Influence of Mold Temperature, Lubricant and its Additional Quantity on Compressibility in Warm Compaction

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Abstract

In recent years, demands for sintered ferrous material with higher strength are increasing. To satisfy these demands, studies and commercial use of the die wall lubrication method, the warm compaction method and the combination of both methods are widely carried out to achieve high density. The die wall lubrication warm compaction method makes it possible to achieve high density by reducing internal lubricant through die wall lubrication, although the method involves several issues such as prolonged cycle time due to lubricant spraying and difficulty in spraying lubricant in the case of compacting with complicated geometry. Meanwhile, the conventional warm compaction method requiring no die wall lubricant application cannot achieve such a high density as in the case of die wall lubrication warm compaction due to higher volume of internal lubricant. However, this report discloses our study result in which the possibility of improving density is exhibited by using a lubricant type with superior dynamic ejection property that can reduce volume of lubricant additive.

Keywords : warm compaction、die wall lubrication warm compaction、lubricant

1. Introduction

We started volume production of high strength sprocket in 2003〔2〕 based on high density compaction of low alloy steel powder to a density of 7.3g/cm^3 or more by using Toyota's proprietary technology, die wall lubrication warm compaction technology (hereafter "DWC")〔1〕. TABLE 1 shows a comparison between the DWC method and the warm compaction method (hereafter "WC") using low alloy steel. While conventional WC method can achieve a density of 7.3g/cm^3 or less, an increase of compacting density by 0.1g/cm^3 allows reduction of compacting cost, facilitates applicability to the compacts with more complex geometry and mitigates troubles related to equipment management. Accordingly, relationship of ejection property and galling in various types of lubricant was studied to identify the type of lubricant that allows continuous compacting with a density of 7.3g/cm^3 or more when the lubricant component is 0.45%.

2. Experimental and Results

First of all, using low alloy steel powder JIP5MoS(Fe-0.6Mo-0.2Mn) +0.65%Gr+X%ZnSt as raw material powder, influence was determined of die temperature and lubricant volume on the compressibility, assuming the case where a cylindrical column of ϕ15×10mm was compacted with 713MPa. The result is shown in Fig. 1. To achieve a density of 7.3g/cm^3 or more at 80℃of die temperature, a reduction of lubricant volume to 0.45% was necessary. However, the decrease in lubricant volume tends to elevate ejection force and incidence of galling. To solve this issue, comparison of ejection property was conducted among 2 types of metal soap(ZnSt、LiSt), ethylene bisamides(hereafter "EBS"), Kenolube (Hoganas) and WAX-type lubricant A (JFE Steel). In the comparison experiment, each type of lubricant was added to the material powder JIP5MoS+0.65%Gr to cause the lubricant component to be 0.45% of total volume. A ϕ15× 10mm cylindrical column was compacted at 80℃ of die temperature and under pressure of 713MPa for each lubricant. Then, the static ejection force and dynamic ejection energy were measured when the sample column was ejected with 2mm/s speed and 25mm ejection distance.

Table 1. Comparison of main characteristics between DWC method and WC method

Technique	TInternal lubricant	Die wall lubrication	Die temperature	Density	Cost	Complex geometry	Necessary equipment
DWC	0.20%	Yes	130℃	7.3≦	△	△	Application+Die heating equipment
WC	0.80%	No	130～150℃	≦7.3	○	○	Powder heating / Die heating equipment
Development method	0.45%	No	80℃	7.3≦	○	○	Die heating equipment

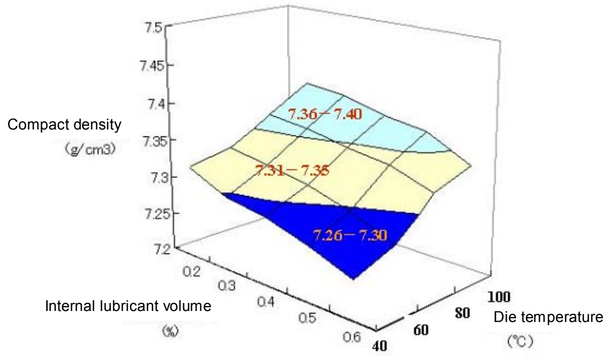

Fig. 1 Compressibility for each die temperature and ZnSt additive volume（713MPa）

Further, the dynamic ejection energy was defined with the area indicated in Fig. 2. Fig. 2 shows the force-displacement graph for each lubricant, and Fig. 3 shows the static ejection force and dynamic ejection energy as well as the status of galling in each case.

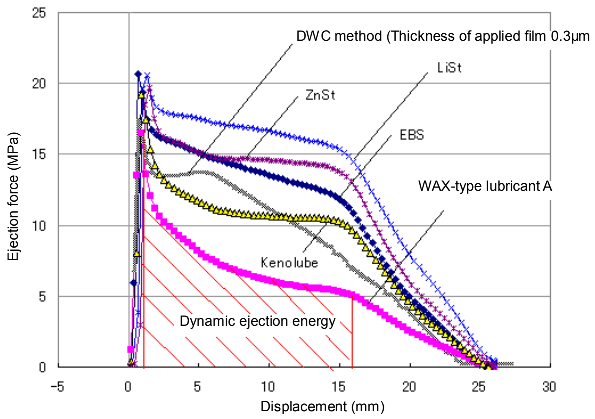

Fig. 2. Ejection force – displacement graph

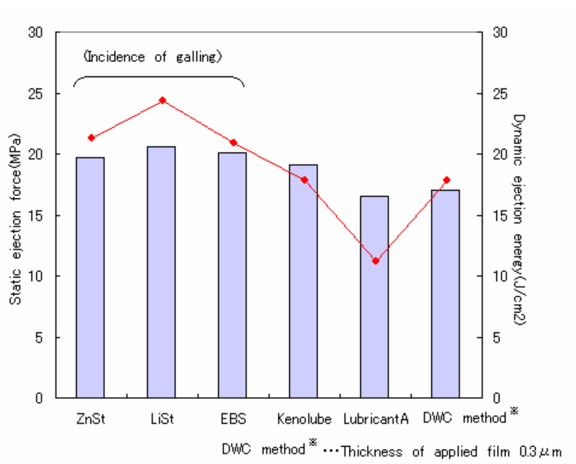

Fig. 3. Comparison of static ejection force and dynamic ejection energy

Galling was generated for ZnSt, LiSt and EBS. On the other hand, the galling wasn't generated for Kenolube and WAX-type lubricant A. In comparison with static ejection force of Kenolube, which is about 20 MPa equivalent to those of 3 type lubricants that generated the galling. However, the dynamic ejection energy was lower with Kenolube in comparison with the other lubricants mentioned above. The dynamic ejection energy of Kenolube was equivalent to that in the case of DWC method. Based on this fact, it is considered that the surface condition of the compact is influenced more significantly by dynamic ejection energy than by static ejection force.

In order to examine possibility of continuous compacting, 1000 sprockets were compacted and the surface condition was confirmed. Compacting condition was set up as material powder JIP5MoS+0.65Gr+0.45%WAX type lubricant A, die temperature of 80℃ and density of 7.35±0.05g/cm^3. This surface condition is shown in Fig. 4. In the continuous compacting, the surface condition was excellent, where no galling was observed. The mass production is planned to start from October 2006 in running change mode

This method was also used for mass production of high strength rotor (target density: 7.35g/cm^3) with complex geometry since May 2006.

Fig. 4. Surface condition（Development method）

Fig. 5. High strength sprocket

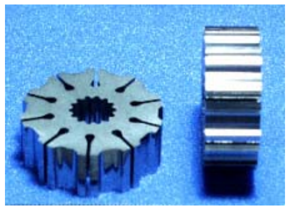

Fig. 6. High strength rotor

3. Summary

Possibility of making compacts with density of 7.3g/cm^3 or more from low alloy steel powder in continuous compacting process was confirmed by using lubricant with superior dynamic ejection property and by reducing the lubricant volume to 0.45%, which was not feasible with the conventional warm compaction method.

4. References

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