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Industrial Tests on "Formowax" Pattern Wax Under Investment Foundry Conditions

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Abstract

Soft pattern waxes used in investment castings are a mixture of paraffin, stearin and minor amounts of ceresin, polyethylene wax and other natural and synthetic waxes. Nowadays foundries conduct the process of pattern wax formulating on their own. However, instability of the ingredients parameters can have a negative impact on the technological characteristics of the obtained waxes. The paper presents the results of tests on applying a ready-made "FORMOWAX" pattern wax developed by Polwax Sp. z o.o. Application of the reference wax was tested for standard patterns made in Specodlew investment foundry.

Keywords: Innovative materials and founding technologies, Investment casting, Pattern waxes

1. Introduction

Making high-quality investment castings is based on using wax pattern waxes manufactured by specialised companies. An investment casting allows for making investment casts from different alloys with the surface quality corresponding to grade N6 to N10 according to ISO – 2632/III and dimensional deviations between CT4 and CT6 according to ISO 8062. Pattern waxes in industrial practice are suited to technical requirements of customers buying the castings and to the equipment of pattern foundry modelling workshop.

The majority of investment foundries use soft pattern waxes with paraffin and stearin as the main ingredients [1]. An addition of synthetic waxes (polyethylene waxes obtained by waste polyethylene depolymerisation [2]) and/or natural waxes (beeswax, Montana wax) allows for obtaining relevant functional characteristics. Producers are forced to purchase the correct ingredients and prepare pattern materials within their own capabilities. Parameters of the available raw materials may be unstable, which may result in unstable technological parameters of the produced mixes.

Polwax Sp. z o.o., as a manufacturer of paraffin and petroleum-based waxes, developed a ready-made soft pattern wax called FORMOWAX mainly based on their own ingredients. FORMOWAX was developed based on the results of tests described in separate publications [3-4]. The method of FORMOWAX formation is subject to patent No. P-394360. The paper describes tests conducted under industrial conditions of Specodlew Sp. z o.o. investment foundry in Krakow.

2. Test method

FORMOWAX and a pattern wax formulated at Specodlew foundry were used for the tests. Carefully selected ingredients and observance of technical and production parameters makes the ready FORMOWAX highly stable and with reproducible physical and chemical parameters. The requirements for the finished product included in Technical Data Sheet are as follows:

Table 1.
Requirements for FORMOWAX

Parameter	Unit	Parameter value	Standard
Congealing point	^{o}C	60 – 75	PN 77/C-04018
Dropping point	^{o}C	62 - 77	PN 55/C-04020
Kinematic viscosity at 100^{o}C	mm^2/s	6.0 – 8.5	PN-EN ISO 3104
Penetration at 25^{o}C	1/10 mm	8 – 15	PN-82/C-04161
Ash residue	%	max. 0.015	PN-EN ISO 6245

A range of samples consisting of ten types of casting parts, covering different dimensions i.e. wall thickness, holes or threads were selected for the tests. Wax patterns were prepared from fresh wax and without its refreshment in three processing cycles. A total of 800 patterns from each mix and 1600 castings were made during the tests.

The course of the test was compliant with the technological process of making castings with an investment casting under investment foundry conditions and covered the following stages:

- preparing appropriate quantities of the tested pattern waxes - the mix used at Specodlew foundry, made directly from the ingredients, was the first wax whereas FORMOWAX was the second,
- wax melting in an electrical bath intended for it, with a possibility of temperature adjustment within 60÷100^{o}C,
- wax homogenisation in an aeration device,
- preparing the pattern wax in a modelling table bath with a possible temperature adjustment, where the pattern wax melting temperature should be within the range between 60^{o}C and 100^{o}C, softening point is usually lower by 25^{o}C÷30^{o}C, (temperatures of the tested pattern waxes were maintained at 50^{o}C),
- introducing the pattern wax into the matrix under pressure. Table 1 presents temperatures of pattern waxes observed at making patterns from fresh wax and in each processing cycle,

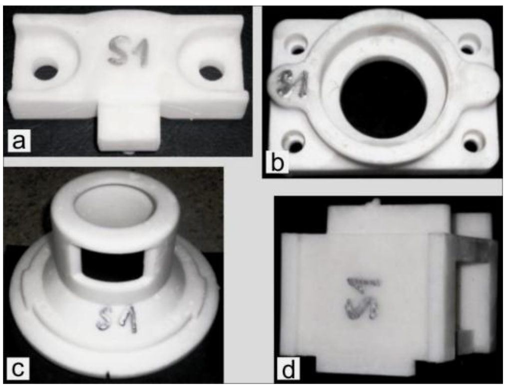

Fig. 1. Sample patterns: a) cable clamp, b) inlet base, c) sleeve, d) large bearing insert

Table 2.
Injection temperatures of the tested pattern waxes

No.	Processing cycle	Pattern wax temperature	
		Specodlew	Formowax
1.	Fresh wax	51^{o}C	52^{o}C
2.	1st	49^{o}C	50^{o}C
3.	2nd	50^{o}C	50^{o}C
4.	3rd	53^{o}C	52^{o}C

- making pattern sets. Cleaned wax patterns were welded with the main inlet, considering the basic feed systems design principles: (relevant and sufficient casting feeding at freezing; ensuring that the finished castings will be free of surface defects; ensuring the greatest yield possible; ensuring the possibility of separating the castings from the feed system). All top inlets, infeed inlets and riser heads were made from the same pattern wax as the patterns.

Fig. 2. Sample pattern sets

- making ceramic forms. Subsequent coats of ceramic mix and quartz sand were applied to the previously degreased pattern sets. Apparent viscosity of the ceramic mix on each coating complied with the technological instructions. Six coats were applied to each mould at eight-hour intervals. The samples were dried in the open air with a forced air flow. All moulds made with the tested pattern waxes were appropriately marked for the test,
- pattern wax smelting from ceramic moulds in an autoclave, in a saturated water vapour atmosphere (for the test purposes heating of the pattern wax from ceramic moulds in an autoclave was adjusted to the ability of recovering pattern wax to conduct three pattern making cycles from the same mix, without refreshing),
- burning out moulds in an electrical tunnel furnace at 950^{o}C to remove the pattern wax and providing the casting mould with appropriate characteristics,
- pouring the moulds with liquid metal,
- separating the moulds from sets by cutting or beating, depending on their type. Pursuant to previous arrangements, some marked castings were selected and passed for quality control to conduct measurements and check their quality. Three dimensions from each range of samples were selected for dimensional testing.

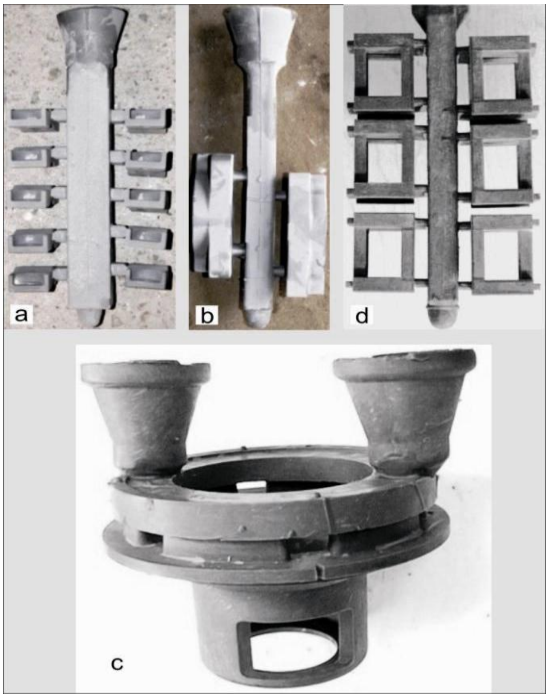

Fig. 3. Sample casting sets: a) cable clamp, b) inlet base, c) sleeve, d) large bearing insert

3. Description of results

Contraction in volume is one of the basic characteristics of each pattern wax, occurring during solidification. A correct contraction in volume should be as small as possible. It is determined as close to 1%. The tests revealed that the dimensions of wax patterns made from FORMOWAX are larger, which means a smaller contraction in volume. The contraction in volume was calculated on the example of some selected measurements and the following results were obtained: for Specodlew wax - 1.43% ÷ 1.53%; for FORMOWAX - 0.99% ÷ 1.17%. A lower thermal expansion was also discovered for FORMOWAX pattern wax.

Solidification time of the pattern wax is a very important factor and it shall be strictly observed to obtain patterns free of defects and with dimensions corresponding to the previously agreed ones. FORMOWAX sets faster, which means a greater heat penetration and hence the time of keeping the pattern in the matrix is shorter than in the case of Specodlew wax. It is also the evidence that FORMOWAX pattern wax has a higher melting point and a narrow solidification point range, which has a direct impact on the mix preparation time.

No pattern breaking or any other obstacles at making the patterns was discovered at making patterns from both tested waxes. Patterns made of FORMOWAX revealed a greater surface hardness at wax pattern inspection, which is favourable at further production during cleaning or joining. The situation can also contribute to a more thorough and precise representation of the matrix interior with the pattern wax (which is of great importance at making patterns with a complicated shape, thin walls and sharp edges, small diameter holes or fine threads).

Patterns from both pattern waxes indicated sufficient strength during further treatment.

In the case of both pattern waxes multitude processing of the same wax mix did not result in changing the characteristics or dimensions of the patterns, which ensures reproducibility at production. Adhesion of patterns at welding is sufficient to ensure good connection to pattern sets in the case of both mixes. Both tested pattern waxes had an impact on the course of ceramic mix application and drying time of the first coating. FORMOWAX mix was smelted from a ceramic mould under the same conditions as Specodlew, with no need to change the autoclave parameters.

Generally fewer defects were observed on the surface of patterns made of FORMOWAX (the most common pattern defects included misruns, air cavities, cracks, deformations, dents). There can be different causes of the defects and they may not be directly related to the type of wax (inappropriate wax temperature, time of keeping the pattern in the matrix not appropriate for the pattern type or insufficient injection pressure). However, eliminating the defects requires doing tests for a larger casting batch at a longer production.

The kind of the tested pattern waxes did not have a significant impact on the final quality of the casting surface. Quality control did not reveal any repeated defects typical of castings attributable to Specodlew or FORMOWAX wax patterns.

4. Conclusions

The conducted test allowed for discovering and comparing characteristics of Specodlew and FORMOWAX pattern waxes. Precision of making a non-machined precise pattern with an investment casting depends on a number of factors including: controlling contraction in volume of the smelted pattern at solidification, improving or selecting appropriate pattern wax, changing the pattern wax injection pressure and temperature or selecting optimum time for keeping the pattern in the matrix.

The presented results and observations provided the basis to state that both waxes revealed similar characteristics as for combining patterns into sets, coating the sets with a liquid ceramic mix or wax smelting. Both pattern waxes are easily miscible, which is important with regard to the possibility of their adapting to special requirements.

FORMOWAX, which has a form of a homogenous solid, with no need of mixing the ingredients, is more convenient to use due to an easier preparation method. It also guarantees maintaining appropriate composition at preparing the pattern wax. The results and findings presented in the report provided a basis to state that both waxes revealed similar characteristics as for combining the patterns into sets, coating the sets with liquid ceramic mix and wax smelting from moulds.

FORMOWAX pattern wax indicates a lower contraction in volume during solidification than Specodlew. The feature translates into smaller measurement errors and greater and more precise possibilities at the stage of designing new products. Furthermore, using FORMOWAX pattern wax allows for obtaining patterns with increased hardness after removing them from the matrix, which could contribute to improving their quality and consequently improving the quality of casting surface.

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