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Investment casting or powder metallurgy – the ecological aspect

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Abstract

The paper presents an analysis of manufacturing methods of material-saving products in relation to investment castings and sintered powder technology. Surface microgeometry, shape accuracy, performance parameters, manufacturing costs and energy consumption were taken into account to make the optimal choice. The analysis was conducted by comparing test results for sintered powder products based on Distaloy AB alloy that consists of 0.55% C, 1.5% Cu, 1.75% Ni and 0.5% Mo and investment castings made of high alloy cast steel and nodular cast iron. The analysis made it possible to choose the best technology, considering also the ecological aspect.

Keywords: Powder metallurgy, Investment casting, Surface microgeometry

1. Introduction

Investment castings manufactured by the lost pattern method are widely used in many fields of industry and owing to their merits, including high quality, reliability and high Weibull modulus value of 80, they are often used in aircraft and defense industries. The mass of the castings may range from a few grams to several hundreds kilograms as manipulators are applied more frequently in ceramic mould (CM) manufacturing process. No restrictions on metal casting material are present. Manufacturing castings from materials intended for plastic working is not a problem either. Moreover, there are no restrictions on repetitive manufacturing.

Novel techniques where models made of polystyrene derivatives are applied make it possible to manufacture inexpensive castings even for individual production.

Owing to the producibility there are no major restrictions on transition from thin to thick walls. Minimum wall thickness is approx. 0.5 mm, minimum wall-to-wall fillet radii being around 0.2 to 0.5 mm.

In manufacturing practice attempts to substitute investment castings with products made of sintered powders are often observed. Sintered powder products, when compared to investment castings, feature considerable technological restraints [2], e.g. the minimum wall-to-wall transition radius r_{min} should preferably exceed 0.25 mm and minimum wall thickness should be of 1 to 2 mm. Moreover, the thin wall-thick wall transitions may not be abrupt. For specialty materials with optimal chemical and grain compositions the R_m strength of sintered powder products can exceed 900 MPa. The products made of sintered powders are not able to transfer substantial dynamic loads (e.g. due to their impact strength). The powders may be pressed twice; this results in a density of 95 percent of the solid material, at the pressure of 1000 MPa. Their surface, if sized, may be very smooth, with $Ra \approx 0.63\mu m$.

Generally [2] powder metallurgy provides products with good wear resistance, suitable magnetic properties, considerable thermal resistance etc.

2. Authors' own tests

A part of tests was performed on actual objects: castings – Fig. 1 through 3, an article made of sintered powders – Fig. 4. The castings shown in figures feature varying wall thickness, and mainly the aircraft impeller where thin-wall blades approx. 1 mm thick evolve into thick-wall impeller body with average thickness of around 20 mm – Fig. 1. The sintered powder product was manufactured by a Polish company.

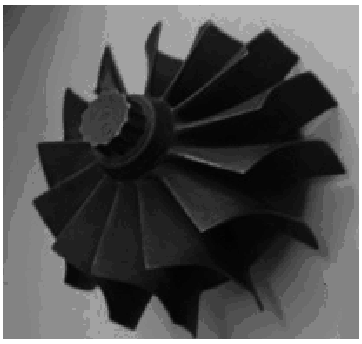

Fig.1. Aircraft impeller – high-alloy cast steel

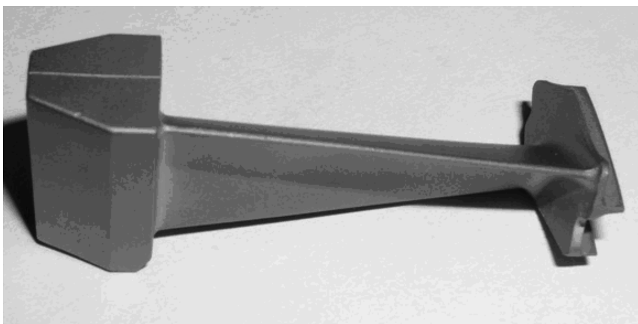

Fig.2. Aircraft blade – high-alloy cast steel. Thin wall casting in the middle part, thickness from 1.0 to 1.5 mm

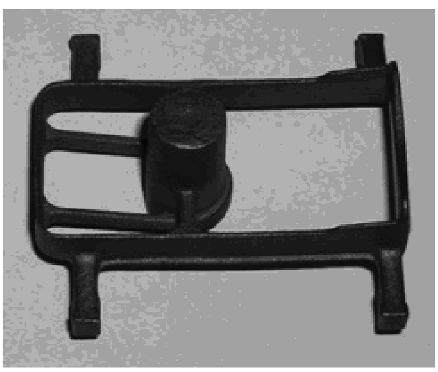

Fig.3. Frame with shank – alloy cast steel

Fig.4. Indented sleeve – product made of sintered powders, Distaloy AB

2.1. Methodology of testing

Surface condition of castings and sintered powder sleeves has been examined (expressed in µm) as well as the condition of wall-to-wall sleeve transition (Fig. 4). The tests were performed with Taylor Hobson or Perthen Mahr profilometers and stereoscopic (Olympus) and toolroom microscopes. The products' shape accuracy was tested on the basis of the wall-to-wall transition accuracy expressed by means of r radius [3]. For castings the value of r ranges from 0.17 (Fe alloys) to 0.23 (Al alloys), at the same time it is worth noting that at least 60 to 70% of the r value is dependant on ceramic mould r_f radius. According to the tests [4], it is smaller than 0.2 mm.

2.2. Test results

Fig. 6 shows the results of surface microgeometry examination as well as an assessment of the profile bearing length ratio tp_{50} for R_{max} = 50%. The resulting average value of R_a (for the sleeve made of sintered powders – Fig. 4) taken from a number of measurements was approx. 1.96 µm and tp_{50} = 89%, while for the casting under test (Fig. 2) R_a = 1.53 µm and tp_{50} = 84%.

Also, the walls joint of the sintered powder sleeve was examined at 8 points. Small ø 26 external shape defects (Fig. 5) have been noticed on Taylor Hobson profilogram, averagely of several micrometers in depth and about 110 µm in length.

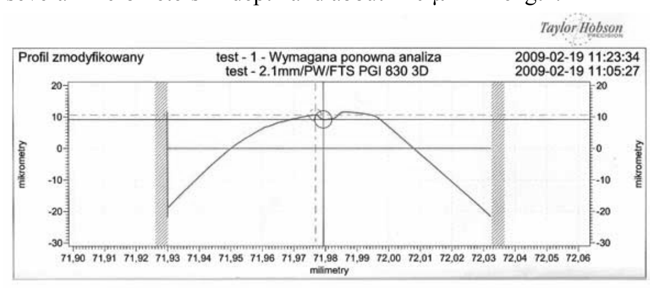

Fig.5. Wall joint of the sintered powder sleeve (external shape ø26)

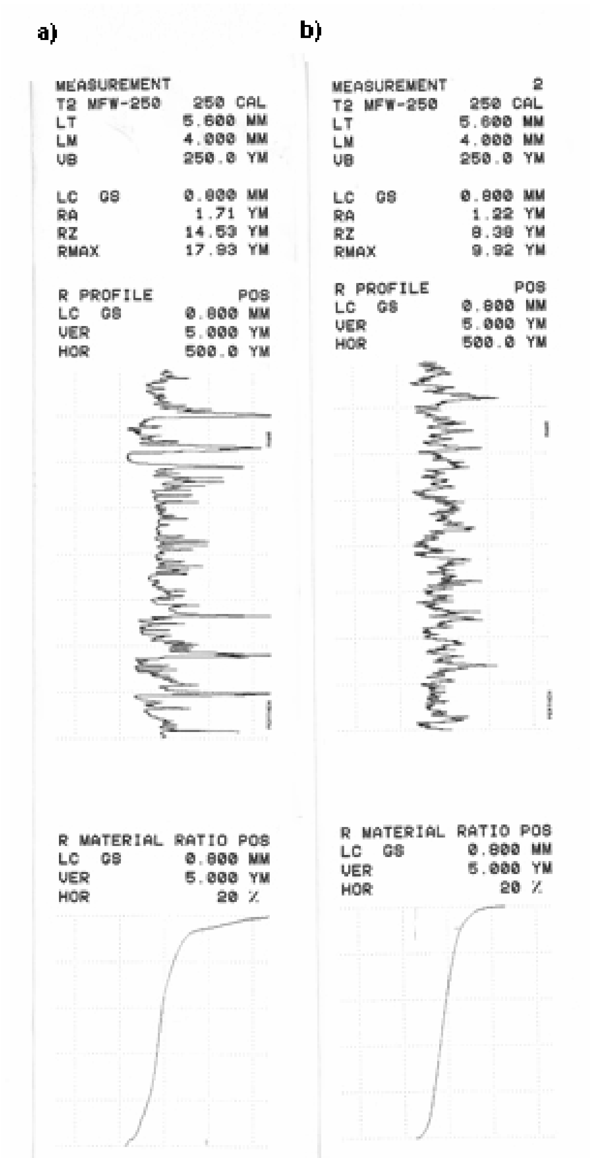

Fig. 6. Exemplary profilogram with the bearing ratio tp_{50} a) for sintered powder sleeve , b) for blade casting

The observed defects were also recorded by means of a stereoscopic microscope manufactured by the Japanese company Olympus. Fig. 7 shows inside diameter defects of ø 8 sleeve, while Fig. 8 and Fig. 9 the diameter of wall joints of external shape ø 26.

Also, in a dozen or so points, the defects were measured by means of a toolroom microscope. The defects were between ten and twenty μm in depth and from 110 μm to 480 μm in length.

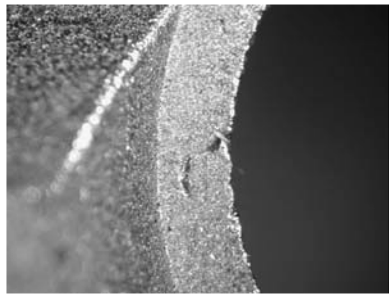

Fig. 7. Internal shape fragment of the sintered powder sleeve (ø 8)

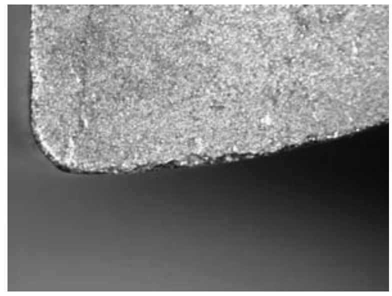

Fig. 8. Wall joint of the sintered powder sleeve (external shape ø26)

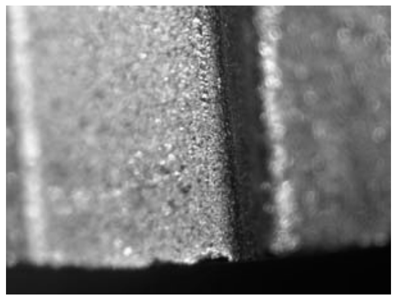

Fig. 9. Wall joint of the sintered powder sleeve

3. Test results analysis

When assessing the results of casting and sintered powder sleeve surfaces examination it can bee seen that the roughness of the casting and sleeve surfaces does not differ substantially (the difference R_a is around 0.4 μm); similarly, the results for the bearing ratio described with tp_{50} (for 50% R_{max}) differ minimally (for casting tp_{50} = 84% and for the sintered powder sleeve tp_{50} = 89%).

On the basis of practice and tests it has been found that applying decorative coatings – e.g. nickel layer – on articles made of sintered powders poses many problems. There are visible “black dots” on their surface, corresponding to the high peaks (profilogram Fig. 6a).

Generally, it may be stated that for the numerous product lots exceeding 1000 pieces it is worth using sintered powder articles instead of castings as the former are considerably less expensive, on average by 30%, and moreover the qualities of castings and sintered powder products do not differ considerably. On the other hand, Al alloy and titanium castings are used much more often than powders.

Additionally, small complex shape castings lots up to 100 pieces are irreplaceable because of costs and, first of all, the quality requirements.

Sintered powders (Fe alloys) owing to their manufacturing ecology have the smallest energy consumption at around 28 MJ/kg, compared to 45 ÷ 60 MJ/kg in the case of castings (Fe alloys) [1]. Taking account of the fact that in the Polish power industry 1kWh = 9MJ (Main Statistic Office (GUS) figures) [7] and that 1kWh causes the emission of 800 g CO_2 to the atmosphere, it is necessary to consider this aspect when choosing the technology.

4. Conclusions

1. Complex shape and small lots investment castings (Fe alloys) cannot be substituted by products made of sintered powders.
2. For larger manufacturing lots and modest level of difficulty the products made of sintered powders may replace castings, owing to lower costs and less energy consuming manufacturing process.
3. In special applications that require better wearability and corrosion resistance it is often needed to replace castings with powders owing to a longer life of the latter.
4. Recycling is much easier for investment castings manufacturing process that that of sintered powders.

Acknowledgements

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