the powder metallurgy method, in which metal powder, primarily made of iron, is filled into a die and pressed to form it, then heated below its melting point to bond the powder together. We have been developing mainly automotive-related parts, taking advantage of the powder metallurgy's ability to mass-produce complex-shaped products at low cost and with high precision through near-net compacting. In this paper, we present the development of various parking support parts. A parking support part is used in the parking lock mechanism that locks the wheels within the transmission when the vehicle is parked. The shape of this part can be changed relatively freely within the layout constraints, which allows the advantages of the sintering process to be utilized. In this sense it is an important part. Figure 1 shows the parking lock mechanism. When the transmission shift lever is set to "Park," the parking rod moves onto the ramp of the parking support, pushing the parking pawl upward to lock the parking gear and the wheels. The crucial part of a parking support is the sliding area between the parking rod and the parking pawl, as it requires high precision and wear resistance. The trend for parking support parts is to have complex, multi-stage shapes to match the transmission layout, which aims to be lightweight and compact. In this paper, we introduce the latest near-net-shape technology that we have successfully developed, presenting examples of parking support parts.

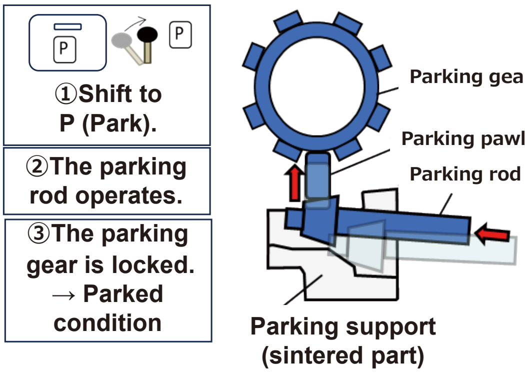


Fig. 1. Parking mechanism

## 2. Application of Powder Metallurgy Technology to Parking Supports

### 2-1 Powder removing compaction technology to improve density difference

The die structure for this product is simple, comprising one upper punch and two lower punches. The part itself has a complex L-shape and the end face needed to be uneven, between the surface where a separate part comes into contact and the rest. When compacting the uneven surface with a single punch, density differences occur because the compression ratios of each surface during compacting (Fig. 2). Density differences cause uneven pressure on the die, which can lead to damage to the die and deterioration of overall length parallelism. For this reason, measures to improve density differences were necessary for near net forming. The prototype demonstrated the occurrence of large density difference between the recessed and raised parts that we were concerned about. First of all, in order to adjust the density of the recessed part, where the density is particularly high, we provided a powder escape to the die to partially remove the powder when the upper punch is inserted into the die (Fig. 3), however the powder escape alone did not significantly improve the density difference. Therefore, we have devised a powder scraping device with large grooves on the die and powder feeding jig, which removes 10% more powder from the high-density area than usual during powder feeding (Fig. 4).

Two steps improved the density difference to within 2%, achieving excellent near-net compacting (Fig. 5).

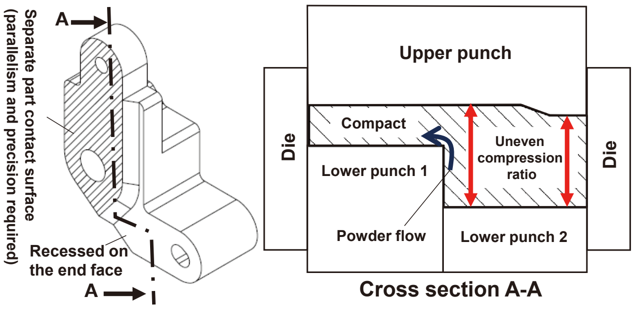


Fig. 2. Die structure and compression ratio

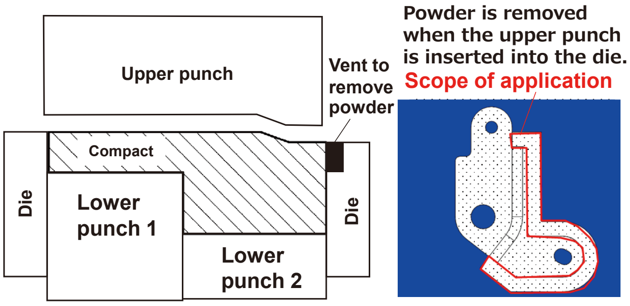


Fig. 3. Step 1: Vent hole

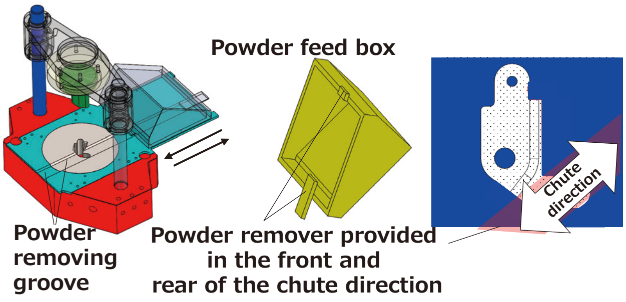


Fig. 4. Step 2: Powder removing

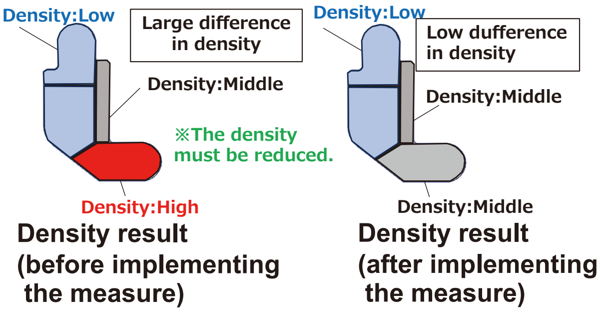


Fig. 5. Result of the measure

## 2-2 Realization of simultaneous compaction of two identical irregular shaped parts

The product has an extremely complex shape, comprising 1) a stepped ramp on the internal circumference, 2) a step on the external circumference, 3) a latch on the side, and 4) a semicylindrical shape (see Fig. 6). Our goal was to completely eliminate the need for machining by fully harnessing the capabilities of powder metallurgy.

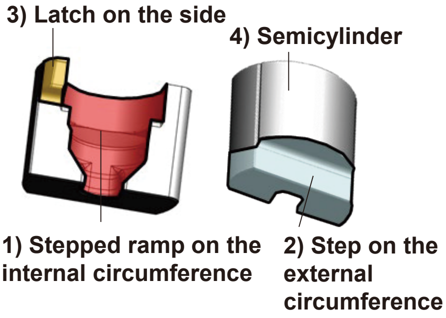


Fig. 6. Irregular product shape

(1) Consideration of mold structure to achieve complete machining-free manufacturing

Although a stepped lower punch is generally used for forming products with a ramp shape on the inner circumference including this product (Fig. 7), the conventional structure in which a multi-stage ramp shape is formed using a stepped lower punch cannot form all shapes. First, we designed a die structure capable of forming the entire shape by vertically reversing the compaction direction, without being bound by conventional design methods (as shown in Fig. 8 (a)). Nevertheless, this mold structure could cause defects such as gouging or seizure between the upper punch 2 and the die 2 due to the upper punch 2 receiving lateral pressure from the compact when pressure is applied. Consequently, we developed a mold structure for simultaneous compaction of two identical products by leveraging the characteristics of (4) semicylindrical shape. In this mold structure, the products are placed facing each other in point symmetry, canceling out the lateral pressure (as shown in Fig. 8 (b)).

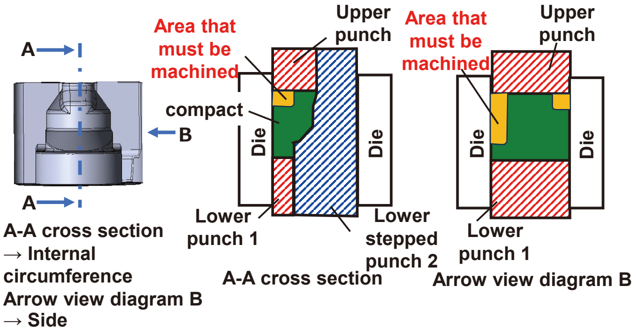


Fig. 7. Irregular product shape

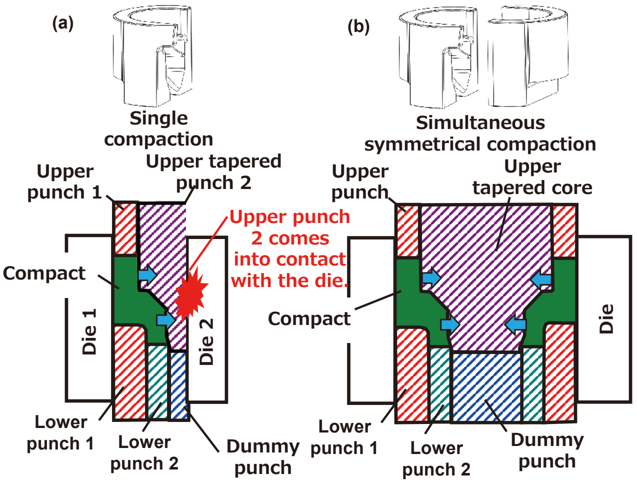


Fig. 8. Die structure that does not require product reversal and machining ((a): single compaction; (b): simultaneous compaction)

(2) Die shape optimization by 3D design

In order to achieve the simultaneous compaction of two identical parts having a complex, multi-stage shape, the mold structure was optimized by simulating the mold shape and mold operation using 3D drawing software (Fig. 9). However, during continuous compaction for trial production, lateral pressure from the compact caused lower punch 1 to gradually tilt toward the die side. This allowed powder to flow into the gap between lower punch 1 and lower punch 2, causing lower punch 2 to tilt toward the dummy punch side. As a result, the sliding performance of the die deteriorated, leading to defects such as unstable product weight (Fig. 10). Accordingly, the following two designs were implemented such as; 1) A design to suppress powder intrusion by providing a gap shape to the lower 1 and lower 2 punches (Fig. 11). 2) A design to suppress punch collapse and improve die sliding by making the lower punch 2 thicker and increasing the volume ratio to improve rigidity without interfering with the die operation (Fig. 12). The above efforts enabled mass production without any machining. Simultaneous compaction of two identical parts also doubled the service life of the dies as well as the production efficiency, and significantly improved productivity.

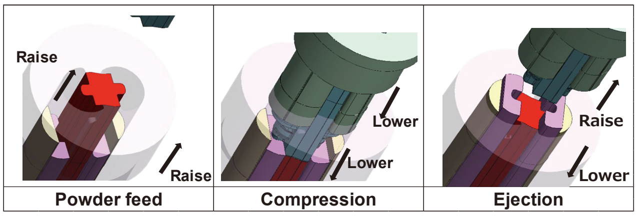


Fig. 9. 3D die design simulation

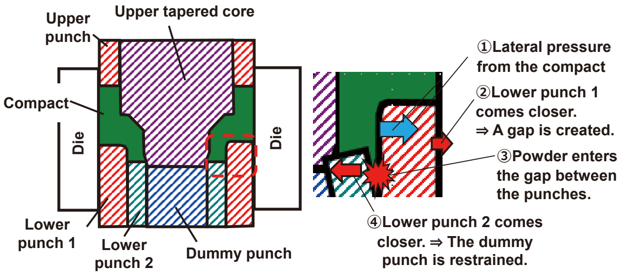


Fig. 10. Factors that contribute to the compaction weight difference

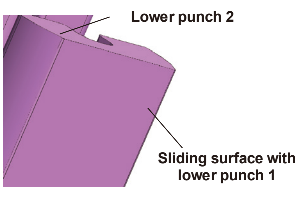
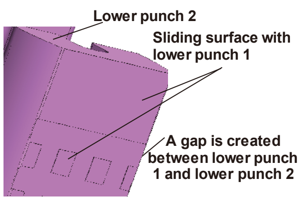
| Before implementing the measure against powder inflow | After implementing the measure against powder inflow |
|---|---|
|  |  |
| Powder flows into the gap between lower punch 1 and lower punch 2 | Powder is removed by the gap between lower punch 1 and lower punch 2. (The amount of removed powder does not affect the manufacturing process.) |

Fig. 11. Measure 1: Design for suppressing powder inflow

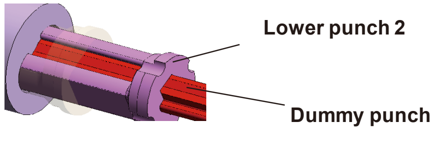
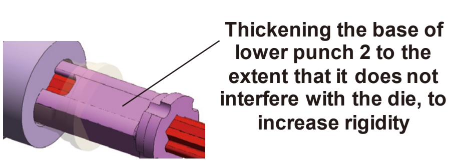
| Three-dimensional die improvement (lower punch 2) | |
|---|---|
| Before implementing the measure |  |
| After implementing the measure |  |

Fig. 12. Meeasure 2: Design for Increasing the rigidity of lower punch 2

### 2-3 Lateral groove (undercut) compaction

In single-axis compaction, products with protrusions and recesses perpendicular to the compacting direction cannot be extracted. This is also the case with a lateral groove (hereinafter referred to as an “undercut”) of this support parking part, which necessitates machining of the undercut after sintering. In order to eliminate machining of the undercut in single-axis compaction, a die structure was developed that does not involve pulling down the lower punch 1, which forms the undercut shape, when the product is ejected. (Fig. 13). However, in the method shown in Fig. 13, lateral pressure from the compact pushes lower punch 1 toward the die side, resulting in gouging and seizure of the die. To prevent this problem, we were inspired by the simultaneous compaction for two compacts in 2-2. We considered that a point-symmetric layout of the product would offset the lateral pressure on the die from the green compact and thereby prevent die gouging, even when the product was not semicylindrical. We succeeded in reducing the die tilt in simultaneous compaction using an undercut core and achieved high-precision undercut compaction (Fig. 14). Moreover, simultaneous compaction doubled the longevity of the dies and the production efficiency.

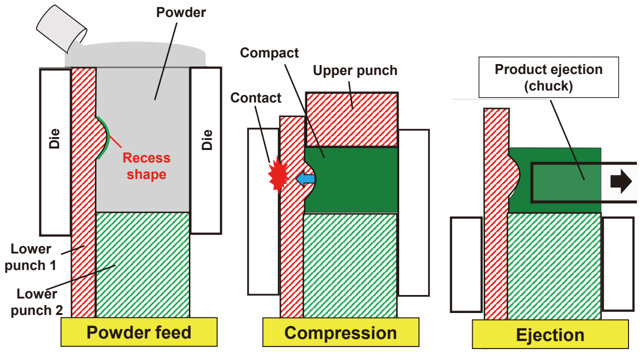


Fig. 13. Compaction method of the undercut die

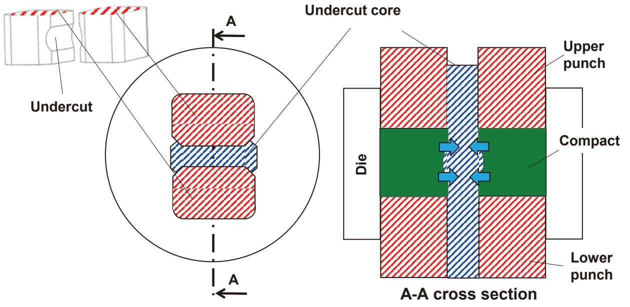


Fig. 14. Undercut dual compaction

### 2-4 Integration of two parts and laser quenching*2

(1) Integration of two parts and adjustment of the compression ratio

This parking support part has a large protrusion on the end face and two diagonally located pin holes that require machining for finishing to meet high dimensional precision. The initial shape of the product was a two-part design in which a separate quenched pin was inserted into a hole created by machining on the side, and this quenched pin acted as a slope that received the mating part, the parking rod. In order to manufacture this part without any machining process, we proposed a design that integrates those two parts and allows near-net compacting of the protrusion on the end face by using the lower punch (Fig. 15). However, creating the protrusion with the end face of lower punch causes a difference of about 60% in the compression ratio, which may lead to a significant local density reduction of the protrusion where wear resistance is required and to loss of product functionality.

In order to adjust the density, a recess was added to the upper punch side of the product that did not affect functionality, opposite to the protrusion, which enabled the integration of the two parts without a significant reduction in density (Fig. 16).

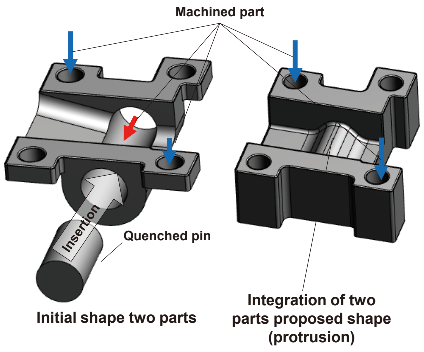


Fig. 15. Initial shape and shape of two parts integrated

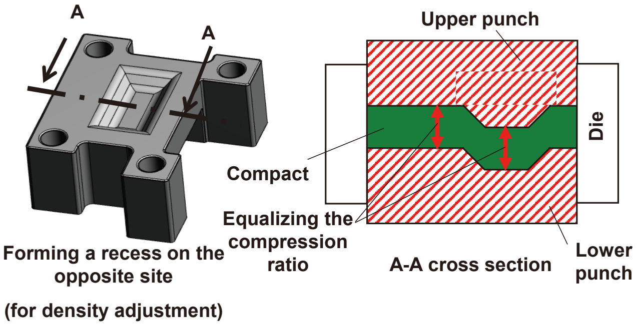


Fig. 16. A recess for density adjustment and balancing of the compression ratio

(2) Utilization of the laser quenching

In general, the carburizing quenching*3 process is used in the manufacture of parking support parts, as wear resistance is required at the sliding area with the mating part. However, there was an issue with the tool life being shortened in machining the two pin holes that must meet high precision requirements due to their large distortion and high hardness after carburizing quenching. To address this, we applied laser quenching at only two areas where hardness is required and mating parts slide, which enables localized quenching (Fig. 17). The use of laser quenching made it possible to prevent hardening of the pin holes, which require machining for finishing, and extended the

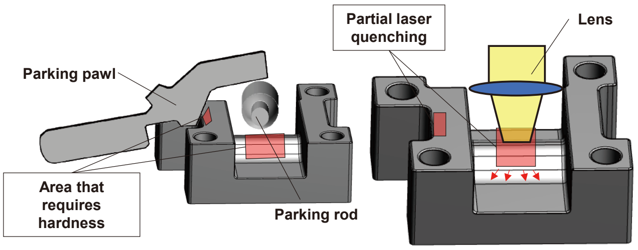


Fig. 17. Use and laser quenching area

service life of the tools (Fig. 18).

Furthermore, the adoption of laser quenching has reduced carbon dioxide emissions from heat treatment by approximately 94% compared to those from conventional carburizing quenching and allowed us to realize an environmentally friendly process design.

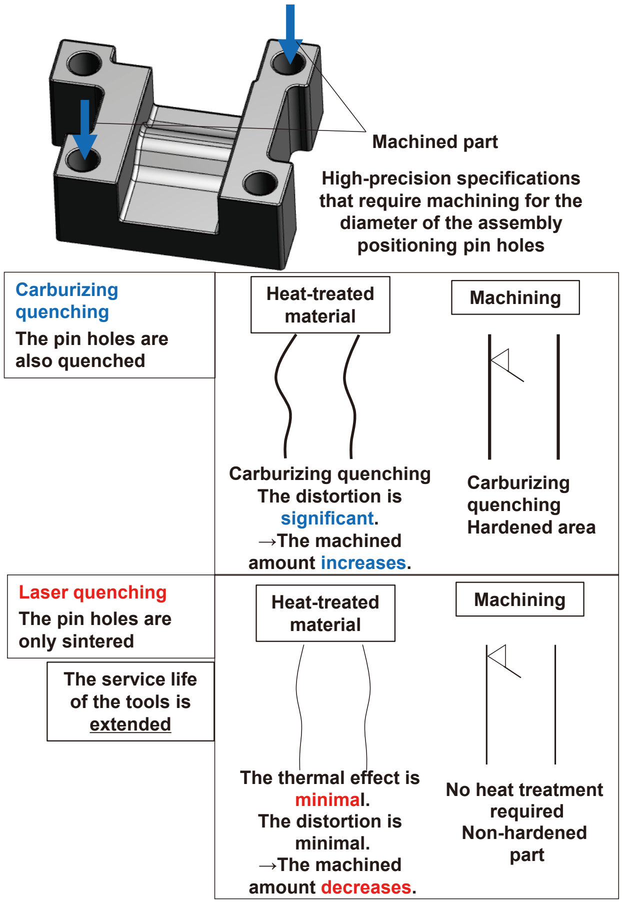


Fig. 18. Extension of the service life of tools by applying laser quenchingthe compression ratio

## 3. Conclusion

We successfully developed near-net-shape compaction for producing parking support parts, which are likely to be installed in electric vehicles, by harnessing the high shape flexibility of powder metallurgy. In this project, we were also able to adjust the density balance by powder removing(1); eliminate the need for machining and improve the service life of the dies and production efficiency through simultaneous compaction(2); and realize environmentally friendly development(3); through undercut simultaneous compaction, integration of two parts, and laser quenching. These innovations have contributed significantly to the expansion of the sintering market.

### Technical Terms

| | |
|---|---|
| ∗1 | Near net shape: A technology used to compact powder into a shape approximating the complex shape of a final finished part. |
| ∗2 | Laser quenching: A technology used to perform partial quenching of only the surface by converging light through a focal lens for localized heating. Product warping caused by quenching is less pronounced than that caused by carburizing quenching. |
| ∗3 | Carburizing quenching: A technology used to quench the entire surface by filling a furnace with a carburizing gas. This enables the quenching of many samples at a time. |

### References

(1) Sumitomo Electric Sintered Alloy, Ltd., J. Jpn. Soc. Powder Powder Metallurgy, 70 (2023)
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(3) Sumitomo Electric Sintered Alloy, Ltd., J. Jpn. Soc. Powder Powder Metallurgy, 69 (2022)

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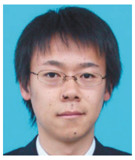

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