Applications in Powder Compaction of Iron Powder – Influence of Tool Material on Tool Life

Odd Sandberg[1, a], Andreas Krona[2, b], Sigurd Berg[3,c], Flemming Kaad[4, d] and Göran Nord[5, e]

[1]Uddeholm Tooling AB, SE-683 85 Hagfors, Sweden
[2]Callo Sintermetall, SE-571 39 Nässjö, Sweden
[3-5]Höganäs AB, SE-263 83 Höganäs, Sweden
[a]odd.sandberg@uddeholm.se, [b]andreas@callo.se, [c]sigurd.berg@hoganas.com,
[d]flemming.kaad@hoganas.com, [e]goran.nord@hoganas.com

Abstract

A high nitrogen PM tool steel has shown to have an excellent galling resistance due to the introduction of a high amount of a low friction phase predominantly consisting of VN. Tool making and heat treatment are according to standard procedures. An increase of tool life of more than two times compared to ordinary tool steels is found. Furthermore, the new low friction tool steel shows a potential for sintered parts with higher densities through the applicability of increased compaction pressure or minimized lubricant amount.

Keywords : Powder compacting, galling, tool material

1. Introduction

An improvement of the mechanical properties of sintered parts is obtainable by increasing the density. With standard single-press/single-sinter (1P1S) parameters a density of about 7,0-7,2 g/cm^3 is possible to attain. To further raise the density of the sintered part up to 7,3-7,5 g/cm^3 or more different actions can be made such as increasing the press force, using warm compaction, heated-die compaction, introducing double-press/double-sinter (2P2S) techniques, and/or reducing the amount of lubricant/graphite. Reducing the lubricant amount is a most important factor for increasing density [1]. However, decreasing the total lubricant amount to 0,2-0,4% or less and especially in combination with excessive compacting stresses, >800 MPa, will inevitably lead to an increased die/punch wear and to higher ejection forces leading to an increase of defects of the green compact. The most common cause for maintenance of a powder compacting die or punch is galling or abrasive wear. The galling situation can be strongly improved by optimizing the tool surface structure and smoothness. Today, the properties of cold work tool steels can be changed by varying the distribution, type, size, amount and hardness of the hard phase appearing in the martensitic matrix. A new low-friction tool steel has shown great potential to significantly reduce the critical die wall friction and thus significantly reducing or even avoiding stick-slip situations at ejection of the green part [2].

2. Experimental and Results

The solid lubricants used in powder pressing is forming a continuous film against the die wall allowing boundary lubrication conditions and metal to metal contact [3]. The lubrication in the compacting zone is normally adequate to avoid severe galling and die surface degradation. However, Solimanjad et al [4]. also states that even if there is a partly coverage of solid lubricant between die wall and the powder compact in the end of the compacting stage there is much less lubricant transferred to the die wall during the ejection phase. This increase of friction will generate higher ejection forces and increased die/punch wear. The lubricating properties are also depending on the surface roughness of the die, which is progressively increasing with time in production. This description of the wear process is clearly visualized on a powder pressing die manufactured of AISI D2 (1,5%C, 12%Cr, 0,8%Mo, 0,8%V) used for compacting a magnet part to a chain saw, Fig. 1. The part was manufactured in a 1P1S process to a density of 7,0 g/cm^3 by using a phosphorous alloyed steel mixed with 0,8% Kenolube™. The D2 die steel could produce 100 000 parts before it was worn to such an extent in the ejection zone that burr occurred on the as-pressed green part and centring of the punch in the die was difficult at interrupted production. The low-friction grade Vancron 40 (1,1%C, 1,8%N, 4,5%Cr, 3,2%Mo, 3,7%W, 8,5%V) had after 335 000 parts generally significantly lower surface roughness compared to AISI D2, Ra/Rmax = 0,5/3,5 and 6/32 um, resp in the ejection zone.

A further density increase is possible by introducing heated-die compaction. However, standard solid lubricants loose part of its lubricating properties at its melting point [4], which normally is in the same temperature range as warm compaction is performed (60-120^{o}C) and special lubricants are needed. Under these compacting conditions it is thus even more advantageous to use tool components with a low friction and which are able to maintain a durable smooth surface finish to secure a robust compacting process. Fig. 2 presents the result from a heated-die compaction, 100°C, 1P1S process to manufacture a balance weight to a chain saw, see right picture in Fig. 1, with a requirement of having a density of 7,3 g/cm³ when using a phosphorous alloyed steel. The lubricant used was 0,4% Kenolube. Compared to the previous case the die is suffering from significantly more wear resulting in only 12 000-20 000 parts before the die is worn out when PM10V or AISI D2 is used as a die material. At this stage the die can not be withdraw to fill level due to high friction. The end part appearance when D2 is used as die material is visualized in fig. 2. When the die is manufactured of Vancron 40 significantly more parts can be produced before die replacement is necessary – still running after 250 000 parts.

Fig. 1. Magnet part to the left and balance weight part to the right.

Fig. 2. Green part appearance of a balance weight after heated-die compaction, 1P1S, of a phosphorous alloyed steel powder, 0,4% Kenolube™, density 7,3 g/cm³.

The new powder metallurgical produced tool steel, Vancron 40, is characterized by its low-friction properties. The grade has compared to conventional tool steels a high nitrogen content, 1,8%, which increases the stability of vanadium nitride. The size and distribution of the hard phase becomes very small and fine in the heat treated microstructure of the final tool part. The high aspect ratio (height to width) and the low friction coefficient of the hard phase together with the interaction between lubricant and the hard phase have resulted in unique low-friction properties. Tool making and heat treatment of the new high nitrogen alloyed tool steel are according to standard procedures and if the tool needs refurbishment this can easily and with short lead time be performed in-house by conventional procedures such as machining, grinding, electro discharge machining and/or polishing as the low friction properties not are concentrated only to the surface, but rather to the bulk material. The conventionally produced grade, AISI D2, has a volume fraction of 13% of the softer M_7C_3 phase and bigger carbides, up to 100 um in length, and an uneven carbide distribution. The low-friction steel is composed of a high fraction, 20%, of a more dense distribution of small vanadium and nitrogen rich particles and a small fraction, 4%, of a Mo-rich carbide, see Fig. 3.

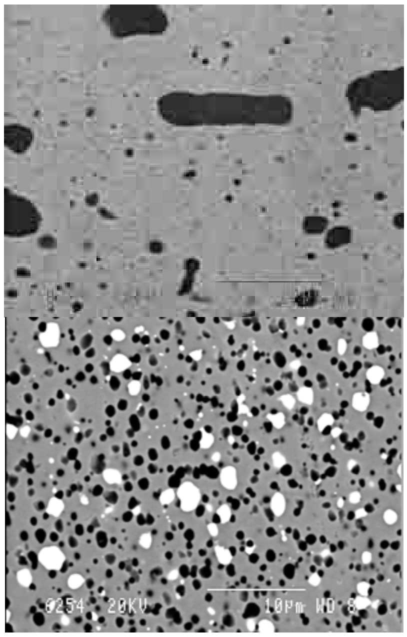

Fig. 3. Microstructure in hardened and tempered condition, 60-62 HRC, for AISI D2 (top) and Vancron 40 (bottom)

4. References

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