THE CAPABILITY OF GREEN SAND MOLD STRENGTH AND MOLD PERMEABILITY MEASUREMENT PROCESS

Petrík J[1]*., Gengeľ P.*[2]
[1] *Department of Integrated Management, Faculty of Metallurgy, Technical university in Košice, Slovakia*
[2] *Department of Ferrous Metallurgy and Foundry, Faculty of Metallurgy, Technical university in Košice, Slovakia*

SPÔSOBILOSŤ PROCESU MERANIA PEVNOSTI A PRIEDUŠNOSTI PIESKOVÝCH FORIEM

Petrík J.[1]*, Gengeľ P.*[2]
[1] *Katedra integrovaného manažérstva, Hutnícka fakulta, Technická univerzita v Košiciach, Slovensko*
[2] *Katedra metalurgie železa a zlievarenstva, Hutnícka fakulta, Technická univerzita v Košiciach, Slovensko*

Abstrakt

Spôsobilosť procesu merania predstavuje jeho schopnosť plniť požiadavky zákazníkov. Vyhodnocovanie spôsobilosti procesu merania vlastne porovnáva požiadavky zákazníka s výkonom procesu s cieľom identifikovať zdroje na meranie (monitorovanie) procesu. Meranie – merací proces sa realizuje v meracom systéme, ktorý zahrňuje merací prostriedok, meracie metódy, operátorov, softvér, podmienky prostredia a prípadne ďalšie faktory. Ak je merací systém spôsobilý, je pravdepodobné, ža aj v ňom realizovaný proces bude spôsobilý, teda kvalitný. Jedna z metód analýzy systémov merania (MSA), analýza opakovateľnosti a reprodukovateľnosti (GRR) bola použitá na vyhodnotenie spôsobilosti merania pevnosti RC2, pevnosti v strihu RT2 a priedušnosti pieskových foriem. Na prípravu zlievárenských foriem sa najčastejšie používa materiál na báze piesku. Bez kvalitnej formy nie je možné vyrobiť kvalitný odliatok. Práve analýza kvality použitých materiálov a práce na výrobu formy má podstatný vplyv na kvalitu odliatkov. Desať vzoriek formovacej zmesi na báze piesku, ktoré sa odlišovali obsahom prachu bolo skúšaných bežnými metódami dvoma operátormi v dvoch opakovaniach. Analyzovaný proces merania je spôsobilý pre meranie priedušnosti, avšak nespôsobilý pre obe metódy merania pevnosti. Na nespôsobilosť má vplyv príliš hrubé delenie stupnice použitého meracieho prostriedku. Rozdiel medzi prácou oboch operátorov a ich vklad k nespôsobilosti je zanedbateľný.

Abstract

The capability of a process is a measure of its ability to satisfy customer's requirements. Process capability studies are carried out to compare customer's requirements with process performance to identify the resources for process measuring (monitoring). The measurement process is realized in measurement system, which involves measurement equipment, methods, appraisers, software, conditions of environment and other factors. If the analyzed measurement system is capable, it is likely that the measurement process, taking place in it is capable as well. One of measurement systems analysis (MSA) methods, analysis of repeatibility and reproducibility (GRR) was used for evaluation of measurement's capability of green sand mold compression strength RC2, shearing strength RT2 and mold permeability. Molding processes were sand is used to make the mold produce by far the largest quantity of castings. Good castings cannot be made without good – class molds. Because of the importance of the mold, the quality of casting processes are often described by the materials and methods employed in molding. Ten samples of green sand with various content of dust were measured by routine methods by two appraisers in two trials. Analyzed process is capable for measurement measurement of permeability, but non-capable for measurement of strenght. The increasing of capability could be possible by increasing of discrimination (more fine scale). The influence of appraisers on capability is positive with negligible difference in their competence.

Keywords: MSA, green sand, permeability, strength

1. Introduction

The demands on the measurement of the qualitative characters of products, services, trades and processes increase in connection with the natural pressure towards to the quality. The measurement is important in production for its all phases. It starts in the research, goes on in development, monitoring of raw materials as the inputs, semi-finished products, process of production as such (which involves quality manufacturing establishments, environment, productive operatives, measurement equipments…) and the final check-out. May be said "What you do not can to measure, you do not know to make".

The requests for the quality measurements, as well as requirement of ever new measurement methods are actuals in all branches of human activities. The growth of measurement quality yields new knowledge as a rule and its application forces the improvement of the measurement.

The quality of measurement process can be evaluated in the same manner as it of any manufacturing process. The measurement process (measuring) is realized in measurement system. The system involves measurement equipment, methods, appraisers, software, conditions of environment and other factors. The application of the standards (e. g. ISO 9000, ISO 10 012, ISO 17 025) has positive influence on the quality of measurement process. The analysis of the capability affords an operative reviewing of the measurement process quality with its quantification.

The aim of measurement management system according to standard STN EN ISO 10012:2004 is to regulate the hazard that the measurement equipment or measurement process could provide incorrect results. Incorrect results negatively affect the final quality of products as a rule with consequential economic or moral damages (e.g. the loss of producer's goodwill). The incorrect results of measurement can eventually affect the health, safeness, property, human environment, governmental interests. Although we, from experience, can suppose that confirmed (calibrated and verificated) measurement equipment will be true (accurate) also at the end of calibration interval, there is obvious danger of equipment misdirection. The probable consequence of measurement equipment misdirection is measuring of incorrect values even with the most accurate and the most true (with the most freedom from bias) measurement equipment. The misdirection can be result of incorrect measurement method, the environment of measurement or incompetent appraisers.

The measurement of green sand mold technological properties is one of the in common used and relatively simple methods.

For permeability and strength properties determination – compression strength (RC2) and shearing strength (RT2) the tested norm-cylinders must be prepared.

The tested norm-cylinders are tested elements for permeability and strength properties determination of bentonite sand mixtures which are prepared on laboratory compression apparatus.

The process of preparation is following: necessary sand mixture charging stock is filled into the core-box, where is compressed by three strokes. It is presenting energy of compression by 9,81 kJ. For the compression strength, shearing strength and permeability tests the cylinder shape test element is used with diameter 50 mm and length 50mm [1].

The permeability determination

From tested sand mixture the tested cylinder is prepared. Apparatus for permeability measuring is prepared to measurement according to used type. Core-box with cylinder is put on the nozzles and a measurement of permeability is carried. The results of permeability from three measurements shouldn't be dididffer more than 10 %.

The compression strength determination

The compression strength is determinated by compressed stress impact onto the norm cylinder. The norm cylinder is compressed by basic mode. The compression strength determination is given by compressive stress, in which the destruction of tested sample is reached. It is given in kPa.

The shearing strength determination

This metod is expressed the sand mixture plasticity. It is used purely for raw bentonite sand mixtures. It is determinate by vertically stress act onto the cylinder axis. Destruction of tested samples is caused by tension. The unit of measure is kPa.

2. The analysis of the measurement system

The aim of submitted work is to analyze the quality of green sand mold mechanical properties measurement by evaluation of measurement process capability. The method, based on the analysis of control processes according to standard VDA 5 (or DIN EN V 13005) regards to the uncertainty of measurement, is often used for capability evaluation. The disadvantage of this method is its restriction for geometric values [2].

Another of the used methods is not standardized yet, but is recommended in the reference manuals, used the first of all in the automotive industry. The most important of them is reference manual MSA – Measurement Systems Analysis. MSA helps conform to ISO/TS 16 949:2002 requirements as well as AIAG standards.

Measurement systems analysis (MSA) is an experimental and mathematical method of determining how much the variation within the measurement process contributes to overall process variability. If the analyzed measurement system is capable, it is likely that the measurement process, taking place in it is capable as well.

The analysis of variance (ANOVA) is one of MSA methods. Its advantages are, that it is capable of handling any experimental set-up, can estimate the variance accurately and extracts more information from the experimental data. The disadvantages are more complex numerical computations and users require a certain degree of statistical knowledge to interpret the results.

More simple method of MSA, GRR (gauge repeatability and reproducibility) studies to evaluate measurement systems. It is a system designed to help engineers and quality professionals assess, monitor, and reduce measurement system variation. In regard to more simply approach the GRR was used for estimation of capability of green sand mold mechanical properties measurement processes [3, p. 97].

3. The method of capability calculation

The ***green sand mold*** strength (the compression strength RC2 [kPa], shearing strength RT2 [kPa]) and mold permeability [N.J.P.] of ten samples (with various content of dust, composition tab. 1) were measured by routine methods (*The compression strength, the shearing strength and the permeability of sand mixtures*).

The measurement was carried out by two appraisers (A, B) with two trials (recommend 2-5 trials).

Table 1 The composition of samples

	1	2	3	4	5	6	7	8	9	10
Bentonite sand mixture										2700
Opening material	2708,91	2618,64	2998,36	2468	2317,69	2618,64	2558,36	2468	2312	
Dust	60,09	150,36	210,44	301	451,35	150,36	120,44	301	451,35	300
Binder	261	261	261	261	261	261	161	261	261	
Water	69	69	69	69	69	69	69	69	69	49
Total	3099	3099	3538,8	3099	3099,04	3099	2908,8	3099	3093,35	3049

4. Results

The computation of capability indices was carried out according to [3, p. 102-120] [4, p. 142-154]. The software Palstat CAQ with significance level α = 0.01 and confidence level α = 0.01 (5.15 σ) was used for capability calculation.

The first step of analysis is to estimate whether the discrimination - the value of smallest scale graduation of measurement equipment is sufficient. A general rule of thumb is the discrimination ought to be at least one - tenth the process variation [3, p. 44]. The discrimination is 5 kPa for the strength and 10 units NJP for permeability. The discrimination is not satisfactory neither for permeability (SD = 52,76 for all measurements) or for strength (SD RC2 = 20.41 kPa, SD RT2 = 4,56 kPa).

The measurement system ought to be in statistical control before capability is assessed, the range control chart was used. The process is in the control, if all ranges are between control limits. This condition was satisfied for all appraisers (fig. 1). If one appraiser is out of control (appraiser B in RC2 measurement), the method used differs from the others.

The area within the control limits of the X-bar control chart represents measurement sensitivity („noise“). Since measurements during one day used in the study represents the process variation, approximately one half or more of the averages should fall outside the control limits. If the data show this pattern, then the measurement system should be adequate to detect part - to - part (sample – to – sample in used experiment model) variation and the measurement system can be provide useful information for analyzing and controlling the process. If less than half fall outside the control limits then either the measurement system lacks adequate effective resolution or the sample does not represent the expected process variation. As can be seen on fig. 2, the analyzed system has sufficient resolution only for permeability measurement.

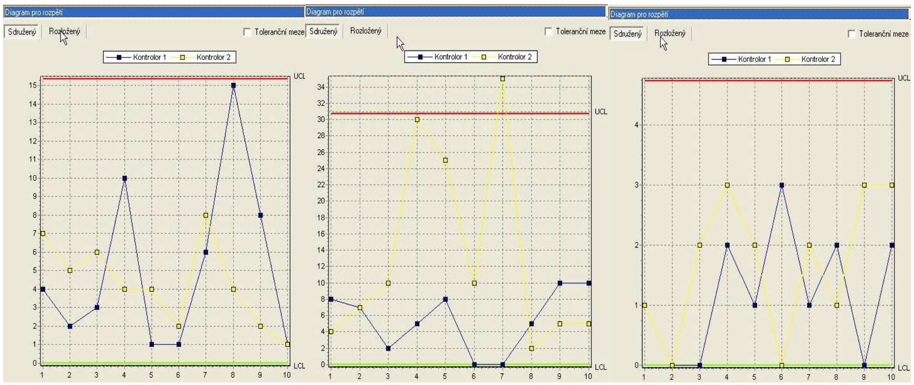

Fig.1 The range control chart: a-permeability, b-RC2, c-RT2

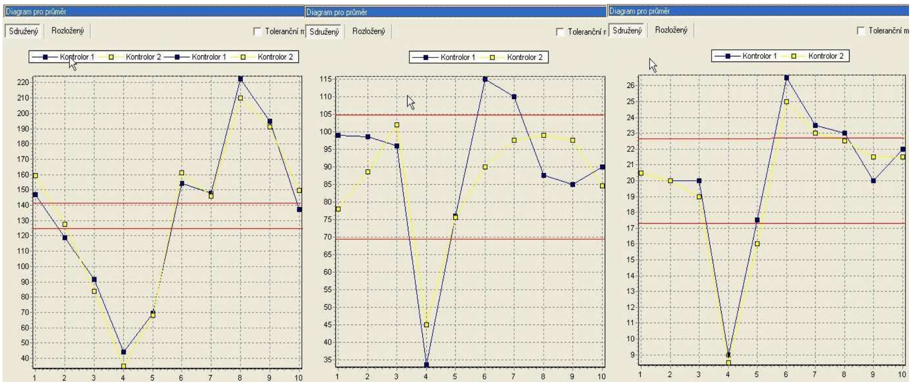

Fig.2 X – bar control chart: a-permeability, b-RC2, c-RT2

The number of distinct categories (“ndc”, based on Wheeler's discrimination ratio) is connected with the resolution of measurement equipment. It indicates the number of various categories, which can be distinguished by the measurement systems. It is the number of non-overlay 97 % confidence intervals, which cover the range of expected variability of product. The “ndc” is greater than or equal to 5 for capable processes, results with “ndc” values between 2-5 may be conditionally used for rough estimations [3, p. 120].

The value of “ndc” of permeability measurement is 18.8, but it of strength measurement is only 3.39 for KC2 and 5.84 for KT2. The analysis of the X-bar control charts, resolution and “ndc” index demonstrate high sensitivity of measurement system for variability of permeability measured value.

The %EV index represents the cumulative influence of measurement equipment, measuring method and environmental conditions on the variability. It is a function of average range of trials of all appraisers. The value of %EV is 7.47 % for permeability, 37.9 % for RC2 and 23.4 % for KT2 . Whereas standardized measurement method was used, the equipment’s resolution above all affects the %EV index, especially in case of strength measurement.

The %AV index represents the influence of appraisers on the variability, for example their liability (responsibility) and competence. It is a function of the maximum average appraiser difference. The value of %AV is 0 % for permeability, 6.4 % for RC2 and 2.49 % for KT2. Low value of index witness good competence of both appraisers.

The %GRR index represents the process capability in practice. %GRR<10 % is generally considered to be an acceptable measurement system, %GRR > 30 % is considered to be not acceptable. Analyzed measurement process is generally considered to be acceptable - capable for permeability, the value of %GRR is 7.47 %. The process is non acceptable for RC2 (%GRR = 37.9 %) and may be acceptable for KT2 (%GRR = 23.49 %).

The %PV is a function of the range of individual measurements samples. It is sensitive to variability of individual sample's permeability or strength. The values of %PV indirectly define suitability of used measurement equipment for specific measurement. The value of %PV above 99 % is for very accurate equipment, above 90 % for suitable, above 70 % for satisfactory and above 50 % for inaccurate one [5, p. 29]. Because %PV = 92.3 % for KC2 and 97.2 % for KT2 used equipment is suitable for strength measurement and (too) very accurate in respect to variability between the permeability of samples (%PV = 99.72 %).

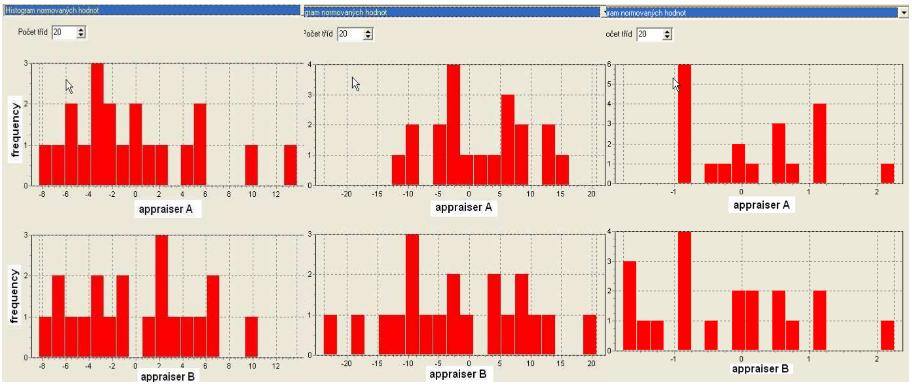

Fig.3 Normalized histogram: a-permeability, b-RC2, c-RT2

Normalized histogram – histogram plot is a graph that displays the frequency distribution of the gage error of appraisers who participated in the study. The graph provides a quick overview how the error, i.e. difference between observed value and reference value (samples average) is distributed. As can be seen in fig. 3, the differencies of bias (systematic error – the difference between histogram's peak and 0) and variability (random error – the width of histogram) between apraissers for all measurements are negligible except for stronger variability of appraiser B in measurement of RC2.

Conclusion

1. Analyzed process is capable for measurement measurement of permeability, but non-capable for measurement of strenght.
2. The increasing of capability could be possible by increasing of discrimination (more fine scale).
3. The influence of appraisers on capability is positivewith negligible difference in their competence.

Acknowledgements

This work was supported by the Slovak Grant Agency for Science VEGA 1/4141/07.

Literature

[1] Vasková I.: Návody na cvičenia z predmetu „Formovacie zmesi“, Technická univerzita v Košiciach, Hutnícka fakulta, Košice, 2009, ISBN: 978-80-553-0141-9
[2] Dietrich E., Es geht auch einfach. Messunsicherheit in Analogie zur Prüfmittelfähigkeit bestimmen, QZ Magazine, 46 (3) (2001) 264-265.
[3] Measurement systems analysis (MSA). Reference manual. Third edition. 2003.
[4] Plura J.: *Plánovaní a neustálé zlepšovaní jakosti*. Computer Press. Praha 2001. ISBN 80-7226-543-1.(in Czech).
[5] Meloun M., Militký J.: *Kompendium statistického zpracování dat*. 1. vydanie. Praha: Academia, 2002. ISBN 80-200-1008-4. (in Czech)