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Visual Testing of Castings Defects after Vibratory Machining

D. Bańkowski *, P. Młynarczyk
Department of Materials Science and Materials Technology, Kielce University of Technology,
ul. Tysiąclecia Państwa Polskiego 7, 25-314 Kielce, Poland
* Corresponding author: Email address: dbankowski@tu.kielce.pl

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Abstract

The paper presents an example of the application of vibratory machining for castings based on the results of visual testing. The purpose of the work is to popularize non-destructive testing and vibratory machining as finishing process, especially in the case of cast objects. Visual testing is one of the obligatory non-destructive tests used for castings and welded joints. The basic requirements concerning the dimensional accuracy and surface texture of cast components are not met if visible surface flaws are detected. The tested castings, which had characteristic traces of the casting process, were subjected to vibratory machining. The machining with loose abrasive media in vibrating containers is aimed at smoothing the surface and reducing or completely removing flashes. To complement the visual testing were also conducted research on the contact profilometer Taylor Hobson PGI 1200. Particular attention was focused on measuring the height of flashes and changes in the surface of smoothed details based on BNIF No. 359 touch-visual patterns. Based on the work, it can be concluded that vibratory machining allows for removal flashes and smoothing of the surface of aluminum alloy cast objects.

Keywords: Non-destructive testing, Visual testing, Vibratory machining, Surface treatment, Finished castings

1. Introduction

In accordance with PN-EN ISO 9001[1] foundry is one of the special production processes. These include processes that result may not be fully verified by inspection or testing of the product, and where the shortcomings of the process of manufacture may appear only during its operation. Various non-destructive testing methods can be used to detect and determine foundry incompatibilities [2-6]. The basic method, obligatory and commonly used is visual testing. However, they only allow the evaluation of external surfaces visible to the eye of the observer. If it is necessary to assess the surface of objects, penetration tests (PT) and magnetic-powder tests (MT) may be used, and the volumetric assessment may be based on the results of ultrasonic (UT) or X-ray (RT) tests. Visual tests due to the lack of the need for expensive and complicated equipment are often the only form of verification of the state of usability of castings with reasonable requirements [7]. The only condition for a properly conducted visual test is adequate lighting of the test surfaces and certified personnel [8] are required to assess and carry out the tests themselves.

It should be remembered that foundry is commonly used to produce elements of complex and complicated shapes with a specific chemical composition. Therefore, the authors decided to present examples of the use of vibratory machining of castings assessed by visual testing. In serial production, usually reusable casting molds (chills) are used for low, high pressure casting or centrifugal casting. Pressure casting has limitations when applied to non-ferrous alloys. Depending on the shape, molds are made of two or more parts. As a result, non-conformities such as flashes, mold shift, mismatch and etc. occur.

In the article [8] undertook actions aimed at reducing traces of the casting process. The focus was mainly on smoothing and cleaning the surface of flashes and surface oxide layers formed during storage. The tested alloy was the Zamak zinc foundry alloy. It should be noted that it is necessary to strive to minimize mass losses during finishing treatments, because too large allowances for finishing treatment translate into a higher unit cost of making the detail [9-15].

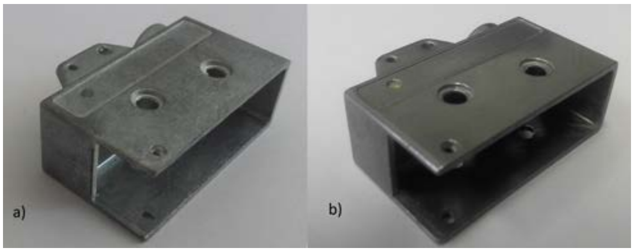

Fig. 1. View of surface faults on the tap casting used on the housing of micro switch [8]

As a result of the research [8], the relative mass loss for single-stage - deburring vibratory machining was obtained processes of 1.74 ‰ with the reduction of the arithmetic mean surface roughness - Sa from 3.39 µm to 0.85 µm. Whereas for two-stage deburring and polishing processes, a weight loss of 2.13 ‰ was obtained. There was also a decrease in the Sa parameter from 3.39 µm even to 0.55 µm. At the same time, it should be emphasized that the geometrical structure of the surface has been significantly smoothed and has been characterized by an isotropic structure after vibratory machining.

Paper [16] attempts were made to remove the outflows (flashes) of iron castings by high-pressure abrasive water jet (AWJ) treatment. As a result of the research, it was found that AWJ treatment allowed to reduce the height of flashes from about 1500 µm to 430 and even 160 µm depending on the cutting speed. The lower the cutting speed was, the better the surface quality was obtained, and this is related to the cutting process kinematics.

2. Casting defects

While geometries generated in CAD programs or technical drawings assume that the surfaces are smooth, the actual geometry of the edges of the workpieces is largely determined by production processes [17], the removal of which is in many cases time-consuming and costly. Material shaping by machining are the dominant ways of shaping objects, which very often require high quality of surface. At the same time, an important economic factor is that the whole process takes place with the least amount of work, machinery and thus time and costs [18-19]. Foundry is a processing which end products are rarely created, and most often they are semi-finished products that should be subjected to roughing and subsequent finishing. There are many disadvantages associated with the casting process which are necessary to remove for functional and aesthetic reasons.

An example may be flashes formed during pressure casting of light metal alloys or castings made of plastic and rubber objects [20]. Flashes should be removed for two important reasons, the first of which is the aesthetics of the details and the danger of injury from sharp edges protruding on the line of joining chill. The second important factor is the dimensional accuracy of the details made, the corresponding and, which is inevitably associated with it, matching parts that work together.

In accordance with PN-85 / H-83105 [21], flash should be defined as "a thin layer of metal occurring in places where parts of the mold or mold and cores do not adhere well to each other" shown in the Figure 2. You may also be tempted to state that the flash is synonymous with the definition of burr, defined in accordance with ISO 13715 [22]. Burr is the external material deviation from the nominal shape of the outer edge. Burrs are formed as a result of machining , but flashes are imperfections arising as a result of casting on a combination of foundry molds.

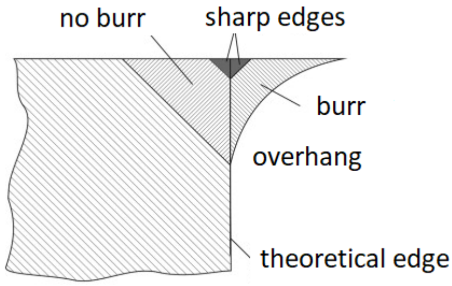

Fig. 2. Scheme of burr according ISO 13715 [22]

Schäfer [23] described a burr as a part of the workpiece arising on an edge or surface that lies outside the desired geometry.

An important aspect is the geometrical structure of the surface of objects made by casting. In the case of cast objects, incompatibilities of the raw surface may occur, such as: roughness, rat tails, porosity, drop, scabs, buckles, sticks or misrun [21]. The condition of the casting surface is determined by many factors, through the molding process used, the quality of the equipment used, molding or core mass and, above all, the properties of the casting alloy. Due to the diversity of these factors, the surfaces of castings do not show repeatability as in the case of mechanical machining. This makes it difficult to assess the roughness of the casting surface with mechanical, optical or electrical devices. For this reason, the surface in the case of castings can be assessed by visual examination [4] through visual-tactile patterns. According to PN-EN 1370 [24], two sets of patterns are commonly used:

– BNIF No. 359
– SCRATA ASTM 802

BNIF No. 359 standards, which consist of three series of reference samples constituting an exact replica of the condition of the casting surface. The samples are evaluated according to the standards from series 1, which includes 12 examples of raw surface or after finishing treatment (cleaning shot blasting), divided into two groups:

- 1 group - includes 4 examples of surfaces with increasing smoothness marked with symbols: 1 / 0S1`, 2 / 0S2, 3 / 0S1 and 4 / 0S1
- 2nd group - includes 8 examples of surfaces with increasing roughness and marked with symbols: 1S1, 2S1, 3S1, 4S1, 5S1, 6S1, 7S1 and 8S1.

The assessment of cast roughness is carried out for the surfaces indicated on the sample by comparing these surfaces with the visual-tactile standard of the appropriate series or category and level, located closest to the casting. The assessment of the dimensions of non-compliance (length, height or depth) is agreed primarily between the customer and the manufacturer [24, 25].

3. Research

The study undertakes research on smoothing the surface and removing the flashes from silumin alloy castings. It was decided to use light metal alloys due to shorter vibratory times. When machining steel parts, the necessary machining times must be extended accordingly [26-28]. Vibratory machining is one of the method for the mass finishing of complex parts [29-31].

Samples in the shape of pipes as in Figure 3 have a characteristic flash (Figure 4) in the place of joining two parts of the chill and a lot of surface incompatibilities, such as buckles, pinholes (sticks) or short run casting. Samples after the casting process, without any mechanical machining were subjected to vibratory machining in a Rollwasch SMD-R25 device. Polyester media of the PB 14 KR series were used in the applied treatment. The media has cone shapes with a diameter of 14 mm and a height of 14 mm. The machining was carried out with the addition of approx. 100 ml ME L100 A22/NF booster fluid to brighten and protect surfaces against further oxidation.

Fig. 3. Unfinished casting

Fig. 4. Example of flash to be removed

The machining was carried out with the filling of the working tumbler approx. 45% of the volume with abrasive media. The container vibration frequency was set to 2750 Hz. Samples before and after treatment were weighed to determine mass losses. Then the machined castings were subjected to visual assessment and measurements of surface roughness were made using BNIF No. 359 touch-visual standards and flash height using the contact profilometer Taylor Hobson PGI 1200.

4. Results and discussion

The aim of the experiments was to reduce the height of flashes by vibratory machining so that the details could pass the visual testing. Excessive height of flash causes rejection of castings. The work examines examples of details cast from aluminum alloy that did not pass the assessment of visual tests at the manufacturing stage. The change in flash height and surface condition based on BNIF No. 359 will be assessed.

For measuring the height of the flash, the contact method was used, where the measuring quill directly reflects the measured surface contour. Examples of flash profiles are provided in Figure 5 and 6. A Taylor Hobson PGI 1200 contact profiler was used to determine the form profile. In addition, the samples were weighed before and after vibratory machining. The loss of mass relative to a mass of the original specimen was calculated the relative mass loss (MMR) is expressed as parts per hundred. [8]. The results of measurements are summarized in Table 1.

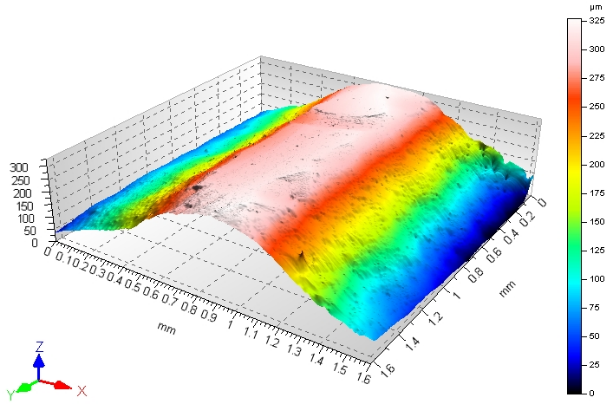

Fig. 5. Surface of flash profile

Table 1.
Results of flashes measurements

	max height, µm	Surface acc, BNIF standard no. 359.	Loss of mass MMR, ‰,
before vibratory machining			
	1129	6S1	0
after vibratory machining			
Time = 60 min	768	4S1	2.27
Time = 120 min	477	3S1	3.68
Time = 180 min	394	1S1	4.81

The conducted tests confirm the possibility of reducing the height of flashes in castings [9, 17]. The value of reducing depends mainly on the processing time. Increasing the machining time will reduce the flashes height. In the examined case, the flash height was reduced from 1129 µm to even 394 µm after 3 hours of vibratory machining. In contrast, treatment for 1 and 2 hours allowed reduction to 768 µm and 477 µm, respectively. Based on the results and literature data, it can be concluded that longer processing times would further reduce the flash height.

When assessing, from the point of view of visual testing, the most important parameter describing the flash is its height. In accordance with PN EN 1370, the criterion for acceptability of size discontinuity can be done by determining the level of focus or based on the agreement between the performer and the client. The flash height before vibratory machining was over 1.1 mm, which resulted in rejection of the prepared blank in accordance with the accepted requirements of the customer, who wanted the flash height to be less than 0.5 mm.

Performing finishing treatment using loose abrasive media in vibratory tumbler allowed to reduce the flash height. Through which the semi-finished product can pass a positive assessment of visual testing according to client requirements.

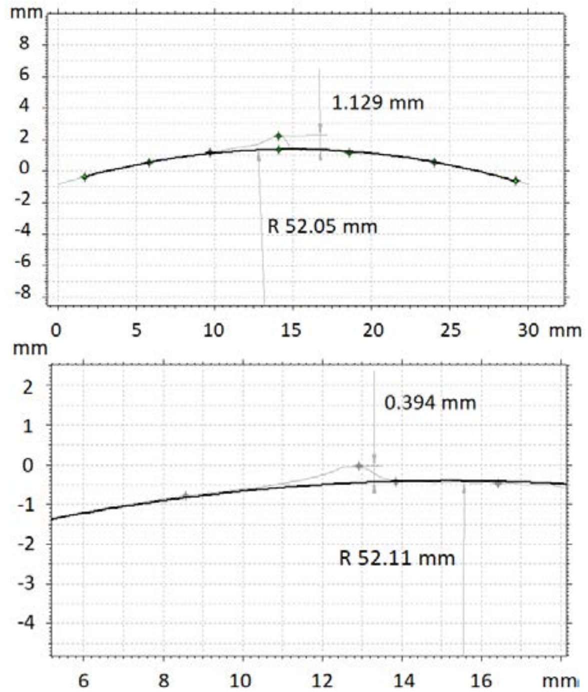

Fig. 6. Surface profile: a) before and b) after flash removal through vibratory machining

Surface evaluation using BNIF touch-visual patterns - No. 359 confirms the positive aspects of vibratory machining. Before machining, the surface could be identified with the 6S1 reference surface. Finishing for 3 hours results in even 1S1 surface according to BNIF no. 359 standards. However, vibratory machining for 1 hour represents 4S1 surfaces and after 2 hours of machining represents 3S1 surfaces.

Based on mass loss measurements, one can come to the same conclusions as when assessing the changes in the height of flashes. With the duration of vibratory machining, mass losses increase. The largest changes can be observed in the first hour of machining, the weight loss was about 2.3 ‰. Machining for 2 hours allowed a weight loss of about 3.7 ‰ and for 3 hours about 4.8‰.

5. Conclusions

Vibratory machining reduces the height of flashes resulting from casting. Thanks to this, the tested items can pass the visual tests in accordance with the imposed criterion.

Machining for 3 hours with PB 14-KT polyester fittings allows reducing the height of the flash from over 1.1 mm to below 0.4 mm

Visual testing in accordance with PN EN 1370 confirm the results of measurements. Observations using the human senses of sight and touch lead to the inference that the obtained edges after just 60 minutes of processing with loose media are slightly rounded. And longer times increase the rounding effect and reduce the height of the flashes.

Comparative tests with the BNIF No. 359 set of standards allow us to conclude that the surface of silumin immediately after casting decreases the surface roughness from the level of reference surface 6S1 to 1S1 after 3 hours of vibratory machining.

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