www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES of FOUNDRY ENGINEERING

DOI: 10.1515/afe-2016-0026

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (2299-2944)
Volume 16
Issue 2/2016

55 – 60

An Assessment of Appropriateness of the Choice of Parameters for Refractory Stampings Fabrication Process

A. W. Orłowicz [a]*, M. Mróz [a], M. Tupaj [a], A. Trytek [a], B. Kupiec [a], M. Korzeniowski [a], D. Pająk [a], K. Sondej [b], L. Kozak [b]

[a] Rzeszow University of Technology, Al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland

[b] ZM Service Sp. z o.o., ul. Przemysłowa 1, 39-100 Ropczyce, Poland

*Corresponding author. E-mail address: aworlow@prz.edu.pl

Received 31.03.2016; accepted in revised form 22.04.2016

Abstract

The paper presents results of an analysis of material density distribution in stampings press-moulded in metal dies from raw refractory materials based on alumina-magnesia-carbon aggregate. The stampings, fabricated on LAEIS HPF 1250 pressing machine, are blanks from which refractory precast shapes are manufactured by means of drying and firing. Samples for material density evaluation were cut out from test stampings with the use of diamond-reinforced disc. Density of the material was determined in thirteen layers of stampings denoted with letters A through M.

Keywords: Die stamping, Refractory materials, Metal die, Material density

1. Introduction

Casting ladles, metal smelting furnaces, and thermal treatment furnaces are fabricated with the use of refractory materials. The matrix of masses used to produce precast refractory shapes include grains of fused and sintered MgO, fused magnesia-chromite aggregate, fused spinel, fused alumina, and other materials. The aggregates are characterised with grain sizes ranging from 2.7 mm to 6.2 mm. Corners of the grains have angles falling in the range from 30° to 90°. Angular shape of the grains makes them susceptible to jamming in the course of stampings press-moulding process. An example view of a stamping surface is presented in Fig. 1.

The stamping fabrication process includes press moulding in cavities of dies filled with a repeatable quantity of raw refractory mass under high pressure of press plunger, followed by thermal treatment aimed at drying and firing the stampings.

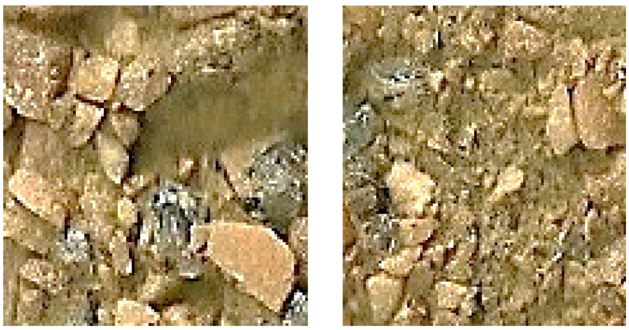

Fig. 1. A view of stamping surface with characteristic clusters of jammed aggregate grains

In the course of drying the stampings, moisture from spaces between grains evaporates which results in reduction of distance between them. This is accompanied by shrinkage of precast shapes. Typical contraction occurring in the drying process is up to 3%. Too rapid course of drying creates favourable conditions for occurrence of negative stresses in the material which results in development of cracks. Precast shapes with excessively diversified density are more susceptible to cracking in the drying process. Cracked shapes are scrapped.

Uniform density of precast shape material is also of great importance for the firing process and for the product service properties, in view of their expected high resistance to abrupt changes of temperature and good thermo-physical properties, such as the thermal conductivity which is inversely proportional to the porosity ratio. Uniform density is also desirable in view of resistance to corrosion induced by hot slug, reactive gases or dusts, and erosion.

In operating conditions, incorrectly fired products made of silica, sillimanite, chromite-magnesite, or spinel materials can be subject to various processes accompanied by increasing volume of reaction products and phase transformations. The phenomenon is commonly known as the secondary expansion of refractory materials.

In the course of prolonged operation, at temperatures close to or exceeding the temperature of firing magnesite products and certain types of chamotte and dolomite products in the conditions involving infiltration of aggressive substances into working volumes of the furnaces, the phenomenon known as after-contraction occurs [1].

To obtain high and uniform compactness of mass in the die cavity, press moulding is carried out in stages taking into account the need to deaerate the mass. To this end, cyclically repeated phases of superpressing are used with gradually increasing values of load applied to the press plunger followed by load release phases to enable deaeration.

An important component of the overall cost of manufacturing products of refractory materials is the price of replaceable components of dies used for press-moulding of stampings.

In Zakłady Magnezytowe Ropczyce S.A. [*Ropczyce Magnesite Works plc.*], a new design of die insert has been developed [2]. To test the inserts in production conditions, it became necessary to adopt new press moulding parameters, more demanding than those applicable to date. On the other hand, new parameters of press moulding were expected to ensure satisfactory quality of stampings.

The objective of the study reported in this paper was to verify correctness of values of basic parameters adopted for the process of press moulding of experimental stampings from refractory materials from the point of view of the density value distribution and susceptibility to development of cracks in the course of drying and firing.

2. Research methodology and description of the experiment

Fig. 2 is a schematic drawing depicting the process of press moulding stampings for precast shapes of refractory materials.

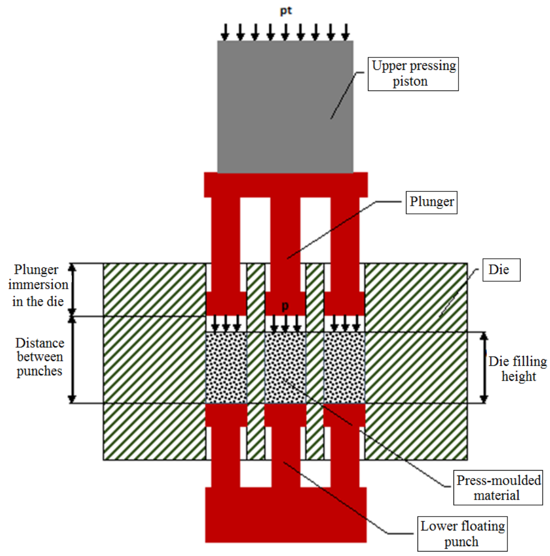

Fig. 2. Schematic diagram of the process of press-forming stampings from refractory material

Fig. 3 shows schematically values of the parameters characterising the process of press-forming the stampings and their effect on distance between the press punches in the course of press forming cycle

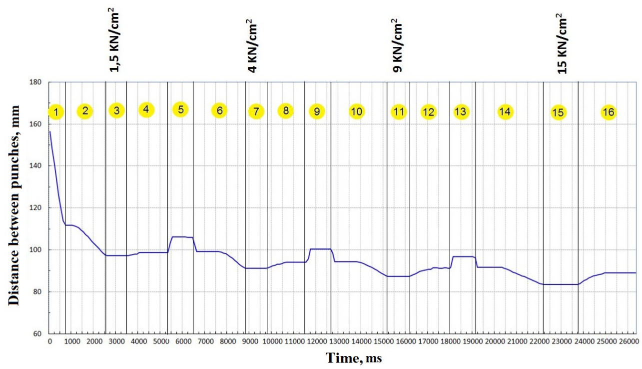

Fig. 3. Values of the stamping press forming process parameters and their effect on distance between press punches: 1 — plunger lowering under its own weight; 2 — pressing up to a preset deaeration pressure (phase 1); 3 — holding the deaeration pressure for a preset time (phase 1); 4 — releasing the deaeration pressure (phase 1); 5 — retracting the plunger up by a preset distance; 6 — pressing up to a preset deaeration pressure (phase 2); 7 — holding the deaeration pressure for a preset time for a preset time (phase 2); 8 — releasing the deaeration pressure (phase 2); 9 — retracting the plunger up by a preset distance; 10 — pressing up to a preset deaeration pressure (phase 3); 11 — holding the deaeration pressure for a preset time (phase 3); 12 — releasing the deaeration pressure (phase 3); 13 — retracting the plunger up by a preset distance; 14 — final pressing up to a preset ultimate pressure; 15 — holding the final pressure; 16 — releasing the final pressure

To determine distribution of material density within the stamping volume, 3 stampings were picked up randomly. Stampings with dimensions 250 mm × 165 mm × 100 mm were press-moulded from alumina-magnesia-carbon aggregate on LAEIS HPF 1250 pressing machine.

Density measurements for specimens taken from stampings were carried out with the use of the density evaluation kit WAS 160/X (RADWAG). Specimens were cut out with the use of diamond-reinforced disc. First, stampings were cut into 13 slices/layers denoted A, B, C, ..., M, each about 9.9-mm thick. The slices/layers were cut into strips (I, II, III), each about 31.3-mm wide. Each strip was cut into five specimens with length 47.6 mm each. Each of the five specimens was cut into two equal parts.

A diagram of the system used to identify specimens for stamping material density measurements is presented in Fig. 4. Three measurements were performed for each specimen and averages were used for presentation of results.

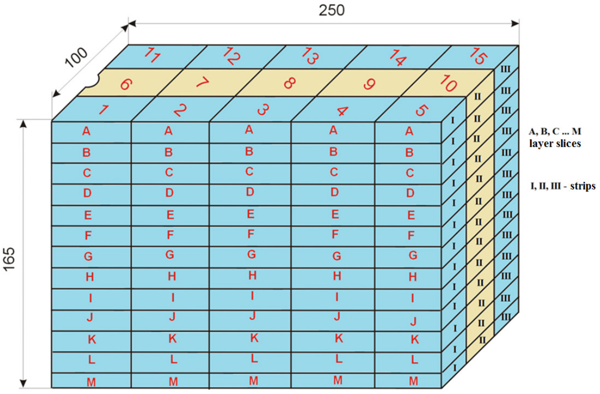

Fig. 4. The system used to identify specimens for stamping material density measurements

An example view of specimens for stamping material density measurements is shown in Fig. 5.

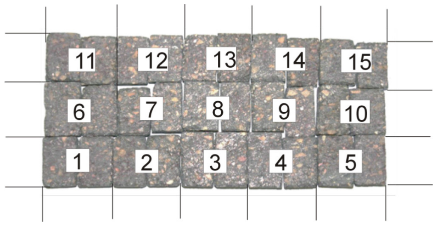

Fig. 5. A view specimens for stamping material density measurements

3. Density measurement results

Results of measurements aimed at determination of the material density distribution within the stamping volume are presented in Table 1. To make the presented data more legible it has been assumed that individual layers remained in contact with each other without any discontinuities which actually existed in the form of saw cuts (about 3 mm wide).

Fig. 6 shows a set of plots representing the distribution of average material density in specimens along strips I, II, and III in individual layers (A through M) of test stampings.

Example distributions of the average material density value in individual layers are presented in Figs. 7–12.

The obtained results indicate that press moulding parameters adopted for testing the new design of die inserts allowed to obtain density values higher than those assumed previously (3.00–3.10 g/cm^3).

Table 1.
Distribution of the average material density within stamping volume (specimens marked as shown in Fig. 2)

Nr próbki	Density, g/cm^3												
	Layer (adopted values of layer position depths with respect to plunger face, mm)												
	A (0-13)	B (13-26)	C (26-39)	D (39-52)	E (52-65)	F (65-78)	G (78-94)	H (94-104)	I (104-117)	J (117-130)	K (130-143)	L (143-156	M (156-165)
1	3,1568	3,1530	3,1492	3,1453	3,1422	3,1395	3,1366	3,1356	3,1378	3,1420	3,1470	3,1522	3,1574
2	3,1521	3,1470	3,1422	3,1377	3,1332	3,1285	3,1250	3,1235	3,1275	3,1325	3,1392	3,1452	3,1507
3	3,1514	3,1458	3,1412	3,1369	3,1332	3,1270	3,1240	3,1222	3,1257	3,1307	3,1385	3,1449	3,1503
4	3,1529	3,1477	3,1428	3,1358	3,1334	3,1279	3,1248	3,1233	3,1260	3,1307	3,1384	3,1456	3,1515
5	3,1575	3,1536	3,1493	3,1462	3,1426	3,1397	3,1381	3,1374	3,1383	3,1423	3,1459	3,1519	3,1570
6	3,1488	3,1434	3,1383	3,1336	3,1285	3,1239	3,1200	3,1183	3,1217	3,1261	3,1320	3,1395	3,1461
7	3,1226	3,1170	3,1092	3,1042	3,0957	3,0892	3,0839	3,0783	3,0836	3,0925	3,1047	3,1160	3,1233
8	3,1185	3,1130	3,1064	3,1003	3,0914	3,0867	3,0802	3,0749	3,0796	3,0881	3,1020	3,1118	3,1187
9	3,1218	3,1170	3,1093	3,1046	3,0955	3,0890	3,0829	3,0781	3,0826	3,0920	3,1042	3,1147	3,1223
10	3,1493	3,1429	3,1383	3,1331	3,1285	3,1240	3,1202	3,1178	3,1207	3,1261	3,1324	3,1407	3,1478
11	3,1559	3,1528	3,1492	3,1464	3,1423	3,1393	3,1376	3,1368	3,1380	3,1426	3,1463	3,1530	3,1564
12	3,1528	3,1483	3,1418	3,1359	3,1321	3,1272	3,1233	3,1216	3,1242	3,1318	3,1385	3,1465	3,1513
13	3,1520	3,1473	3,1418	3,1371	3,1325	3,1273	3,1222	3,1210	3,1228	3,1301	3,1383	3,1444	3,1504
14	3,1534	3,1479	3,1426	3,1381	3,1332	3,1284	3,1233	3,1212	3,1233	3,1307	3,1388	3,1447	3,1522
15	3,1568	3,1530	3,1492	3,1453	3,1422	3,1395	3,1366	3,1356	3,1378	3,1420	3,1470	3,1522	3,1574

It has been assumed that individual layers contact each other without discontinuities wchich in fact are the saw cuts (about 3 mm wide). Pont 0 mm corresponds to upper surface of stamping reproduced by pressing punch face.

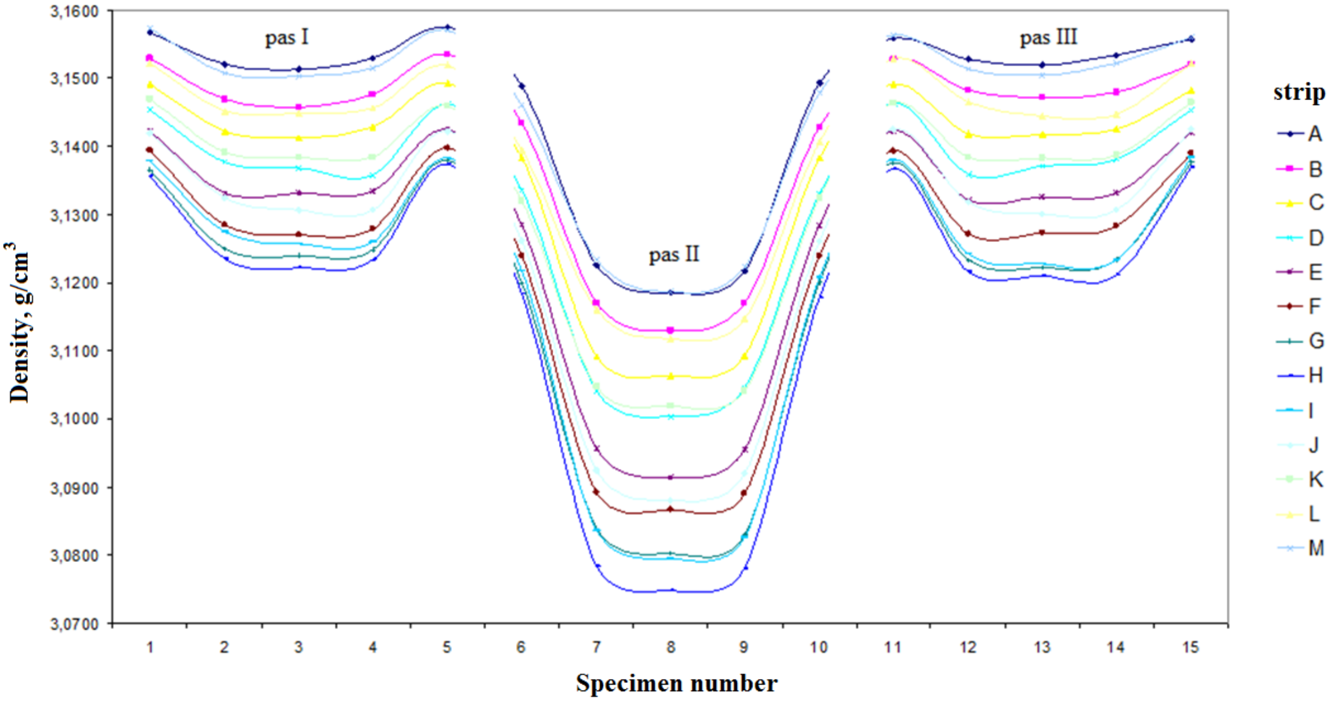

Fig. 6. Distribution of the average material density along strips I, II, and III in individual layers A through M

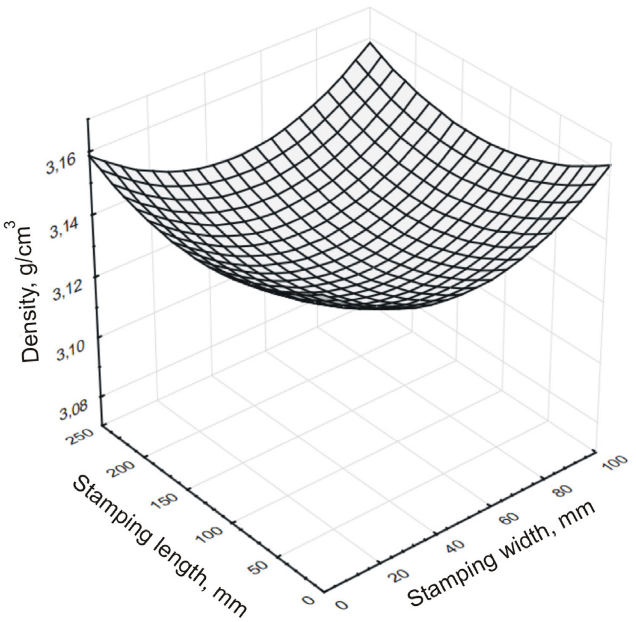

Fig. 7. Distribution of the average material density in Layer A

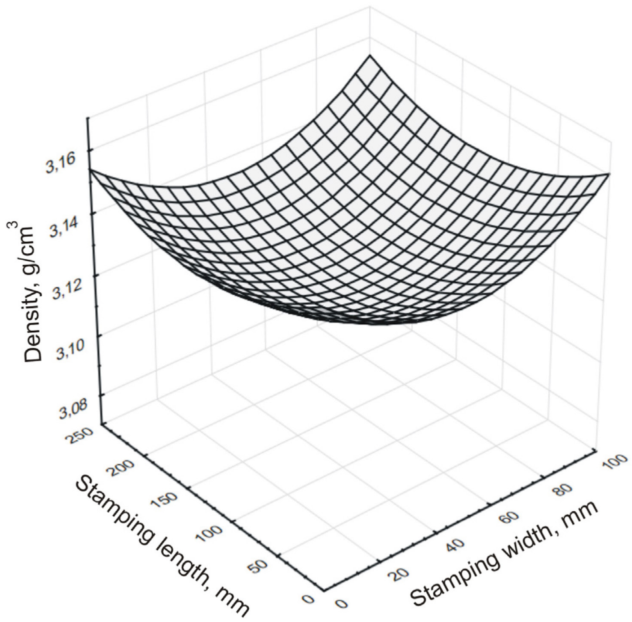

Fig. 8. Distribution of the average material density in Layer B

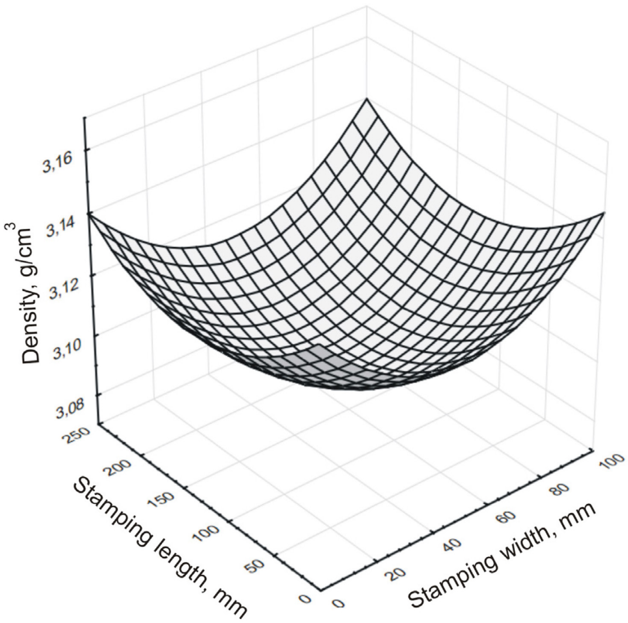

Fig. 9. Distribution of the average material density in Layer F

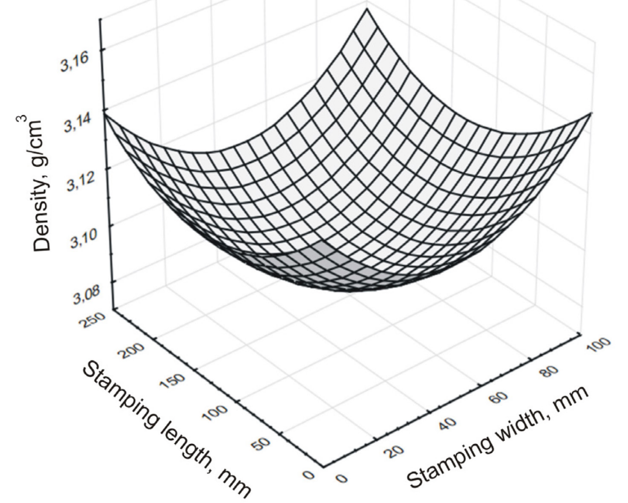

Fig. 10. Distribution of the average material density in Layer G

It turned out that the material density values within stamping volume were diversified. The highest density value was measured in areas adhering to the mould. The material density in stamping areas adjacent to surfaces reproduced by the bottom punch and the plunger was similar. At the same time, it was higher compared to density of the material in layers lying at half height of the stamping.

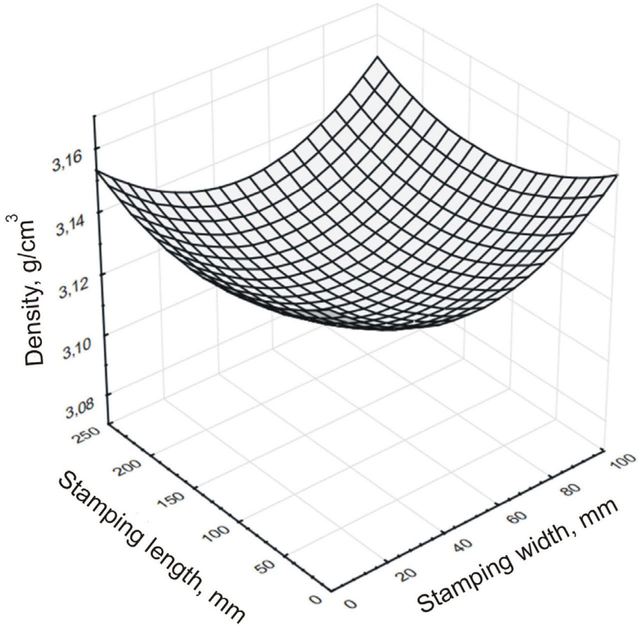

Fig. 11. Distribution of the average material density in Layer L

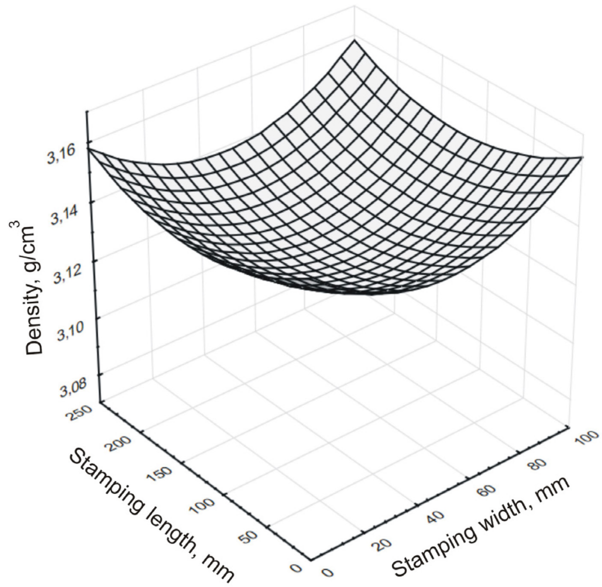

Fig. 12. Distribution of the average material density in Layer M

Assessment of quality of the precast shapes fabricated with the adopted press moulding parameters did not indicate any increase of susceptibility of the stampings to cracking in the course of drying process compared to shapes produced with the use of press moulding parameters adopted previously. On the grounds of this observation, the proposed parameters have been accepted for application in testing the usefulness of new die insert designs.

4. Conclusions

Appropriateness of the choice of parameters adopted for production of stampings press-moulded from refractory materials for the purpose of testing new designs of die inserts has been confirmed, as the stampings did not show any increase of susceptibility to cracking in the course of either removing from the mould or drying.

A characteristic feature of stampings formed for precast refractory shapes is a non-uniform distribution of the material density within volume of the product.

The highest density characterises the material adjacent to corners, edges, and side walls, while the material in inner areas of stampings shows the lowest density values.

Acknowledgements

The study presented in this paper was carried out in the framework of project entitled INNOVATIVE TECHNOLOGICAL PROCESS OF MANUFACTURING MOULDS FOR PRODUCTION OF REFRACTORY MATERIALS co-funded from Operational Programme Innovative Economy, Measure 1.4-4.1 Support for goal-oriented projects and support for implementation of results of R&D works.

References

[1] Encyklopedia Techniki. Metalurgia (1978). Wyd. Śląsk, Katowice.

[2] Segmented die insert for fabrication of stampings. Utility design application No. W 124983.