An Integrated Approach to Optimize the Interaction of Powder Concepts, Tooling and Compaction Aspects in PM Component Manufacturing

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ABSTRACT

To maintain its competitiveness towards other manufacturing techniques, the PM industry must continue to offer solutions that combine high demands on both mechanical properties and close tolerances of the sintered components in a robust, reliable and productive cost effective way.

One effective way to shorten time to market, reduce development costs and minimize risks to successfully implement new PM solutions into new applications is to combine unique competencies regarding powder concepts, tool design and powder compaction aspects to develop new offerings and advance the limits for PM parts manufacturing.

It is most desirable, for both economic and technical reasons, to achieve the highest possible utilisation of powder, tooling and press technology. Experimental work for proper powder, tooling and pressing solution is performed utilising an integrated team approach.
Improving tool wear resistance / reducing die-wall friction using proper combination of die material, powder and precision pressing is highlighted in this paper.

INTRODUCTION

To continue to expand the PM market into new applications, there is a need for cost effective and robust ways to manufacture components with both increased performance and improved tolerances. A challenge for the PM industry is to save on the high tool production cost and cut the lead time from idea to real product in order to be able to compete with other manufacturing technologies methods such as casting, forging or machining.

Tailored made materials and tooling combinations with optimised pressing parameters serving specific purposes can offer a unique opportunity for applications of high performance PM parts and exploits a great market of iron-based PM materials.
Optimization of the interaction between powder concept and tool material to obtain a robust and consistent compaction of the components is one way. Another is to improve the pressing precision of the compacts in case of multiplaten applications.

In this presentation results of an integrated team approach to optimize the interaction of powder concepts, tooling and compaction aspects in PM manufacturing will be described. The results from a number of research activities related to product quality improvements, productivity gain and tool/powder interaction regarding improved lubrication, wear reduction and precision pressing is high-lighted.

EXPERIMENTAL

The presence of friction is a critical factor throughout the powder compaction cycle. During the pressing, friction has a major impact on the density gradients within the pressed part. Friction is also important during the ejection stages of the press cycle as it influence for instance the surface quality of the parts and causes tool wear [ref. 1-4].

The precision and scatter in weight and dimensional of PM components is determined by the performance of the powder mixes used as well as the press technology and tooling quality. In [ref. 5] the improvement in part precision from using a high performance powder mix in combination with advanced compaction press for multi –level components have been reported.

The work presented in this paper was divided into two parts. In the first one the interaction between powder and the die material was studied. The aim was to improve tool wear resistance and also reduce die-wall friction using proper combination of die material and powder mix.

In the second part modified measuring methods as well as innovative methods to determine the optimum pressing position were studied. The objective was to minimize the tolerances of the pressed parts. Height variations at the part are mostly caused by the elongation of the machine due to different weights and as a result different forces. To minimize this elongation influence, the measuring device was assembled as close as possible at the tool itself. An other approach was to integrate an extreme accurate force measuring device to eliminate actively the elongation of the machine and tool.

Five different steel and hard metal dies were used for theses experiments which are denoted in this paper as Die A – E. The dies were provided by Alvier AG. The tooling was designed with an in press tool change concept for shortening the tool changing time. The pressing was applied using TPA 800 ton fully hydraulic Dorst press with a bag-on-press system for optimized flow of the powder. Components with a diameter of Ø50mm and height of 27 mm was pressed to a density of 6,90-7.05 g/cm³. The gravity filling principal was utilized for theses tests. The hydraulic press is equipped with a control system, allowing weight and compaction force measurement on every individual part.

The powder mix used in this part of the study was commercial water atomized Höganäs powder Astaloy CrM mixed with graphite and different amount of lubricant, Lube E™. The chemical composition of the mixes is presented in Table 1 below. Both compositions were made as ordinary elemental mix (Premix).

Table 1. Material used for the experiment

ID	**Base material**	**C** **%**	**Lube E** ™ **%**	**Theoretical density** g/cm³
Material 1	Astaloy CrM	0,5	0,8	7,34
Material 2	Astaloy CrM	0,5	0,4	7,53

1000 parts were pressed continuously with a pressing speed of 5 parts/min. Part temperature, weight scatter and density of the pressed parts were measured. Surface roughness measurements of the die surfaces were performed in order to study the effect of powder composition on the different tool material. Die surface was measured before and after every test. The surface roughness of the dies were measured at three different heights 25, 50 and 70 mm from the top of the die. Three measurements were made at every height and a mean value is presented. Both axial and radial surface roughness measurements were performed. The nominal press parameters for the tests are presented in Table 2.

Table 2: Initial parameters for the experiments

Actual diameter	Mm	50.00
Pressing area	cm²	19.63
Nominal pressing force	kN	1276.3
Nominal part height	Mm	27
Die temperature at start	°C	24
Filling height	Mm	56-57
Target no. of pressed parts		1000

The precision tests were carried out on a 250t DORST press, TPA250H/3, equipped with 3/3 level tooling. The powder mix used part of the study was a high performance powder mix, Starmix BOOST, from Höganäs AB. The mix composition was Distaloy® AE + 0.65% graphite + 0.65% Lubricant. The apparent density of the mix was 3.43 g/cm³ and the Hall flow rate was 25.9 s/50g.

For each method 50 compacts were pressed to a density of 7.1g/cm^3 at a stroke rate of about 10 strokes/minute. The geometry of the part is shown in figure 6.

RESULTS

Influence of tool temperature

The difference in part temperature when using material 1 with 0,8% lube E™ was insignificant. The temperature instantly rose to about 60 ºC for all of the tested dies. Temperature of the parts during pressing of 1000 parts for different tool materials using material 2 with 0,4% Lube E are shown in Fig.1. For all dies except Die B a steady-state level of temperature was reached after 300 pressed parts. The heat generation was of course different depending of the tool material and frictional properties. The temperature for the Die E was over 65 ºC just after pressing of 10 parts and the steady-state temperature 75 ºC was higher compared to the others. Frictional heat seems to be lower for the Die A and steady-state temperature was 67 ºC. The behavior of the Die B diverges from all others as can be seen from Fig 1. Steady-state is reached after 800 pressed parts compared to 300 for the rest. An explanation to this behavior can be that the frictional heat increased during the compaction run. This explanation is supported by the larger increase in surface roughness for die B, see fig 4b below.

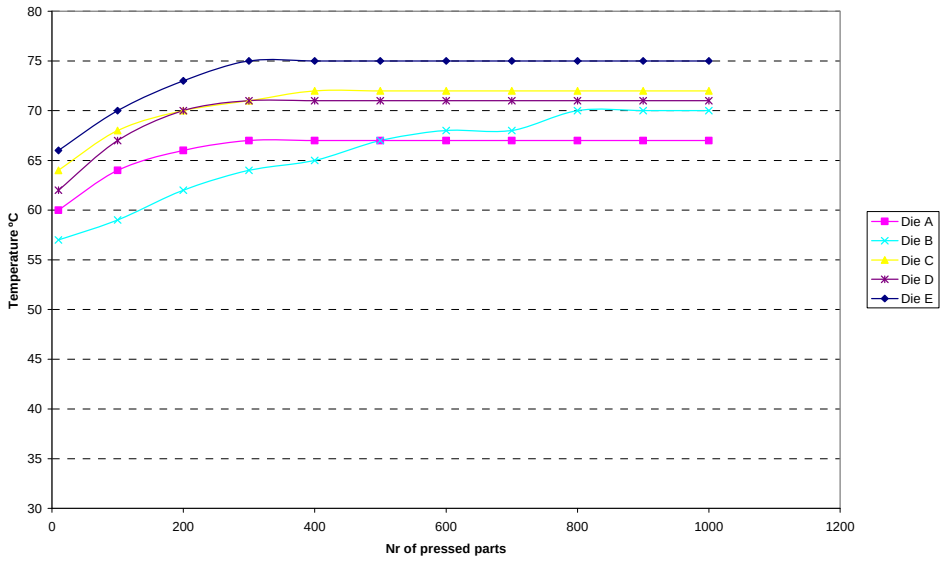


Fig 1: Temperature of the parts for material 2

Weight scatter

The weight scatter was not affected by the tool material. Fig. 2 shows the weight scatter for Die 3 with a deviation of ±0,4%. The weight scatter as well as compaction pressure deviation was mainly affected by the fill performance of the powder mixes and the filling method.

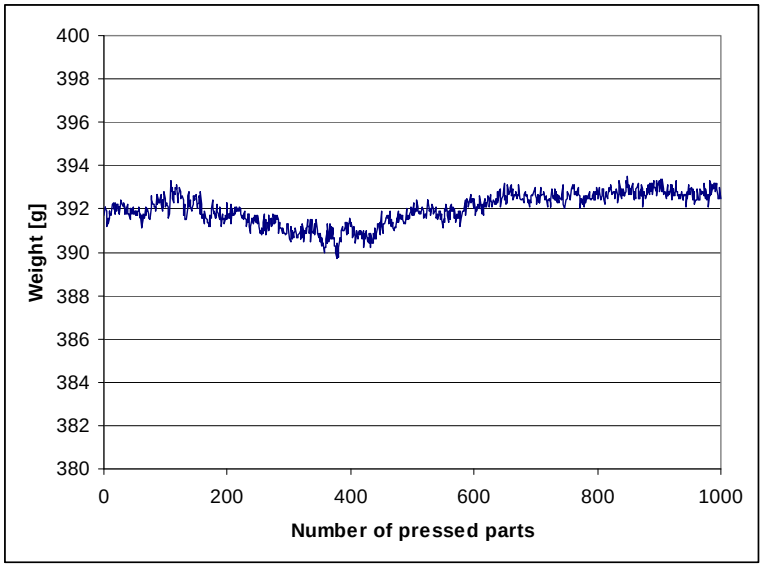
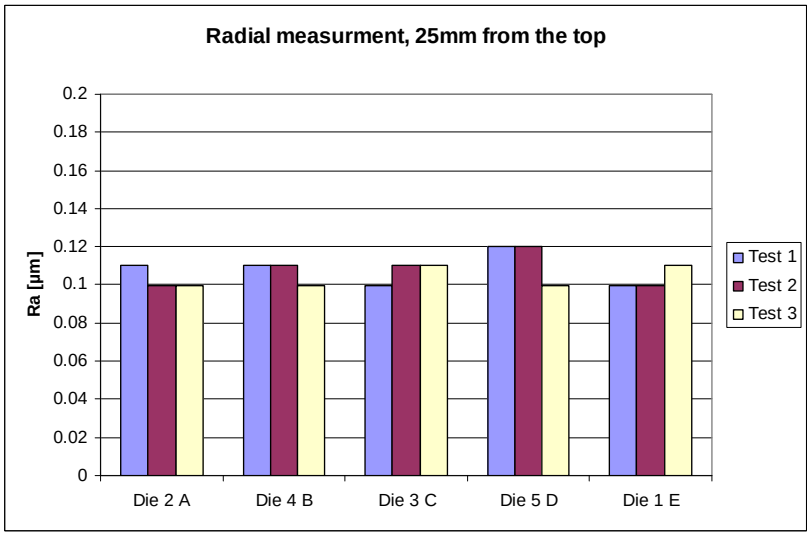


Fig 2: Typical weight scatters of the press parts

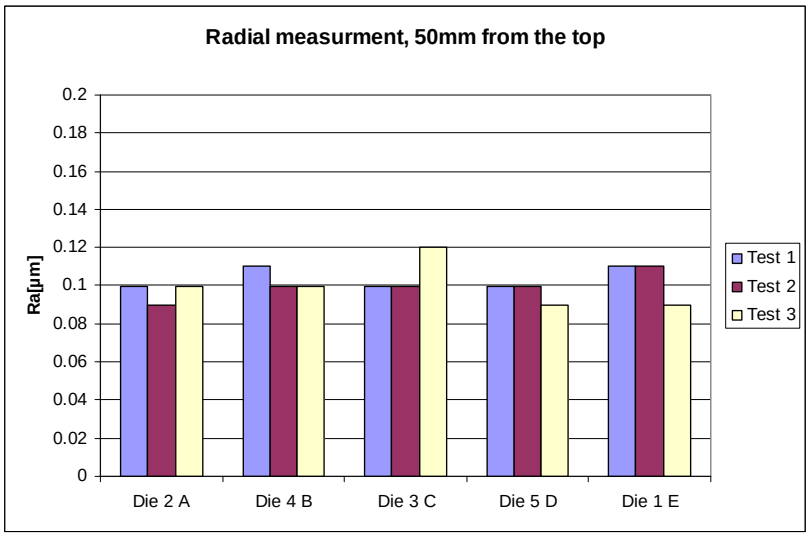
Surface roughness measurement

In order to detect wear and scratches on the tool die surface, surface roughness measurement both in radial and axial directions at different height inside the die was performed. The results for radial measurements are presented in Fig 3a-c. The first measurement, Test 1, was conducted before pressing and Test 2 and 3 were performed after pressing 1000 parts of material 1 and 1000 parts of material 2 respectively. The results only exhibit small differences in radial surface roughness between the dies.

a)



b)



c)

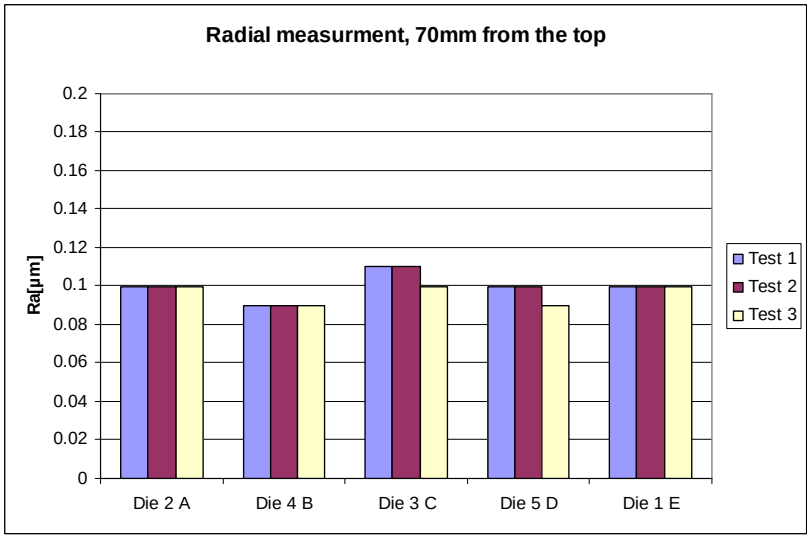


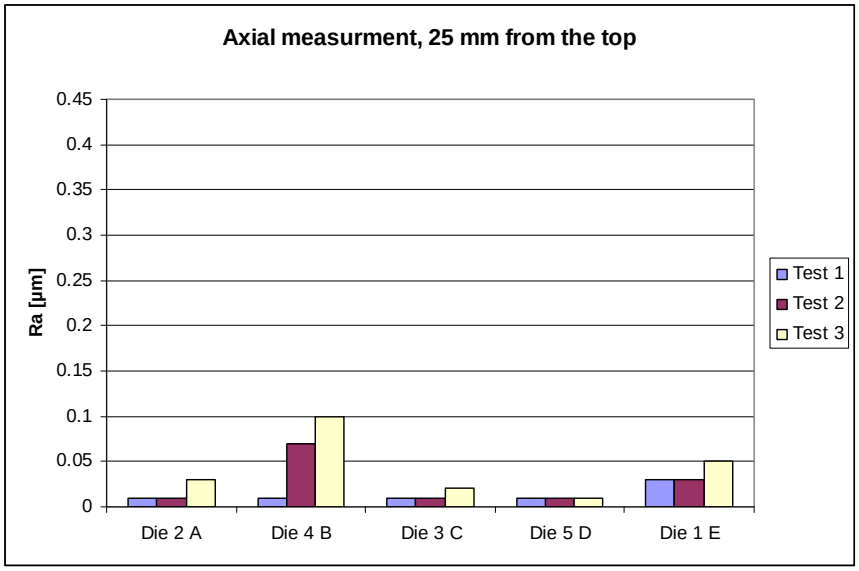
Fig 3 a-c: Radial surface roughness measurements of the dies at different height before and after pressing 1000 parts of material 1 and 1000 parts of material 2 respectively

Fig 4 a-c presents the results from axial surface roughness measurement at different height inside the dies. It seems that the die surfaces were more influenced in axial direction than radial direction. Deterioration of the surface quality for some of the dies was much more significant in axial direction. After pressing of the first 1000 parts of material 1 the Ra value increases by several times for Die B. After the third measurement which was done after pressing of 1000 parts with powder mix containing only 0,4%

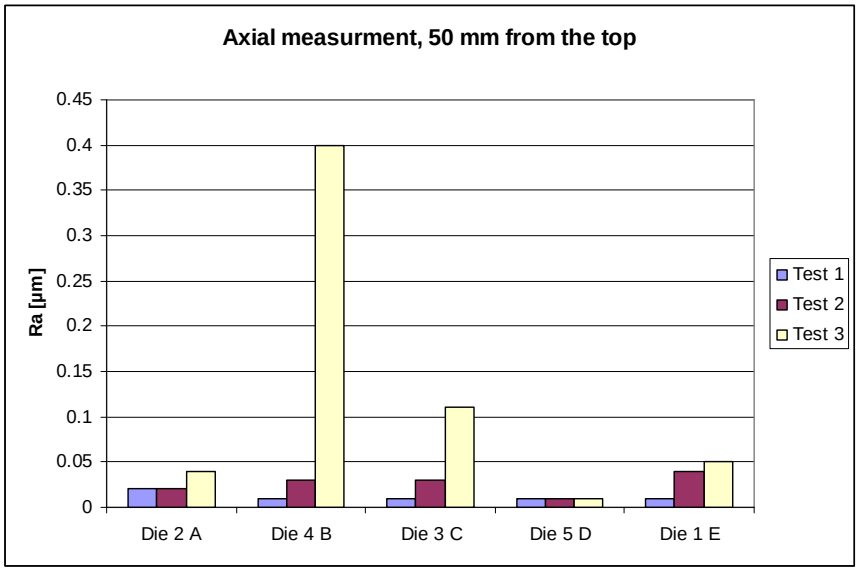
lubricant the deterioration of the surface quality was obvious. The Ra value increases from 0,01µm to 0,4µm.

The surface roughness of the Die C and E were also affected of the pressing. The most damage occur at the height of 50 mm for all Dies. The surface of the Die D seems to be unaffected through all of the tests. The surface roughness of this die was not at all affected by pressing of 2000 parts with a small amount of lubricant. The results indicates that a combination of Die material D and a powder mix with Lube E™ as lubricant can be a suitable option for pressing of high density components with less risk for tool damage.

a)



b)



c)

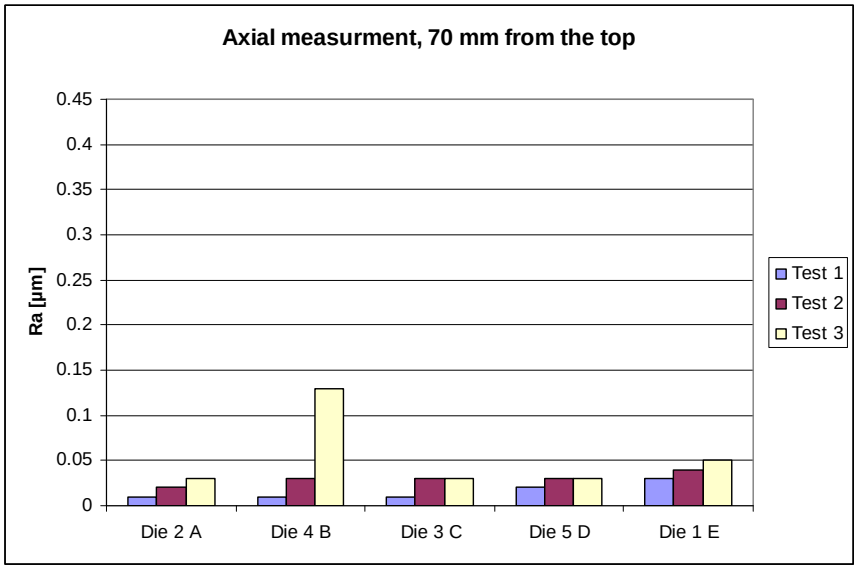


Fig 4 a-c: Axial surface roughness measurements of the dies at different height before and after pressing 1000 parts of material 1 and 1000 parts of material 2 respectively

Improved tolerances by precision compaction

The results are shown in Fig. 5 below. The dark blue curve shows the tolerances in height, sorted by height, pressed using the standard process. In the diagram, you only see the deviations from the average value. The red curve represents the results that can be achieved using new measuring methods. The yellow curve shows the pressing results achieved when using the innovative determination of the pressing position. The blue curve indicates the results when combining the above described methods. It is obvious that 50 compacts are within a tolerance range of ±0.01mm. As shown in Fig 5, innovative measuring methods can improve part tolerances by approx. 50 %. Similar positive results can be achieved by the new calculation of the pressing position. When combining the two methods, the tolerances on the compacted part were reduced up to 75%. Then 50 parts were within a range of ±0.01mm; this corresponds to a part tolerance of ±0.015mm with cp=1.67. Further studies on quantifying the possible further improvements of part precision in combination with advanced and better flowing/filling powder concepts [5] are ongoing.

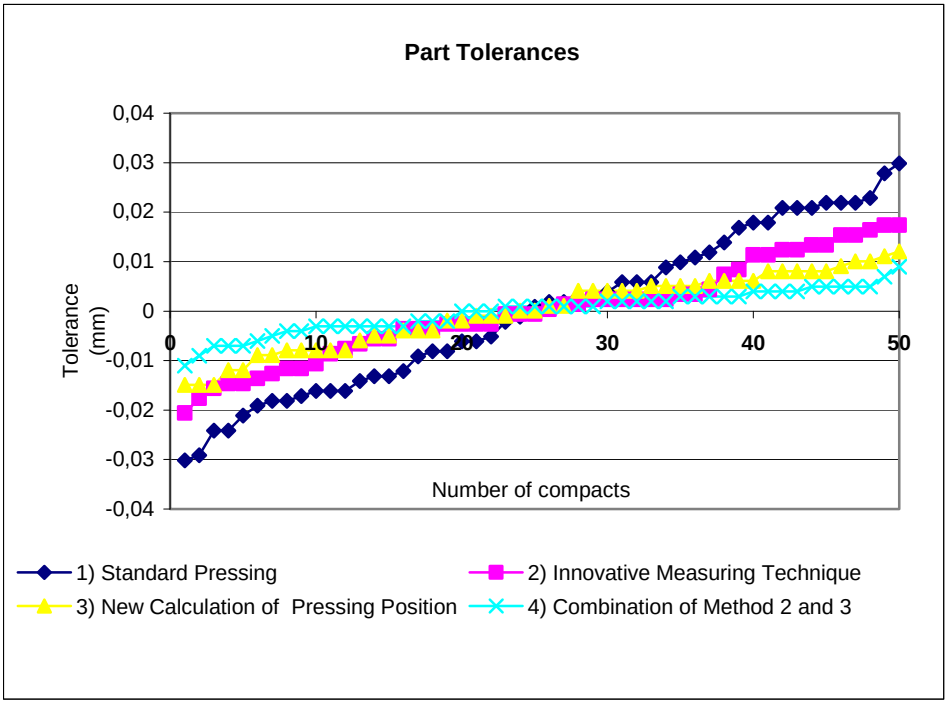


Fig. 5. Comparison of height tolerances on a synchronizer pressed with different methods

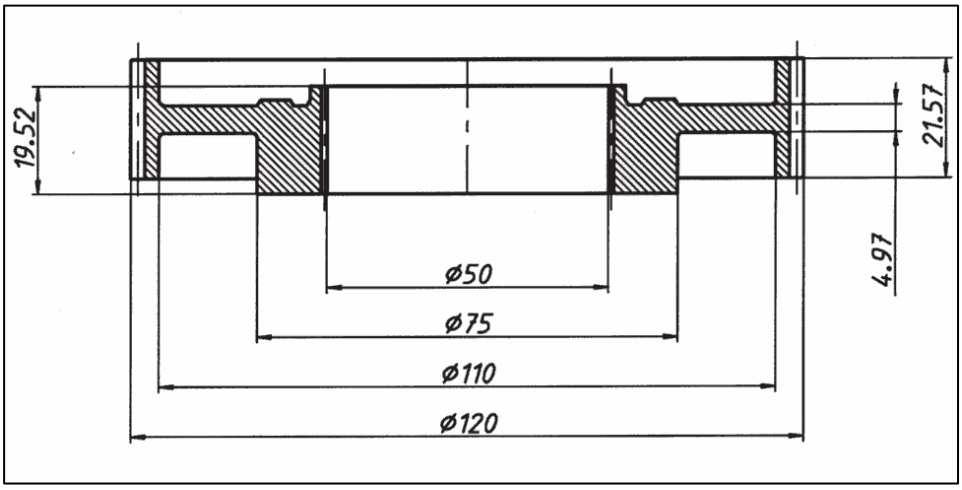


Fig 6: Geometry of the pressed part

CONCLUSIONS

Some conclusions that can be drawn from the work carried out are:

- A combination of Die material D and a powder mix with Lube E™ as lubricant can be used for pressing of high density components with less risk of tool damage.

- Heat generation of Die B was different from all other dies. It reached the steady state after pressing of 800 parts compared with 300 for the others. Temperature is a good indication for detecting of deterioration of die surface quality.

- The most influence on the die surfaces was in axial direction and not the radial.

- The most damage has been detected at a height of 50 mm from the top.

- Tolerances of compacted parts under the chosen conditions were reduced by 75% utilizing precision pressing

The work presented in this paper is the result of ongoing studies and more work is in progress. Further optimization of lubricant content will be studied. The utilization of precision pressing technique in combination with improved powder concepts, die coatings and filling methods will also be carried out.

REFERENCES

[1] P. Doremus, E Pavier, "*Experimental Equipment and Measuring*" 1998 P/M World Congress, Granada, Spain October 18-22 1998

[2] S. Strijobs, "*Friction between a Powder Compact and a Metal Wall*" Science of ceramics 1976 ISSN: 0582-2114

[3] E. Pavier and P. Doremus, "*Friction behaviour of an Iron Powder Investigated with Two Different Apparatus*", International Workshop on Modelling of Metal Powder Forming process, Grenoble, France, 21-23 July 1997, pp.335-344.

[4] N. Solimanjad "*A New Method for the Measuring and Characterisation of Friction at a Wide Range of Densities in Metal Powder Compaction"*. Powder Metallurgy, Vol. 46, No 1, 2003, pp.49-54

[5] M. Larsson, W. Rau, D. O'Keefe, "*Improved Dimensional Precision by High Performance Bonded Mixes and Advanced Compaction Presses"*, Advances in Powder Metallurgy & Particulate Materials 2008, Vol. 1, Part 3, pp. 165-175