ARCHIVES
of
FOUNDRY ENGINEERING
Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 14
Special Issue
1/2014
67-72
14/1

Influence of Wax Pattern Surface Quality on Prime Coat of Ceramic Mold

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Received 17.03.2014; accepted in revised form 31.03.2014

Abstract

The authors have made an attempt to enrich the knowledge about the influence of wax pattern washing process and its influence on the quality of the shell prime coat. Two types of wax were investigated: A7Fr/60 and KC2690. A7Fr60 is used for pattern fabrication, while KC2690 is typical sprue wax. The goal of work was to establish wax solubility accuracy in Trisol 60 Plus and Houghto Clean 530 versus time and influence of dipping time to wax samples surface quality. Additionally, after exposition of wax samples, their surface morphology was characterized with the use of laser profilometry and surface roughness measurement. The quality of formed prime coat was established by X-ray tomography. The measurement of wetting angle of the wax by binder was conducted. The results have shown that the main factor which influences the quality of the prime coat is surface wettability rather than wax surface roughness.

Key words: Quality management of castings, Technological properties of wax pattern, Ceramic shell mold, Roughness, X-ray tomography

1. Introduction

Literature about the waxes used in investment casting is relatively low and the main attention is focused on the mechanical and thermal properties of the wax. Much of the available literature is focused on the dimensional accuracy of the patterns [1, 2]. Most of the effort is put on the relationship between the dimensional accuracy of wax pattern and its influence on obtained casting dimensional accuracy [3, 4]. Few studies concerning the influence of removal of the wax pattern from the steel dies and its influence on the roughness of the pattern can be found [5]. Despite the fact that wax materials are used in numerous industrial applications, only a few publications on the surface morphology of wax, such as [6] can be found. There is a lack of information concerning the impact of technological processes on the surface of the wax pattern and its impact on the quality of the ceramic shell mold, especially face coat.

Therefore, authors of this study attempted to characterize the surface of the wax models and reagents degreasing surface models in industrial environments. The manufacturing process of wax pattern by injection into steel dies requires using of the antiadhesion composition which prevents pattern deformation during removal from the matrix. It is necessary to carry out the wax surface cleaning process before the building of the ceramic shell mold to remove the oily residues. Wax surface preparation for the building of the prime coat is an important stage in the investment casting process. If the wax is not properly degreased, slurry is unable to adhere to the wax surface and the final casting surface can have defects like cracks, run - outs or inclusions. Changes introduced to the was pattern surface during degreasing process were investigated in presented paper.

2. Experimental

Experiments were conducted with the use of common industrial wax and chemicals. Two types of pattern wax were used: A7FR/60 and KC2690. A7FR/60 is used for the pattern of responsible parts of turbofan engines and it contain the filler, while KC2690 is used for production of gating system pattern. As the antiadhesion composition, Blaysil 200 was used. Two chemical reagent to remove the antiadhesion layer form the wax pattern surface were used: Trisol 60 Plus and Houghto Clean 530. Trisol 60 Plus is a mixture of high purity, very low aromatic hydrocarbons combined with biodegradable emulsifiers and surfactants. Houghto Clean 530 light distillates of paraffin. Each producer recommend the exact procedure of washing wax pattern, in case of Trisol 60 Plus the washing procedure has 4 steps: first is immersion of washed wax detail in the chemical reagent for 5 seconds, then the residues are rinsed in water. Houghto Clean 530 is self -drying reagent which requires only 5s immersion in the chemical reagent and the washed detail is left for self-drying.

The wax pattern were prepared by injection of melt wax into the steel die.

The solubility of wax in the washing chemical reagents was determined by immersion of wax samples with known weight and controlling of the mass los with the passing time. The experiment was conducted in room temperature.

The laser profilometry observation of the wax samples surfaces (0.5 mm x 0.5 mm) were conducted to recognize the influence of the washing chemical reagent for the surface quality and possible surface development. The used equipment was laser optical profilometer Wyko NT9300. Two times of sample immersion was applied: 5 second and 1 hour. During the observation the surface roughness (R_a) was determined.

The quality of the inner layer of shell mold was investigated during X-ray tomography observations. The wax samples were prepared by washing in the chemical reagents for 5s and 1 hour, and the prime coat was formed on the dried sample surface.

The measurement of the wetting angle of the sample surface by colloidal silica binder was conducted. The wax was degreased by Trisol 60 Plus or Houghto Clean 530 for 5, 30 and 60 s.

The full ceramic shell mold was built on the wax pattern which were washed for 5s in Trisol 60 Plus or Houghto Clean 530. The surface roughness of inner layer after shell dewaxing was measured with the use of optical profilometer.

3. Results

The results of weight loss measurement of wax samples immersed in chemical washing reagents are shown in figure 1. During first 50 minutes of samples immersion no differences of the accuracy of samples dissolution was observed. The differences of dissolution accuracy were visible after 50 min of immersion. KC2690 has almost completely dissolved after 100 min of immersion. The loss of sample A7FR/60 wax immersed in Trisol 60 Plus was smaller than the sample immersed in Houghto Clean 530. The observed differences in dissolution accuracy can be connected to the presence of filler in A7FR/60 wax, which moderate the process. It is expected that the short times of sample immersion should not have influence on the wax pattern dimension accuracy.

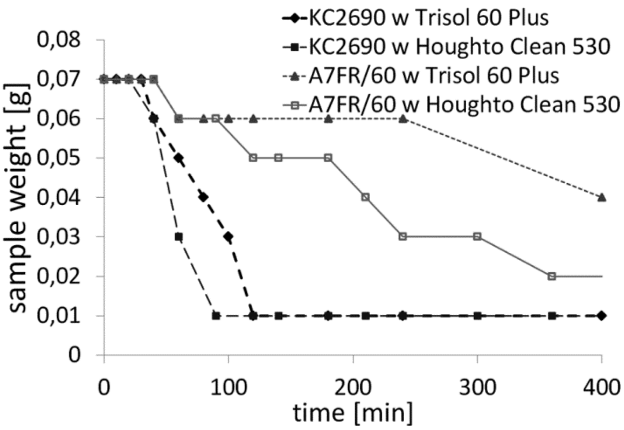

Figure 1. Accuracy of wax dissolution in chemicals for pattern wash: Trisol 60 Plus or Houghto Clean 530

The laser profilometry observations of wax pattern surface reveals visible changes after immersion in the chemical reagent. In figure 2a the initial sample surface of AFFR/60, after being taken out form the steel matrix is shown. The sample surface which was immersed for 5 seconds and 1 hour are shown on figure 2B and 2C respectively. Surface of A7FR/60 after immersion for 5 s and 1h in Houghto Clean 530 is shown in figures 2D and 2E. What can be easily recognized are cracks on sample immersed for 1h in Trisol 60 Plus.

Observation of initial (before degreasing) wax pattern surface of KC2690 is shown on figure 3A. The sample surface which was immersed for 5 seconds and 1 hour are shown on figure 3B and 3C respectively. Surface of KC2690 after immersion for 5s and 1h in Houghto Clean 530 is shown on figures 3D and 3E. No cracks or significant surface changes were observed after immersion of sample in the chemical reagents.

The measurement of surface roughness revealed differences of R_a value in dependence of type of the wax, time of immersion and the chemical reagent influence. Immersion of KC2690 for short time (5 s) has insignificant influence and average value of R_a is 1 μm. The increase of surface roughness is observed for KC2690 samples immersed for 1 h. For Houghto Clean 530 the R_a is equal to 1.7 μm, while for Trisol 60 Plus immersion R_a is equal to 3.3 μm.

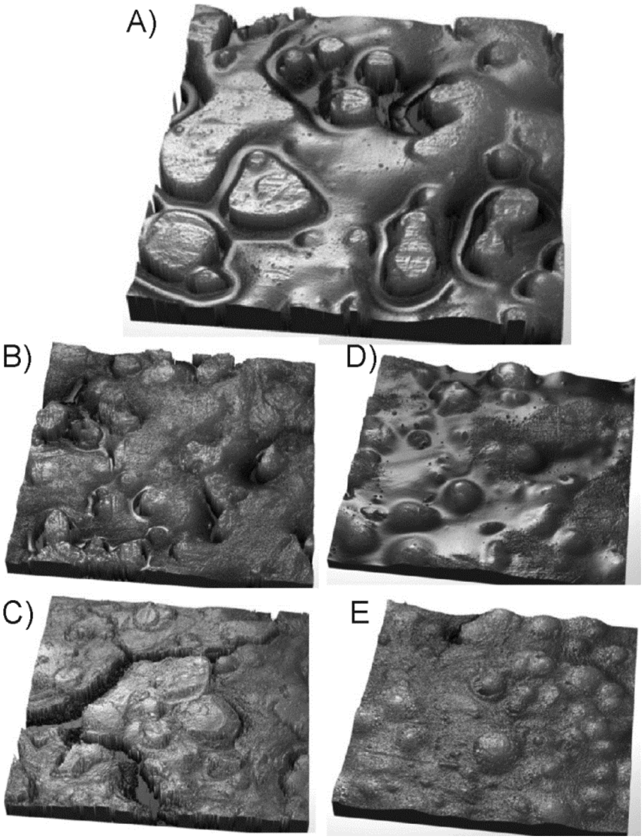

Figure 2. Images of A7FR/60 pattern wax initial surface (a), after washing for 5s in Trisol 60 Plus (b), 1h in Trisol 60 Plus (c), 5s in Houghto Clean 530 (d) 1h in Houghto Clean 530 (e)

Immersion of A7FR/60 samples for 5 s causes decrease of surface roughness. After 5 s immersion in Trisol 60 Plus the R_a decreases from 3.9 to 3.1 µm. For the sample immersed in Houghto Clean 530 the R_a value dropped from 3.9 to 1.1 µm. For the samples immersed for 1 hour the substantial increase of surface roughness was observed, for sample immersed in Trisol 60 Plus the R_a value reached 7.9 µm and 5.4 for sample immersed in Houghto Clean 530. The higher value of R_a for sample immersed in Trisol 60 Plus can be a result of cracks appearance.

The measurement of wetting angle conducted on the sample dewaxed for 5, 30 or 60 s (figure 6) have shown that the wettability increases with the increased time of immersion for both of the investigated chemicals. The wetting angle obtained for samples washed in Houghto Clean 530 has been lower in comparison to wetting angle obtained for sample degreased in Trisol 60 Plus.

The X-ray tomography of the prime coat of ceramic shell mold revealed the low quality of layer formed on samples immersed for long time (1 hour). Tomography results are shown on figures 7 and 8. On figure 7A a prime coat formed on A7FR/60 wax which was degreased for 5 s in Trisol 60 Plus is shown and on figure 7C for wax degreased for 5 s in Houghto Clean 530. No defects, like cracks or wax sample deformation are visible for both of short-time-immersed samples. On figure 7B and 7D the A7FR/60 sample washed for 1hour in Trisol 60 Plus and Houghto Clean 530 respectively, are shown. Inner layer, like cracks, and edges deformation are well visible. Also a penetration of fluid ceramic mas is observed. On figure 8 the observations on inner layer quality obtained on KC2690 wax are shown. Regardless the time of immersion or type of the chemical reagents no layer defects are observed. Produced layer is continuous and no layer penetration inside the wax pattern was observed.

The observations of prime coat surface after wax burnt out are shown on figure 9. The measured surface roughness on inner surface of ceramic shell mold was 2,07 µm for mold build on A7FR/60 washed in Trisol 60 Plus and 5,74 µm for sample washed in Houghto Clean 530.

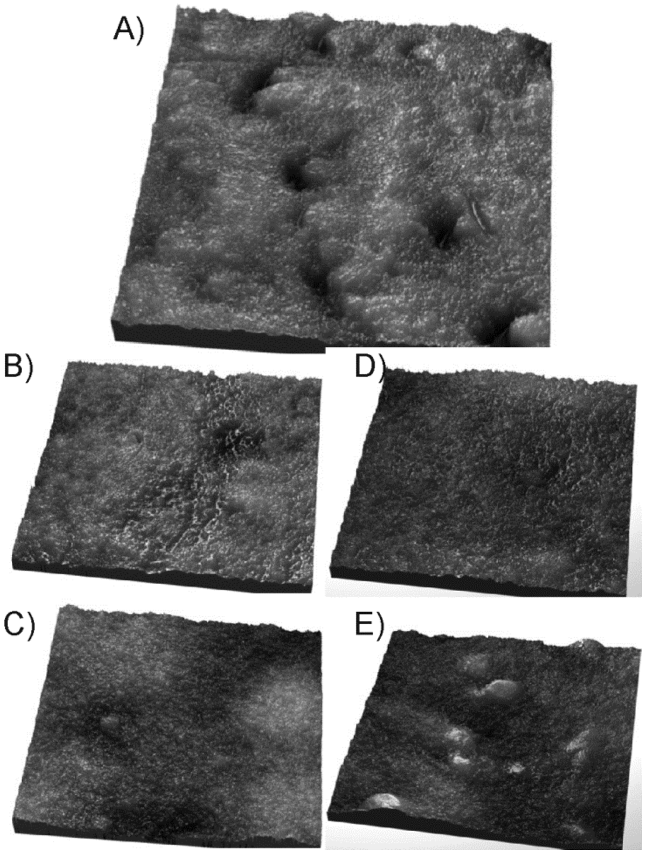

Figure 3. Images of KC2690 pattern wax initial surface (a), after washing for 5s in Trisol 60 Plus (b), 1h in Trisol 60 Plus (c), 5s in Houghto Clean 530 (d) 1h in Houghto Clean 530 (e)

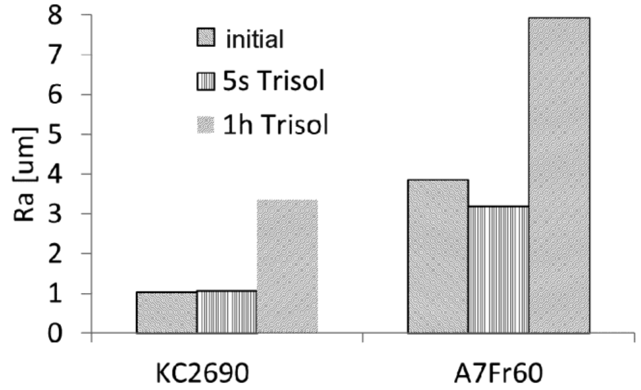

Figure 4. Sample roughness of wax pattern washed in Trisol 60 Plus for 5 s or 1 h

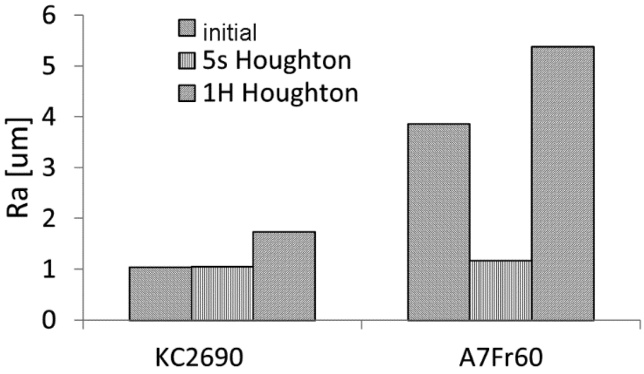

Figure 5. Sample roughness of wax pattern washed in Houghto Clean 530 for 5 s or 1 h

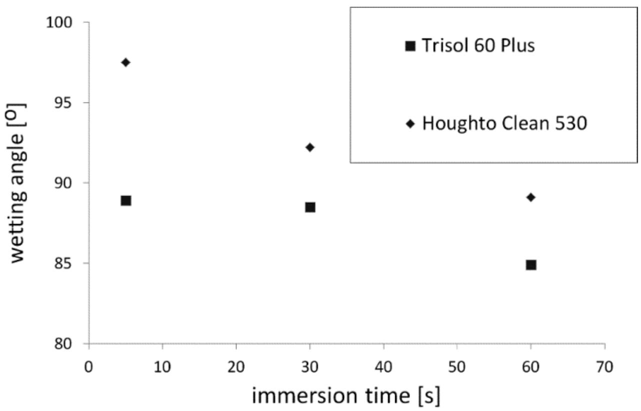

Figure 6. Wetting angle of drop of binder on the wax sample immersed in the Trisol 60 Plus or Houghto Clean 530 for 5, 30 or 60 s

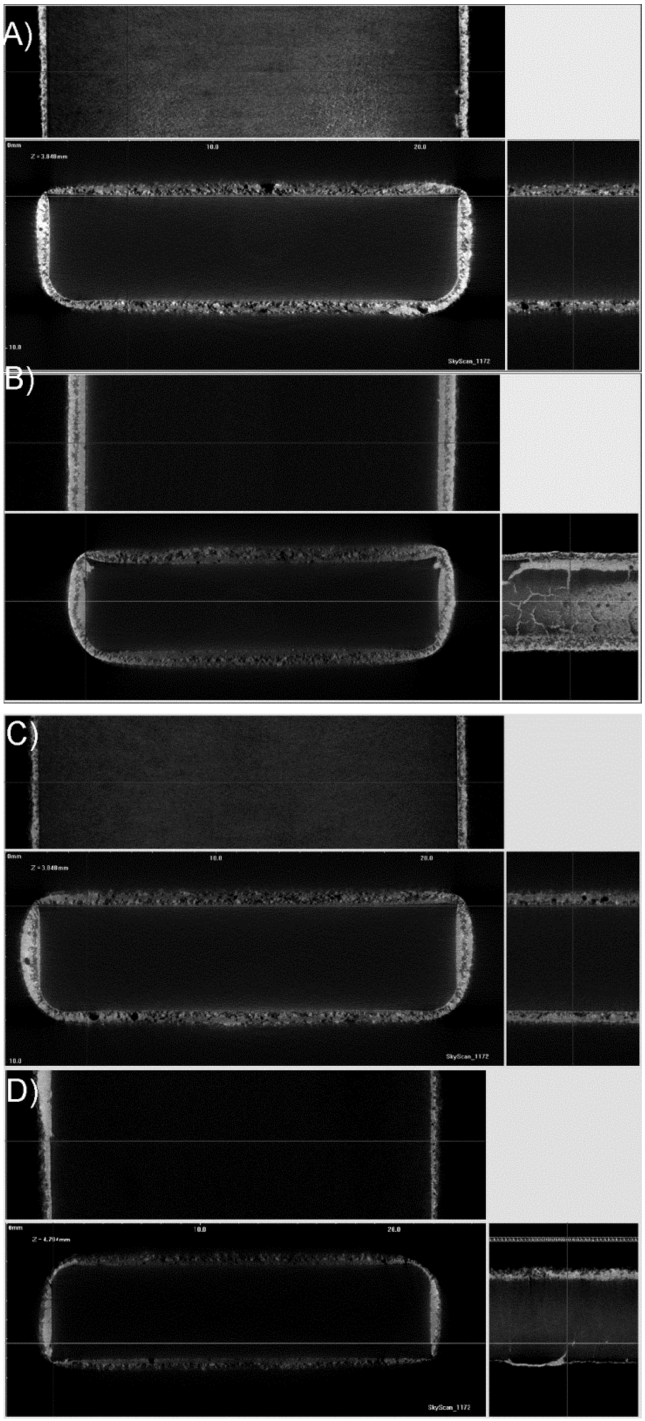

Figure 7. Tomography images of ceramic inner layer formed on A7FR/60 pattern wax after washing for 5 s in Trisol 60 Plus (a), 1h in Trisol 60 Plus (b), 5s in Houghto Clean 530 (c) 1h in Houghto Clean 530 (d)

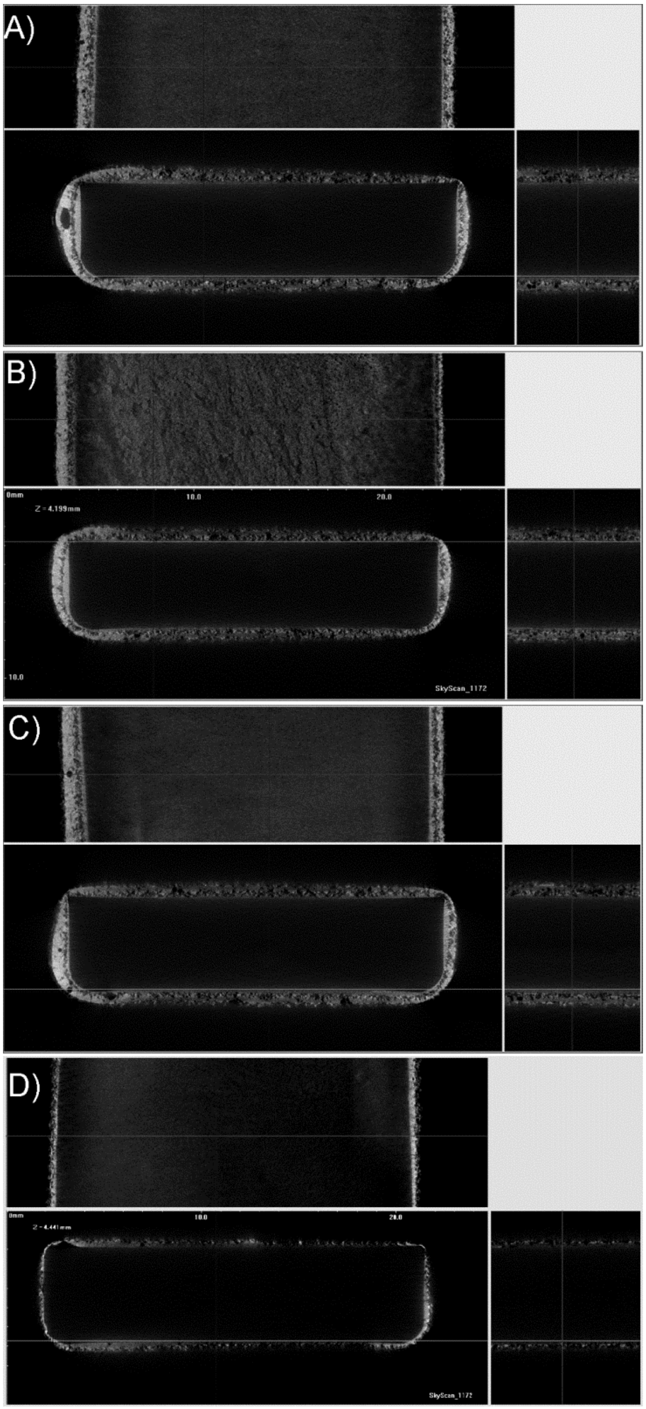

Figure 8. Tomography images of ceramic inner layer formed on KC2690 pattern wax after washing for 5s in Trisol 60 Plus (a), 1h in Trisol 60 Plus (b), 5 s in Houghto Clean 530 (c) 1h in Houghto Clean 530 (d)

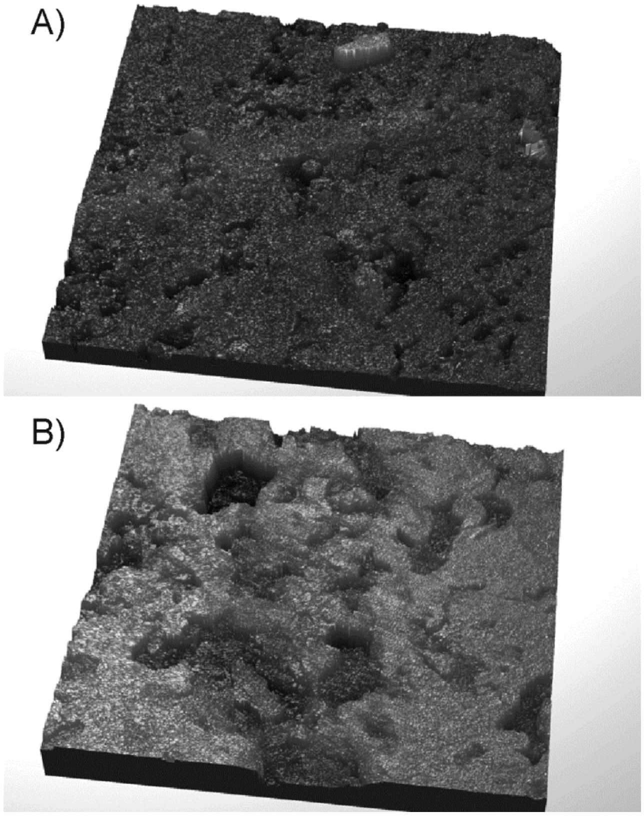

Figure 9. Prime coat morphology of shell mold after burnt out. Surface of wax dewaxed in Trisol 60 Plus (A) and Houghto Clean 530 (B)

3. Discussion

The significant differences of wax accuracy of dissolving in degreasing chemical reagents has probably been the effects of presence of filler in A7FR/60 wax, while the KC2690 wax is paraffin wax without phases other than hydrocarbons. During dissolution of A7Fr/60 wax the filler particles can slow the dissolution of hydrocarbon phases as the contact surface of hydrocarbon phase with chemical agent is decreased by presence of filler particles on the surface. This can be confirmed by observation of surface morphology. Sample of A7FR/60 wax surface is more developed than the surface of KC2690. On A7FR/60 surface the hillocks are present which is result of filler particles presence.

The surface roughness changes for KC2690 wax after degreasing are relatively low which makes the surface roughness insensitive for the degreasing time. However the dissolution accuracy should be considered according the sprue pattern accuracy.

The A7Fr/60 surface roughness should be considered in context of appearing wax model cracks. The slow dissolution of wax in degreasing chemical should not have influence on pattern dimensional accuracy. However the recognition of filled wax dissolution phenomena should be specifically recognized in future.

Comparison of surface roughness on inner surface of ceramic shell mold proofed that the wax surface parameters are not the proper parameter to predict the quality of the ceramic shell mold. Presented results have shown that the main area of interest should be focused on the parameters of the prime coat and not the surface roughness of wax. The size of the ceramic particles in the binder fluid mass is average size 12 µm. This makes the surface roughness of the wax pattern do not predetermination the ceramic shell mold quality.

Wax surface wettability by the binder ceramic mass and its dependence from the used type of chemical reagent have shown that the slightly lower wetting angle was obtained for sample washed in Houghto Clean 530.

5. Conclusion

Obtained results have shown that the chemical reagents used for wax pattern surface degreasing have significant impact on the wax sample surface quality. More experiments should be conducted to specify the optimal time of sample degreasing which allows to obtain the lowest wetting angle of the binder.

No dependence of the prime coat roughness from the wax surface roughness were determined.

The quality of the ceramic shell mold should be discussed mainly in field of defects appearing in final cast rather than in direct dependence from was pattern surface parameters.

Acknowledgements

The research has been carried out under the INODLEW program "Optymalizacja technologii wielowarstwowej ceramicznej formy odlewniczej do precyzyjnego odlewania krytycznych części turbin silników lotniczych" (Optimization of technology for production of multilayered ceramic shell mold for precision casting of critical parts of gas turbines for aircraft industry) funded by the polish National Centre for Research and Development under the Agreement No PBS1/B5/6/2012.

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