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QUALITY ASSURANCE OF THE COMPACTION PROCESS AT GREEN SAND MOULDING

ZAPEWNIENIE JAKOŚCI PROCESU ZAGĘSZCZANIA PRZY FORMOWANIU NA WILGOTNO

Several parameters during the moulding process of green sand directly affect a casting quality, energy consumption and cycle time. Insufficient compaction can result in rough casting surfaces and even breakage. Too much compaction requires more energy, can cause casting defects due to low gas permeability and causes more wear of the pattern and equipment. Unnecessary holding periods of particular process steps increase cycle time and also cause higher energy consumption.

Depending on the moulding process parameters, the properties of the moulding material and the geometry of the pattern, different regions in the mould experience different accelerations and forces resulting in varying mould properties. The effect of different moulding parameters was examined using small sensors. During the mould compaction the sand density in different regions of the mould was recorded over time. These results allow foundry personnel to monitor, adjust and optimise the moulding process.

Keywords: Mouldmaking, Compaction, Mould Sand, Quality, Sensor

Parametry procesu formowania na wilgotno mają bezpośredni wpływ na jakość odlewów, zużycie energii, czas trwania cyklu. Niedostateczne zagęszczenie powoduje powstanie chropowatych powierzchni a nawet spękań. Nadmierne zagęszczenie zwiększa zużycie energii i prowadzić może do powstawania defektów wskutek przepuszczalności gazu, ponadto powoduje dodatkowe zużycie oprzyrządowania odlewniczego. Niepotrzebne przestoje w trakcie poszczególnych etapów procesów wydłużają czas trwania cyklu, prowadząc do nadmiernego zużycia energii.

W zależności od parametrów procesu formowania, właściwości formowanych materiałów oraz geometrii formy, siły i przyspieszenia działające na poszczególne regiony formy będą różne, w rezultacie właściwości odlewu będą różne. Wpływ zmian poszczególnych parametrów procesu formowania zbadano przy użyciu niewielkich czujników. W trakcie procesu zagęszczania mierzono gęstość masy formierskiej i jej zmiany w czasie, co umożliwi personelowi odlewni skuteczne monitorowanie, regulowania i optymalizację procesu formowania.

1. Introduction

The quality of castings produced by clay bonded sand depends strongly on the compaction of moulding sand during the mould production. The process of mould production is for this kind of casting production similarly important as the processes of mould filling, solidification and cooling. When the production of casting starts, the foundryman must take up many decisions. Unfortunately, he has not enough theoretical knowledge, so he must use his practical experience. Despite the good experiences the moulding technology is often developed by trial-and-error method. It needs a lot of time and costs.

The problems of the moulding technology are:

a) Lifting of difficult mould parts,
b) Distance between the patterns and between the pattern and the flask wall,
c) Selection of the optimal properties of the moulding sand,
d) Choosing the flask height,
e) Mass of the moulding sand.

Furthermore, the modern moulding machines permit a compaction of the moulding sand by different processes of compaction: squeezing, air-flow-squeezing, impact, preimpact or impact in combination with squeezing. Also in this field the foundryman has a lot of problems:

a) Choice of processes or combination of processes,
b) Effect of duration of the compaction,
c) Sequence of different processes.

At present we do not have the possibility to use the defined knowledge for answering these questions and the development of the moulding technology is based on the experiences of the foundrymen. The main question is: “Will the moulds or the parts of moulds be able to re-

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sist the different loads, occurring during: lifting of cods, rollover and transport of the mould, core setting, assemble of mould, melt filling and shrinkage during the solidification and cooling of casting?". In order to produce quality castings the mould must meet all technological requirements.

In the theory of strength or in the theory of steel construction there are safety criterions for the determination of the usability of the detail or the steel construction.

$$\frac{\sigma_{\text{act}}}{\sigma_{\text{per}}} \leqslant 1 \qquad \frac{S_d}{R_d} \leqslant 1$$

(Mechanical engineering) (Steel construction)

where: σ_{act} – actual stress, σ_{per} – permissible stress, S_d – design value of action, R_d – design value of resistance.

The equations show the formula for the estimation of safety criterions. When the ratio is less than 1, the detail or the steel construction can be used without any danger of destruction. For the creation of scientific connection between the above mentioned parameters it is necessary to declare the mould to be a detail for the building of the casting and to proof the usability by the relationship of strengths and resistance of the mould.

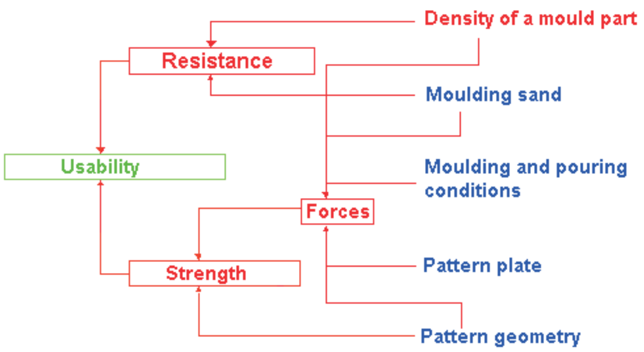

Fig. 1. Parameters for the determination of the usability of a mould

Fig. 1 shows the connection between the resistance of the mould independent of the mould density and properties of moulding sand. If these both parameters are increasing to the moulding and pouring conditions and the position of the patterns on the pattern plates, then it is possible to determine forces, which occur during the usage of the mould. Considering the pattern geometry we can estimate the strength for each part of the mould. The comparison between strength and resistance of the mould gives the information on usability of the mould. In this way it is possible to assess the mould quality before pouring.

2. New measuring devices

Fig. 2 shows the newly developed sensors. The sensor SP-P can be used only in the processes of squeezing or blow-squeezing. The sensor is relatively small and can be used in DISAMATIC-machines. This very compact sensor is displayed in Fig. 2a. Its size is 22 mm in diameter and 23 mm in height. Sensor LP-I has a more universal design and can be also utilized with impact moulding and airflow-squeezing in addition to squeezing and blow-squeezing. The transducer can compensate for the action of the air pressure on the sensor during airflow or impact moulding. Sensor LP-I, however, is somewhat larger than SP-P. It is 22 mm in diameter and 27 mm in height and is shown in Fig. 2b.

a) Sensor SP-P b) Sensor LP-I

Fig. 2. New measuring devices

In order to optimise the compaction process, the change of density of the moulding material must be recorded during mould making. Special transducers were developed for this purpose. They are integrated into the pattern plate so that only the spherical sensor protrudes from the surface of the plate. The force resulting from the moving moulding sand during a mould compaction, is recorded using the data acquisition system. The original sensor signal is equivalent to the displacement of the spherical sensor during compaction. Standard green sand specimens from production sand with a compactability of 38.5% were used for the measurements. The specimens were produced of equal volumes of loose moulding sand. The compaction pressure was increased from 0.25 to 2.00 MPa in increments of 0.25 MPa. A linear relationship exists between the sensor reading and the density of the specimen (Fig. 3).

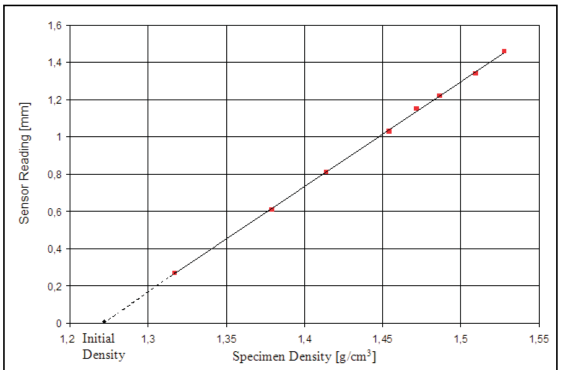

Fig. 3. Plot of sensor reading vs. mould density

3. Calibration

If different mould properties are to be measured with the new method, the interactions between these properties and the signal must be known. Thus, the sensor must be calibrated.

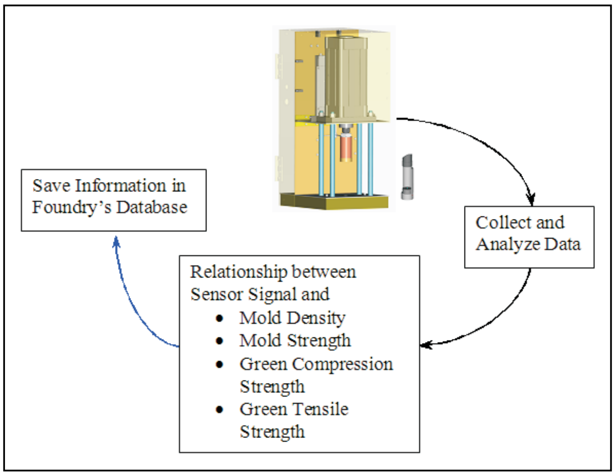

Fig. 4. Scheme of the calibration sequence

In order to calibrate the sensor, test specimens of the particular moulding material have to be produced. The sensor reading and the mould properties are measured on these specimens. The scheme of the calibration procedure is displayed in Fig. 4. The collected data are processed using computer software. The results are related to the particular moulding material and a database is built. The transfer of data is possible by cable or the telemetric system.

4. Practical experiments

The sensors can be used for different purposes in the foundries:

- Optimisation of the moulding machines for obtaining a constant quality product,
- Continuous monitoring of the mould quality for the certification,
- Investigation of the lifting process between a pattern plate and a flask,
- Continuous improvement of moulding process and quality assurance.

The validity of the calibration results obtained from the standard specimen for real moulds was tested several times during actual mould production by different moulding processes. It was proven, that the results from the specimen could be applied to actual moulding processes. Fig. 5 displays one of these experiments. Production green sand was used for the measurements. Before the measurements the sensors were calibrated accordingly. The sensors were installed at the pattern plate at locations of different degrees of difficulty for moulding. The ratio between depth and width at the first location was 3:1 (very difficult), while at the second location 1:1 (moderately difficult).

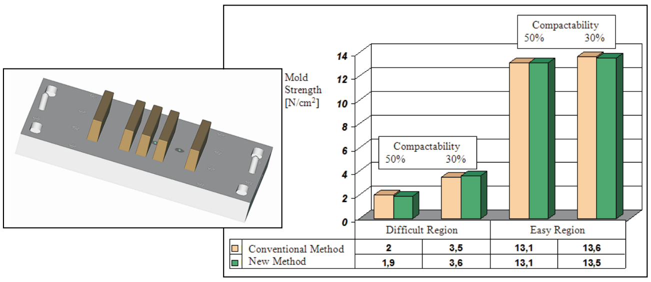

Fig. 5. Measurement of mould strength directly at the mould

Measurements were taken at compactability values of 50 and 30%. The compactability values were entered manually into the data acquisition package. Moulds were produced using squeezer. In order to double check the values obtained by the sensors, the mould strength was also measured manually at the same locations using a mould sand tester. The data measured using both techniques are in good agreement. Thus, the conclusion can be drawn, that the calibration values obtained with standard specimen can be utilized in a production environment. Similar experiments were repeated with equally good results for other mould making technologies.

5. Optimisation

The use of the sensors is meaningful for the process of optimisation of moulding machines with two-stage or multi-stage compaction processes. It is also helpful at moulding machines for the best choice of the compaction method with regard to the effect of compaction and the cost of production of the defined castings assortment. For the optimisation of a moulding machine its compaction characteristics must be measured by the sensors. After this, a comparison between the compaction characteristics and the parameters of the moulding machine, e.g. gradient of pressure, duration of air stream, duration of preimpact, value and duration of pressure – must be made.

Fig. 6 demonstrates the results of optimisation of the air-flow-process with squeezing. The compaction of moulding sand was carried out by air-flow with a vessel pressure of 6 bar and a opening time of the valve of 0.6 s. After this the moulding sand was compacted by squeezing with 1 MPa. The compaction of sand by air-flow is low. The compaction is higher by squeezing. Furthermore, it is reported, that the squeezing started after 10 s (compaction characteristics before optimisation).

For increasing the productivity the compaction started 5 s earlier (compaction characteristics after optimisation). It is possible also to decrease the time after the compaction by squeezing, so that the production time of a mould can be decreased to 10 s. The quality of moulds has not changed.

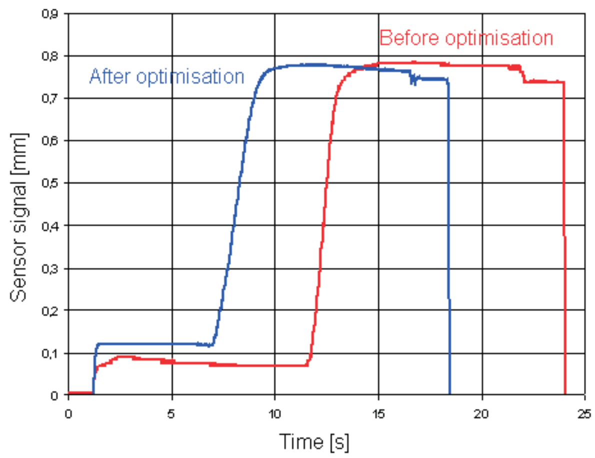

Fig. 6. Optimisation of air-flow and squeezing time during the compaction (time saving: 5 s per mould)

6. Impact moulding

The previous two examples dealt with the compaction period of the mould making process. Removing the mould from the pattern without damaging its features is equally important. One of the most common causes for scrap formation are pieces of moulding sand breaking off and sticking to the pattern when the mould is pulled off the pattern.

Many factors can contribute to this problem and finding the actual cause is sometimes very difficult. Quite often not one single factor but a combination of several factors result in breakage. The new sensors can be used to evaluate and minimize the danger of breaking moulds. The mould compaction and mould withdrawal have to be analysed at least at two locations on the pattern. At the same time the properties of the moulding material during production need to be monitored. The next paragraph will focus on the moulding equipment as the significant factor.

The forces resulting from the motion of the sand during compaction were recorded at two symmetrically positioned locations on the symmetrical pattern plate. The sensor readings were recorded for a large quantity of moulds. The experimental setup is shown in Fig. 7. Sensor 1 was installed at the location where the majority of mould breakage occurred. Measurements began with attaching the compaction unit to the moulding envelope and lasted for 10 seconds resulting in recording of the whole cycle including compaction and withdrawal.

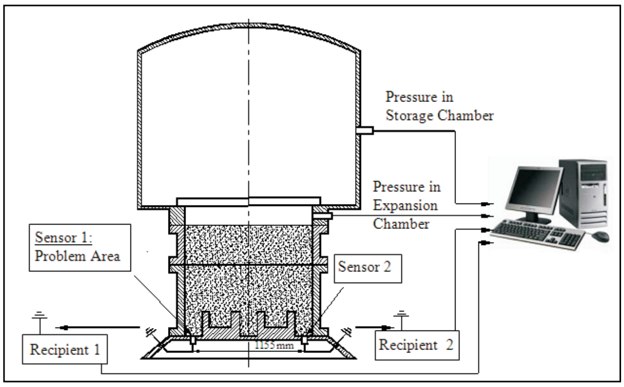

Fig. 7. Schematics of the experimental setup for analysing mould withdrawal

Fig. 8 shows a typical measurement result of the whole moulding cycle. The sequence starts with turning on the hydraulics to attach the compaction unit to the moulding envelope. After opening the valve the pressure in the expansion chamber increases rapidly, the pressure in the storage chamber is reduced slightly until the pressures are equalized. The moulding material is accelerated towards the pattern plate and is subsequently compacted at the pattern surface. It can be seen that the actual compaction is finished rapidly. It is also evident, that the compaction at Sensor 1 (problem area) is less than at Sensor 2. This cannot be a result of the compaction action of the equipment. Possible causes are either uneven filling or pre-compaction due to striking off the excess moulding sand above the filling frame.

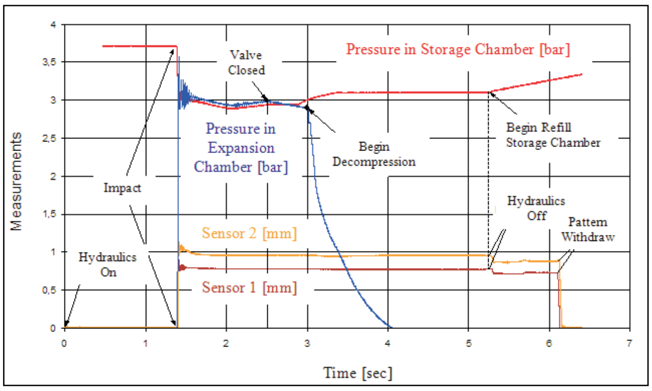

Fig. 8. Single measurement of the parameters during a complete cycle by impact moulding

The oscillations of the pressure in the expansion chamber and the density plots subside immediately after the impact. These oscillations do not cause a change in the density of the moulding material. It can be seen that they occur simultaneously at both sensor location. Therefore it is unlikely that they are the cause for the mould breakage.

The valve between the storage chamber and expansion chamber could be closed as soon as the pressure on both sides is equalized. However, the valve is only closed after 1 second. Depressurization starts 0.4 seconds after closing the valve. 0.2 seconds elapse between the end of depressurization and withdrawing the pattern. This time could be used to increase the output of the moulding equipment. A fluctuation can be observed at Sensor 1 and Sensor 2 during this time period. It is caused by the operation of the equipment, rather than a density change in the moulding sand. The hydraulic cylinder at the compaction unit creates a non-uniform movement between the pattern plate and mould. Approximately at the same time refilling of the storage chamber with compressed air for the next cycle begins.

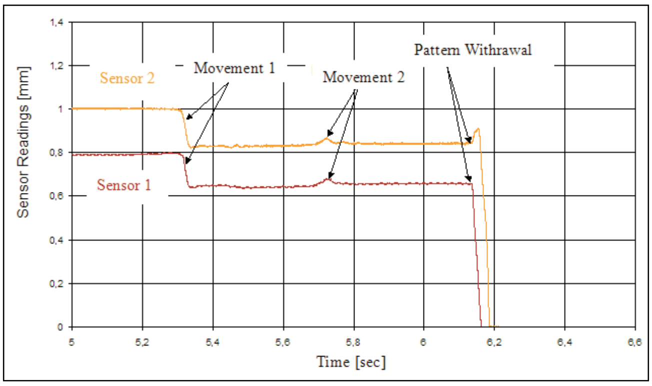

Fig. 9. Sensor readings before and during the mould withdrawal

The sensor readings on the pattern before and during the mould withdrawal are displayed in Fig. 9. As soon as the hydraulic system – that is used to attach the compaction unit to the moulding envelope – is turned off, a small gap is formed between the pattern plate and mould. Another small movement occurs 0.4 seconds after relieving the pressure. Immediately at the beginning of the mould withdrawal the pattern tilts slightly and another force at the sensor becomes evident. Analysis of the data has shown that mould breakage was caused by a combination of the pattern tilt, insufficient mould density and the mould withdrawal velocity. Every factor must be controlled in dependence of its effect on the other factors. A general remedy would be to have more even compaction, smoother motion during withdrawal and a lower withdrawal speed.

7. Conclusions

With the described above measuring devices the foundry personnel has the opportunity to monitor for the first time the compaction of Green Sand during mould making. This enables to set precisely the parameters of the moulding machine for a particular casting. Optimising the settings of the moulding equipment helps to lower energy and material consumption, increase productivity and as a final result to decrease the production costs.

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