

Review of technologies for identification of die casting parts

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ABSTRACT

Part traceability is increasingly required not only for safety critical applications, but for a growing number of applications within various industries. Die castings are no exception to this and with the structural/high integrity market as the fastest growing segment, it is no wonder that traceability and marking of die castings are becoming a hot topic. High integrity parts typically have an identification requirement for 100% of the parts produced. This does not only allow immediate access to alloy and process data in case of an incident with the part, it also helps to improve part quality and management. Different technologies are available on the market and provide inherent pros and cons. The die casting industry presents several aspects that are very important to consider when choosing the right marking technology. Complex components with uneven surfaces, often at high temperature when being marked, short cycle time and post marking processes like shot blast treatment are among the most important ones. Part marking – while a vital step in the production process of the castings – should never be the bottle neck in the process, nor should it be a contributor to scrap rate. This paper aims to analyze the different marking methods available and to point out the most suitable one for inline marking of die casting parts. Some marking results are presented with the emphasis on the influence of the temperature, the cycle time and the shot blast post-treatment. The results show that a laser based technology is well suited to address all the requirements of the die casting industry.

INTRODUCTION

Traceability and therefore individualized marking of castings is becoming an increasing requirement both during the development process (where it helps to quickly identify flaws in the process and which process parameters need to be modified) as well as for series production of high integrity parts [1]. The obvious challenges in an industrial die casting environment are (a) fast cycle time (and part marking should certainly not be the bottleneck in this very capital intensive process), (b) marking on surfaces that are not perfectly flat, (c) parts that are typically still at elevated temperature when marked, and not perfectly clean but covered with remains of lubricants or dirt, and (d) the marking's ability to also withstand additional processing like heat treatment, shot blasting, washing, etching, conversion coating, etc.. Finally, the marking should remain safely on the part for its entire operational lifetime.

Traditionally part marking required clamping the parts in a precise position in order to obtain perfectly repetitive marking. When cycle time is key and process complexity and investment need to be minimized, then we would ideally like to have a marking system that will work perfectly even at a distance and with a certain tolerance (e.g. at 1 foot from the marker with a tolerance of an inch or two either way, so the part does not have to be clamped in any point but simply held by the extraction robot in front of the marker). This paper will present a review of the technologies available to identify die casting parts. It will present pros and cons of different technologies and for which utilization they are adapted. Result will then be presented including the effect of the temperature on the marking speed and the effect of post treatment such as shot blast.

REVIEW OF TECHNOLOGIES

LABELS AND NAMEPLATES

Labels and nameplates have been used for decades to identify parts. It consists of a label that is printed then glued to the surface. This technology is being replaced because it no longer meets the needs of industry since labels can

fall off either during subsequent process steps or while parts are in use, therefore jeopardizing readability. Furthermore, there is a cost associated with labour to apply the label as well as consumable material required. However, it is possible to make colored labels. An example is presented in Figure 1.



Figure 1: Printed label (sticker)

Labels are not well suited for die cast parts for many reasons. The uneven surface would make them difficult to apply and the high temperature of the parts would imply costly heat resistant labels.

PIN STAMPING AND DOT PEEN

Pin stamping / dot peen is another technology used to trace parts – and one that is already being applied in die casting. An example is presented in Figure 2 on an aluminum die casting surface.

The method is based on a pin that produces a deformation on the marking surface. There are single and multi-pin marking systems typically using a pneumatically driven metal pin to permanently indent the marking surface with a (simple) dot matrix/2D code and/or human readable codes, logos, graphics etc. Identifiers formed by this method are strong because the mark is engraved deep in the material. On the other hand, it is relatively slow and can even contribute to the scrap rate at the die caster as it is not always perfectly repetitive. This technology is suitable for applications that are not cycle time constrained, do not need any contrast in the marking and simply need permanent identification. This process can typically accommodate surface irregularities of up to 1/4”.



Figure 2: Pinstamp®/Dot peen marked die casting.

Again, this technology is used but not really well adapted to the die casting industry for several reasons: First, the cycle time is too long. Second the uneven shape of the part may interfere with the pin marker unit which has some footprint and needs to come in close contact with the part. Third, the part needs to be held in a precise position every

time which is more difficult to integrate into the process. Fourth, most high integrity die cast parts have precise surface quality requirements so that the surface alteration generated by the pin stamper can in certain cases even exceed the surface quality specification.

INKJET PRINTING

Ink is directly applied to the surface with the use of a gun-body and a microscope nozzle. An example of inkjet marking is shown in Figure 3 on an aluminum slab. Like the label and nameplates, it can create colored labels. The durability is dependant on the quality of the ink used and the environment. In addition, it can be affected by chemical aggression. It is useful if you need colored and heat-resistant labels.



Figure 3: Inkjet printing.

In die casting, this is not typically used because subsequent process steps, especially machining in the CNC machine or surface treatments like shot blasting or even washing/etching/conversion coating would too easily erase the marking or at least make it very difficult to read.

DIRECT MOLD MARKING



Figure 4: Direct mold marking and punch

This is commonly used in die casting but not for marking each single part with an individual code. It is used to mark longer term information like the alloy, production facility, customer logo, or the day and shift the casting was produced at. It can also give information about which tool / cavity was used. It is not used to mark parts with individual information about the precise process parameters etc. or to integrate a 2D barcode in the part surface.

LASER MARKING

Laser marking of metals is based on a surface modification that creates a contrast [2]. This phenomenon is used to mark code on metal parts. This technology is a fast and robust way for generating high contrast identifiers on metal parts [3]. It offers great reproducibility and does not use consumables. In Figure 5 we can see a laser marking on an aluminum die casting part.



Figure 5: Laser marked identifier on aluminum die casting alloy.

As a laser is capable of marking with great precision on uneven surfaces at high temperature, it seems to be a very good choice for direct part marking of die casting parts [4]. However, the fact that the black marking presents an elevation with respect to the bare aluminum surface makes it more sensitive to degradation to shot blasting post treatment [2].

STRATEGY

Laser technology seems to meet the criteria for identification of die casting parts. We want to study the effect of post marking treatment like shot blast on laser marking. Since the marking is above the level of the aluminum, a simple marking will be erased. In order to achieve a laser marking process that is capable of resisting shot blast treatment, we developed the concept illustrated in Figure 6. We know that the black is created by a rough surface where there are many peaks so the light is trapped. We also know that the black is raised compared to the rest of the surface. To protect the code, we want to mark it on a lower surface. To do this, we scan with the laser multiple times to remove some material prior to the black marking process itself. We think this will allow conserving the contrast after the shot blast treatment.

Our assumption was that the crater etched on each individual black cases of the 2D barcode will protect these surfaces against the shot blast process. Then, the necessary depth of the pre-etched crater depends on the dimension of the steel balls used for the post treatment process and on the size of each individual case of the 2D code. The larger the individual cases within the 2D code, the larger the balls must be.



Figure 6: Sketch of the idea behind the protected marking.

An important consideration with this approach is the possibility of having multiple black cells next to each other and oriented so that the craters merge together. This would have the effect of increasing the necessary dimension of the balls. To avoid that, it may be possible to use a code with more cells than needed for the message to be encoded. This would allow more possibilities in the placement of the cells.

EXPERIMENT

The results presented in this paper were obtained with a fiber laser operating at a 1.06 μm wavelength and delivering an average power of 100 W. The laser pulse duration is 100 ns at a frequency of 100 kHz. A data matrix was marked on the sample with various laser parameters. Before marking the code in black, a different number of passes was made in order to obtain different depths at the black case locations. The number of passes varied from 3 to 15. For the pre-etch passes, the test was done with a speed of 3 000 mm/s to 7 000 mm/s and with a line spacing of 0.025 mm, 0.05 mm, 0.1 mm and 0.125 mm. The black cases were all done with the same parameters, which are a speed of 400 mm/s and a line spacing of 0.125 mm. Moreover, codes of 6 mm x 6 mm and 4 mm x 4 mm were produced.

The shot blast experiments were done with two different ball sizes, S170 and S460, that have a diameter of 0.355 mm and 1 mm respectively. The test duration and the flow rate of shot can be controlled. However, the speed of the shot cannot be changed. We used a surface profiler Dektak 150 in order to measure the surface before and after treatment.

RESULTS

In Figure 7, we can see the profile of a surface before treatment. We can see that to pass 3 times with the laser does not seem to be enough, since the marking is higher than the aluminum level. Figure 8 presents a 2D profile of an individual black case, before and after the shot blast treatment with S170 ball size, where between 0 and 400 μm is the untreated aluminum surface. After 400 μm , we can see the profile of the laser mark. This shows how the surface is modified by the shot blast treatment, which is quite destructive for the black marking.

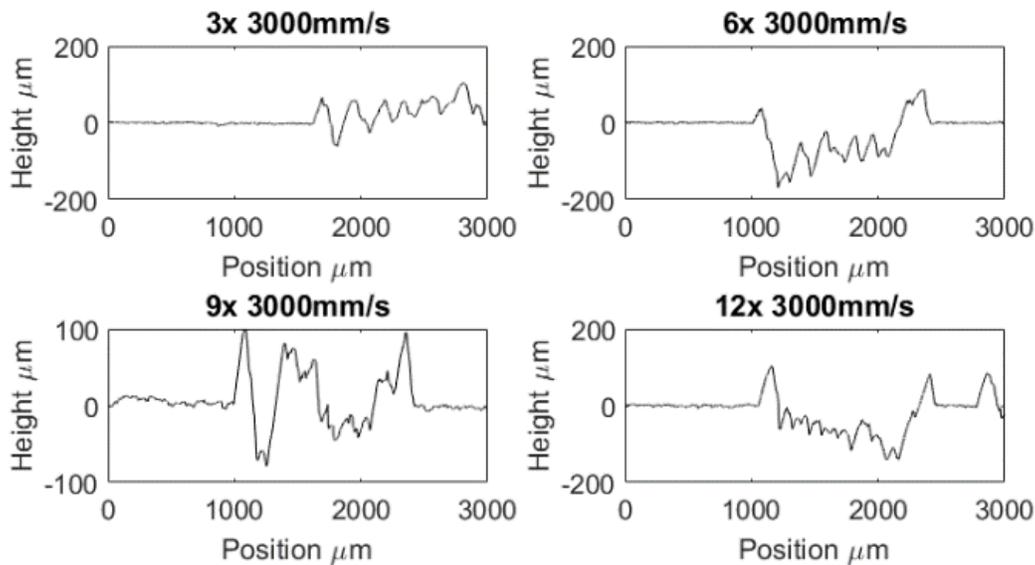


Figure 7: Surface profile of samples before treatment where the laser was passed multiple times before marking the black.

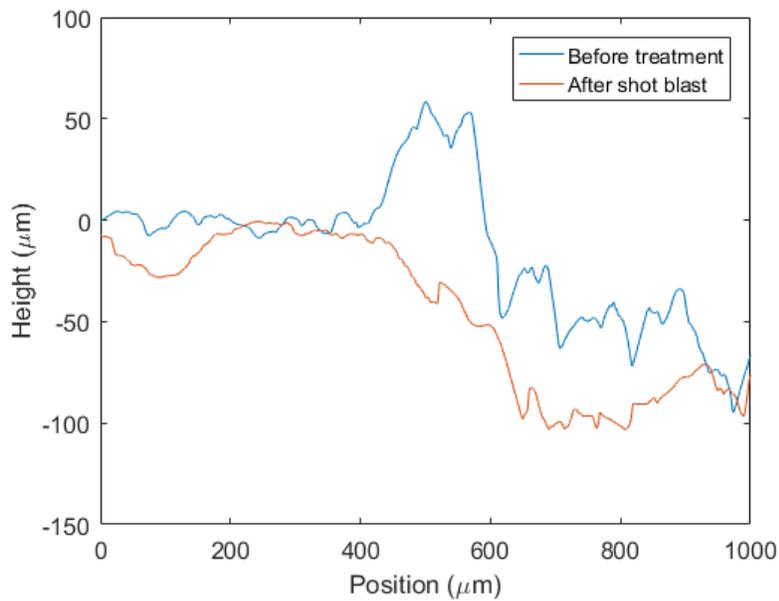


Figure 8: Surface profile measured with Dektak 150 of a marking before and after treatment with S170 balls.

Photographs of the marking are presented in Figure 8 and Figure 9. Left image of Figure 9 shows the marking before treatment and after shot blast with S170 balls (center) for 60 seconds.



Figure 9: Photo of a marking before treatment (left) and after shot blast with S170 balls (center).

In Figure 10, we can see two samples after 20 seconds shot blast treatment with the 1 mm diameter balls.

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Figure 10: Photo of 2 samples after 20 seconds shot blast with S460 balls.

After the process, we observe that some samples had been less affected by the shots than others. This led to some samples being very damaged and others almost intact. To be more precise, 15 were damaged and 10 were almost intact. The 10 almost intact were subjected to another treatment, this time with the S170 balls for only 20 seconds. A sample is presented in Figure 11. We have analysed the surface with a mapping in 3D done with the Dektak 150. It is presented in Figure 12.

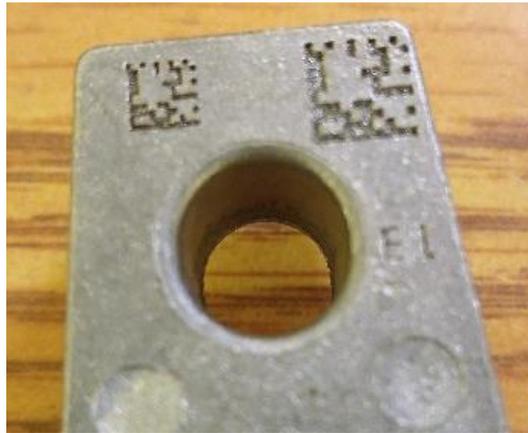


Figure 11: Photo of sample after a treatment of 20 seconds with S460 balls and another 20 seconds with S170 balls.

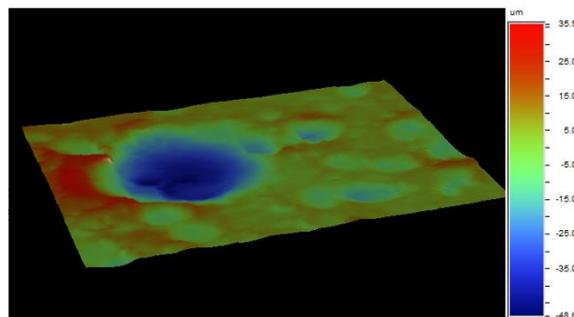


Figure 12: 3D profile of surface after being hit by S470 and S170 balls.

We see in this surface a hole that was created by the impact of the S460. This hole has a diameter of 0.42 mm and a depth of 48 μm . We can see around this other holes created by a smaller impact that are done by the S170 shot. These have a diameter of 0.24 mm and a depth of 20 μm .

DISCUSSION

Shot blast is a treatment that is used in the die casting industry to smooth the surface and eliminate sharp edges and burrs. Its operation is simple. Kinetic energy is given to the ball, which can have different parameters to achieve different surface finishes, by a rotating turbine wheel. The balls hit the metal part and change the surface property. We can see the difference in the profile of the surface in Figure 7. The peaks that are contributed to the black marking are visible in the blue curve but are completely erased by the shot blast process. Also, the edge left by the laser etching process at the periphery of the case is completely removed by the treatment.

The dimension of the balls used has a significant direct influence on the result. In fact, the speed of the ball cannot be changed, so a larger ball has more energy. This is what happens on the test with the S460 balls, like we can see in Figure 10. A hit by these balls was evaluated to create a hole 48 μm deep. The surface of the sample is filled with holes created by these impacts. Since the treatment is lowering the aluminum level, it is enough for the shot to touch the marking and erase it. After the treatment we see no marking as it has been completely destroyed in the treatment.

For the smaller balls, the S170, different observations can be made. In Figure 9, we see the surface before and after the treatment. The shot has less kinetic energy than with the S460 balls. The surface of the aluminum is smoother since the shot created holes half the depth of the previous larger shot. On the other hand, the data matrix is not readable. This is due to the lack of contrast. We can see the code, but the black is completely erased. The algorithm is not capable of reading the code. Since for this test, only the biggest code was done, the balls were too small and entered the cell of the code thus destroying the black marking inside.

Another factor to take into account is that the results depend on how much time the part was left in the process, but this is quite random. We can have parts in really good condition and others in bad condition even if they have undergone the same treatment as in Figure 10. The longer the treatment, the most likely the parts will be affected.

The location of the code on the part is also important. We have seen on some samples codes that have been completely erased on one side of the part, but are still there on the other side. If it is on the flat side, the code is more likely to be hit, since there is nothing to protect it. If it is beside a protrusion, it is less likely to be erased.

Smaller balls are also available. Since they have less energy, maybe this will not affect the marking. However, this process may be too soft and may not do the deburring job correctly.

CONCLUSION

Laser marking is the most suitable process to permanently mark die castings. It can achieve the desired cycle times, quality and repeatability. It can easily withstand almost all surface treatments typically applied on die castings. The main challenge remains shot blasting which was researched in depth. All the shot blasting parameters previously presented play a role in the resistance of the code. With adequate shot blasting conditions, it should be possible, in our opinion, to preserve a readable code after shot blast treatment on a die casting part. This also includes having a relatively small time of the process. It is also important to have balls that are not too big because we have seen that they are destroying the aluminum surface. The balls must be big enough to not reach the bottom of the cases in order to keep the black surface intact. The dimension of the code is also a determining parameter. We think that the smaller cases increase the chance of obtaining a readable code after the treatment. The laser process should be optimized in order to achieve a cell size of around 0.25 mm wide and approximately 100 μm deep. We think this would allow using the standard S170 balls and keeping the blackening at the bottom intact. Further tests will be done to demonstrate this and will be presented at the NADCA conference.

Thanks to its versatility, laser technology can adapt to multiple requirements, including fostering resistance to treatments that are very common in die casting industries. Laser marking meets many industrial needs, namely robustness, speed, ability to mark on uneven surfaces as well as at high temperature.

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