Recommended Surface Finishes for PVD Coated Die Casting Dies

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Introduction

Mercury Castings has been using PVD coated die inserts for many years, and recently reported that more than 60% of their dies incorporate one or more PVD coated insert. As outlined below, over the years, Mercury has used an empirical method to determine the best approach for preparing the surfaces of dies prior to the deposition of PVD coatings, to maximize performance during the die casting process.

Several years ago, Mercury started applying Phygen's CrN and AlCrN PVD coatings to the faces of several dies and observed success with reducing soldering problems, and also found that the enhanced solder resistance arising from the use of PVD coatings extended die insert life. At the recommendation of Phygen, these die surfaces were diamond polished prior to the deposition of the PVD coating. Over time, Mercury expanded the use of PVD coated inserts, not just for soldering reduction, but also to provide an overall increase in insert life. However, when applying PVD coatings to inserts that already ran well (solder-free) in production, feedback from the Mercury shop-floor personnel was that, when brand new, these diamond polished and PVD coated inserts would often cause slides to stick in the part. However, after struggling through some initial shots (as many as 1,000 or so), the inserts would "season" or "break-in" and start to run well without soldering. The solution identified by Mercury and Phygen to address the "seasoning" issue was to use Mercury's standard surface finish (220 draw stone polish) on these inserts prior to coating. With the 220 draw stone polish finish, the PVD coated inserts would enter production without the need for a "break-in" period, and with no process changes.

Therefore, Mercury learned that different surface finishes (diamond polish versus draw polish) need to be applied to die inserts prior to PVD coating, depending upon the thermal conditions experienced by the coated inserts. This is described in detail below.

Diamond Polishing Prior to PVD Coating

Experience with running PVD coated die inserts at Mercury has shown that, regardless of whether or not an insert is water cooled, diamond polishing the die surface prior to PVD coatings works best for core pins and die inserts that are located in portions of the die that are exposed to high temperatures. These include cores located in heavy sections of a casting, inserts that see high gate velocities or are positioned directly in front of gates, or thin inserts having a high surface area to volume ratio. Characteristics that Mercury personnel use to help determine if an insert should be diamond polished prior to PVD coating include sections of inserts with heavy solder buildup, or areas that require significant added spray to help manage die temperatures. The advantages Mercury observe when diamond polishing these areas prior to PVD coating include increased insert life, reduced soldering, and improved cycle times (due to spray reduction).

Examples of die inserts at Mercury that see a large amount of heat, and so require diamond polishing prior to PVD coating include the water jacket die inserts and long blade inserts shown in Figure 1.

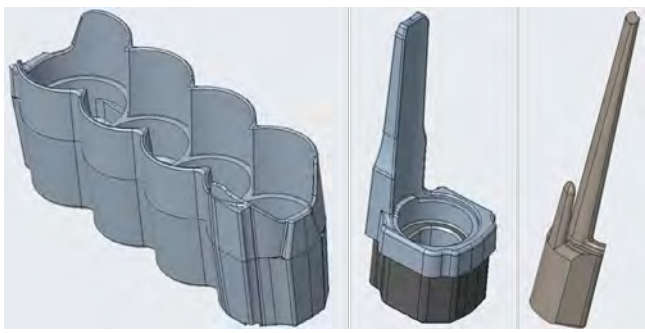

***Figure 1** – Examples of die inserts that require diamond polishing prior to PVD coating (water jacket and two blade inserts).*

Draw Polishing Prior to PVD Coating

For die inserts that run cooler, are not exposed to high gate velocities, or don't see as much heat, experience at Mercury has shown that a better finish for the die prior to PVD coating is a rougher draw polish. This surface finish is generally applied to die inserts that tend to be larger (with a low surface area to volume ratio), or inserts that are not located adjacent to gates. Characteristics that Mercury use to help determine if an insert would be processed via a 220 draw stone finish include little-to-no soldering on the insert, inserts that currently run well in production without extra spray, and applications where Mercury is looking to improve insert life without process changes. Advantages typically gained when draw polishing and PVD coating such inserts is increased insert life.

If these types of inserts are given a smooth diamond polished prior to PVD coating, it is Mercury's experience that they will not initially run well, and as noted earlier they

need to be "seasoned" or "broken-in". It is not clear exactly what is occurring during this seasoning process, but the shop floor personnel report that sticking is often observed during early shots, and the inserts need to be "babied" to get them through this run-in period.

An example of an insert that runs cooler, and so would be 220 draw stone polished prior to PVD coating, is the insert shown in Figure 2 from an exhaust die casting.

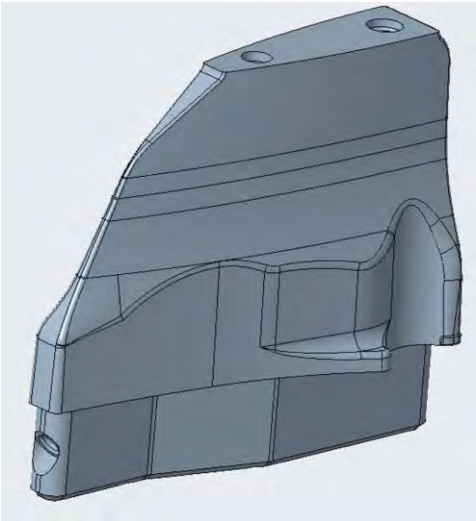

***Figure 2** - An exhaust insert that requires 220 draw stone polishing prior to PVD coating.*

Characterization of Surface Finishes

To better quantify the two surface finishes described above, diamond polishing (smoother) and 220 draw stone polishing (rougher), two samples of hardened H13 steel were prepared for surface roughness measurement. The samples, which are shown in Figure 3, were about 4¾-inches by 3-inches by 1-inch and were prepared as follows. The draw polished sample was prepared at Ultra Polishing Inc. It was roughened in one direction using a 220 stone (see the sample on the left in Figure 3).

The polished sample (right side of Figure 3) was prepared by Phygen. Phygen's approach to polishing is to use the appropriate abrasive and a suitable number of steps to first remove the large surface undulations, pits, nicks, lines, and scratches, and then to move progressively to remove smaller defects to achieve the desired smooth surface finish. This results in an extremely smooth, polished surface. Phygen provides additional advice, noting that it has seen a lot of polishing short cuts and what they refer to "cheating" of the required polishing steps. They note that it is not just necessary to get the surface as "shiny as a mirror", which can often be achieved with just one buffing step, but it is necessary to go through the multi-stage buffing process outlined above.

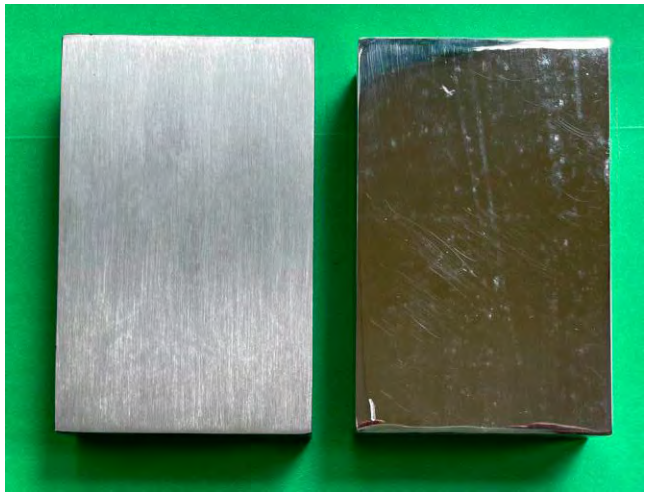

***Figure 3** - Photographs of the 220 draw stone polished (left) and the diamond polished (right) H13 steel samples.*

A Wyko NT2000 3D optical profilometer was used to measure the surface roughness of the two samples shown in Figure 3. Surface profiles of the two samples are shown in Figure 4, indicating that the diamond polished sample is significant flatter than the draw polished. The quantitative surface roughness values are listed in Table 1, showing that the Ra values for the draw polished samples are 10-to-25 times larger than the Ra value for the diamond polished sample.

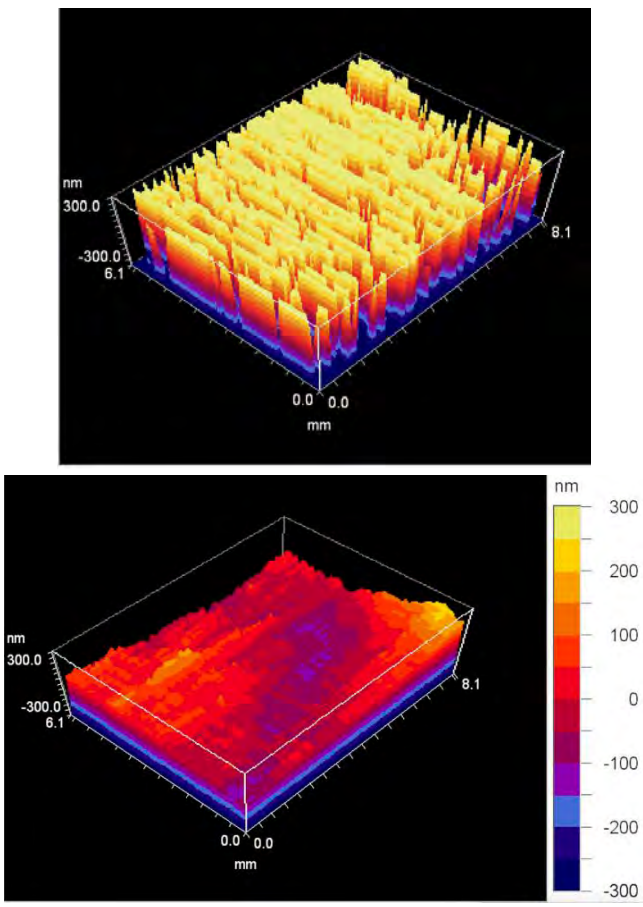

***Figure 4** - Surface profiles of the two H13 steel samples shown in Figure 3.*
Top: 220 draw stone polished (scratches run from top-left to bottom-right).
Bottom: Diamond polished.

***Table 1** – Surface roughness measurements for the two H13 steel samples shown in Figure 3.*

Measurement	Roughness - 220 Draw Stone Polished		Roughness - Diamond Polish
	Parallel to scratches	Perpendicular to scratches	
Ra	0.43 µm	1.04 µm	0.04 µm

Specific Example

Figure 5 shows a thermal image of a slide from a gearcase die, where all the inserts have been PVD coated. The image was taken as soon as the slide was pulled past the casting, and it can be seen that the regions highlighted by the green arrows are much hotter than the regions highlighted by the blue arrows. Based on the criteria previously laid out, prior to PVD coating Mercury diamond polished the inserts highlighted by the green arrows (thin, hot inserts), and used a 220 draw stone finish on the inserts with blue arrows (larger, cooler inserts). This combination of surface finishing plus PVD coating reduced solder in problem areas for this tool, and increased tool life with without any required process changes.

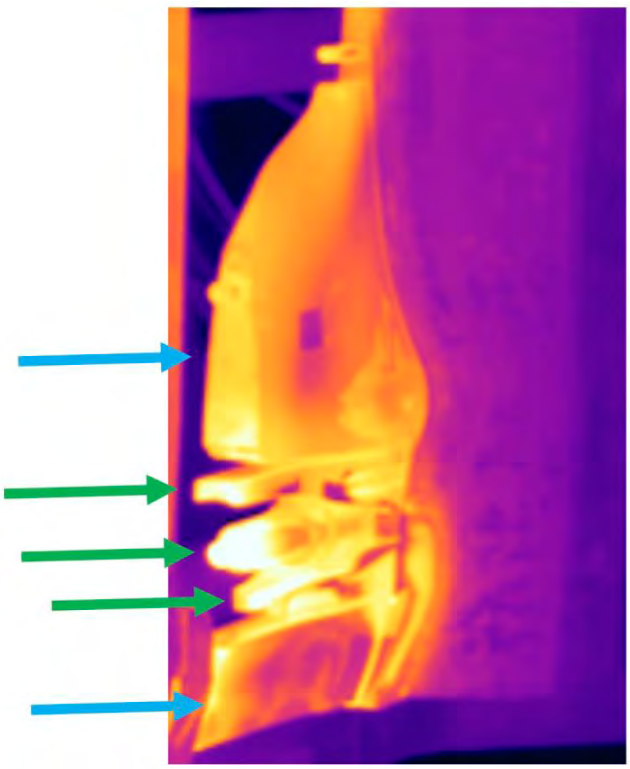

***Figure 5** – Thermal camera view of die inserts from a gearcase die.*

Summary

In summary, coating die inserts with Phygen's AlCrN and CrN PVD coating has helped Mercury Castings to reduce solder, extend die life and run faster cycles. Experimentally Mercury has determined that specific surface finishes need to be applied to the die surface prior to PVD coating, to optimize performance of the PVD coated casting die. For inserts that run hot, or are located in front of gates, it is better to diamond polish the inserts prior to PVD coating. However, for larger die insert that run cooler, or are well away from the gates, a better finish is a 220 draw stone finish, as this eliminates the need for "seasoning" of the die.