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HIGH PRECISION DETERMINATION AND STATISTICAL EVALUATION OF SURFACE ROUGHNESS ALTERATIONS OF SELECTED MATERIALS

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Abstract: In practice, ninety percent of the engineering faults initiate from the surfaces by means of the mechanisms of fatigue crack wear behavior, corrosion and erosion. In this point of view, researchers are attracted by measuring surface and near-surface zone suitability of work pieces and evaluation studies. Surface roughness is a factor not only in composing the work piece aspect but also in defining the performance of the work pieces in coating processes. In this study, 3 different test specimens are subjected to molten glass that was in forming temperature and the changing surface roughness parameters have been monitored with precise measuring techniques. The obtained data is evaluated by SPSS 13.0 statistical package program. Results are informative about the product quality either.

Keywords: Mould steel, Surface roughness, Tactile measurement, Statistical evaluation.

1. INTRODUCTION

Surface roughness is an important relevance condition has to be followed carefully especially for forging dies and moulds performances. Beside its performance the surface texture of forcing moulds is also directly affects the quality of the final product. Under this fact, the aim of this work is to find out the surface roughness changes of different mould steels and identify the mould's surface performance in production.

In this study, test specimens consist of DIN 1.2787 stainless steel that is widely used in manufacturing glass household goods, DIN 1.2080 stainless steel specimen and the specimen of the latter material that was surface boronized are being used.

A long life high performance is expected from a finished surface in tolerance limits determined in technical drawings. Formability, hardness, thermal expansion, thermal conductivity, polishing and easy welding capability and corrosion resistance are the general basic specifications expected from glassware moulds. High and sharp surface roughness peaks causes important negative effects not only on the effective lifetime of mould but also product quality. A glass mould is being lubricated rather frequently. This operation prevents the stick of molten glass to the mould material and supplies the cooling of the mould. It is expected from a mould material to have a good capacity of oil retention. Waviness, limits the mould lifetime and product quality, is a major defect not only for glassware group but also for glass containers.

Fig. 1.Initiate and finished surfaces of a glass mould steel

The obtained roughness data is informative about the possible quality of the product either. The mould surface contacts with molten glass means the product at every stage of forming process. Therefore, every negative effect of mould steel moves to the final product and it results as performance losses and lack of conformities not only in manufacturing but also in usage steps of the products. Comparison of surface roughness alterations of different mould steels helps to find an optimum solution of selection of materials which could supply at desired quality surfaces.

The obtained results are very informative about the most important requirements of usage of the steel DIN 1.2080 as a glass mould material like surface roughness alterations and the effects of them to the mould lifetime and final product quality.

The paper follows with the short remind of experiment and the further results of experimental work which detailed in the reference [3].

2. SHORT REMIND OF THE EXPERIMENT

Molten glass (soda-lime-silicon) cullet has contact with mould material at each step of production process. Every negative condition of materials to be carried to the final product and that circumstance occurs as a performance loss at production and usage steps of product. Today boronising is commonly preferred coating operation in glassware production industry to remove such negative effects.

Constructed computer controlled mechanism has an electrical resistance furnace that contains molten glass in and a pneumatically lifting system carrying mould sample supplies the contact of them when required. The samples prepared by high speed machining and hand polishing techniques from rather frequently use glassware mould steels DIN 1.2787 contacted with molten cullet. DIN 1.2080 is another tested material. And the solid boron carbide coated DIN 1.2080 is the third sample has been tested.

Required initiate (before thermal cycling) surface texture parameters are determined with a high precision AFM (Atomic Force Microscope), has 100x100 μm^2 scanning area and 10 µm z axis access capacity, contact type scanning microscope and a precision tactile measurement profilometry, Form Talysurf INTRA. Surface roughness measurements of thermally cycled samples are completed in profilometry. 0, 1.000, 5.000, 10.000 and 15.000th thermally cycled samples R_a, R_{sk}, R_p, R_q, R_{ku}, R_v, R_t, R_z, R_c, W_a, P_a and *mr2%* surface roughness parameters are calculated and evaluated. The profilometry using in concurrent measurement of dimensions, forms and surface conditions of workpieces in 1.0mm range 16nm resolution, a tactile surface inspection device.

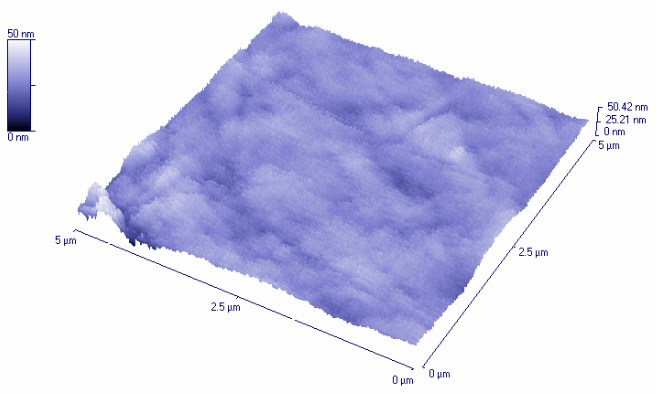
Discussed Parameters:

R_a ; is the universally recognized, and most used, international parameter of roughness. It is the arithmetic mean of the absolute departures of the roughness profile from the mean line.
R_q ; is the root mean square parameter corresponding to R_a,
W_a ; is the corresponding parameter from the waviness,
R_v ; is the maximum depth of the profile below the mean line within the sampling length,
R_p ; is the maximum height of the profile above the mean line within the sampling length,
R_t ; is the maximum peak to valley height of the profile in the assessment length,
R_{sk} ; skewness, is the measure of the symmetry of the profile about the mean line. It will distinguish between asymmetrical profiles of the same R_a or R_q,
R_{ku} ; kurtosis, is a measure of the sharpness of the surface profile,
R_c ; average height of the profiles within a sampling length.
$R_z = R_p + R_v$ and is the maximum peak to valley height of the profile within a sampling length,
P_a ; is the corresponding parameter from the primary profiles,
Mr2 ; is the material ratio corresponding to the lower limit of the roughness core.

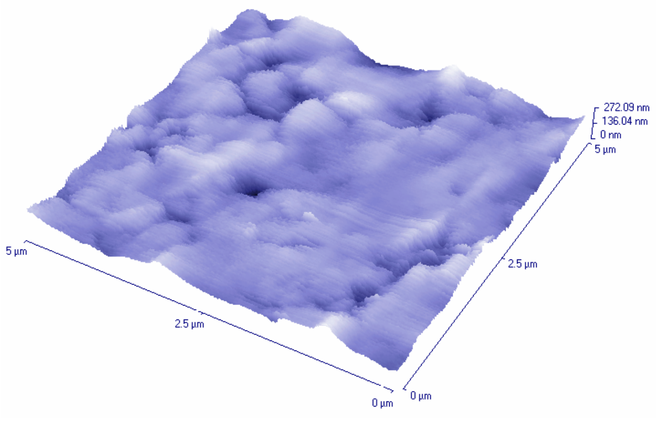
Experimental results are revealed in the following section.

3. EXPERIMENTAL RESULTS AND DISCUSSION

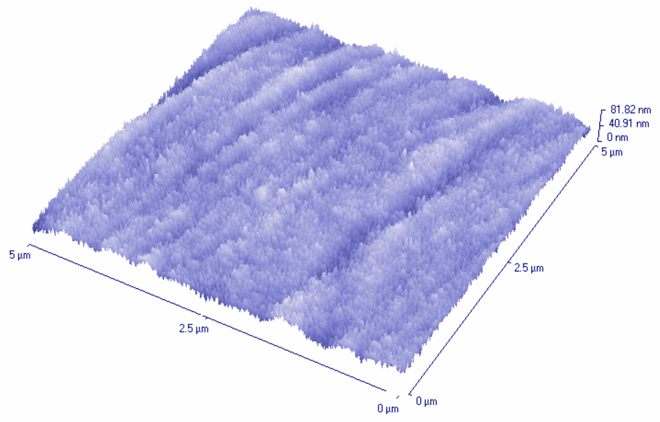
Real surfaces, as a rule, contain at least two levels of asperities, such as waviness plus roughness or roughness plus subroughness. The AFM images represent the surface textures of a metal surface formed by various processes (machining, failure, oxidation etc.).



(a)



(b)



(c)

Fig. 2. a) Initial surface topography of the material 1.2080
b) Initial surface topography of the material 1.2080 / Boronized
c) Initial surface topography of the material 1.2787

The initial data represent the matrix of surface height deviations [4]. The high waviness affinity is visually determined in the third sample (Figure 2/c). The existence of the boride atoms on surfaces like a brittle layer is known as a limiting disadvantage of boronizing applications [5]. Because of the extra thickness of that brittle boride layer on second sample, the beginning surface roughness parameters of sample B are determined greater than the other samples (Figure 2/b).

Table 1. Determined different roughness characteristics of surfaces at selected intervals

DIN 1.2080 (A)												
Number of Cycling	R_a (µm)	R_{sk} (µm)	R_q (µm)	R_p (µm)	R_{ku} (µm)	R_v (µm)	R_t (µm)	R_z (µm)	R_c (µm)	W_a (µm)	P_a (µm)	mr_2%
0 (A)	0,0237	0,3415	0,0682	0,0294	2,9341	0,0531	0,1621	0,1213	0,0779	0,1689	0,0566	95,8
1.000 (B)	0,0445	-0,2026	0,1403	0,0611	6,8142	0,1458	0,4830	0,2860	0,1954	0,2631	0,1474	92,7
5.000 (C)	0,1043	-0,9834	0,2559	0,1388	6,4605	0,3820	1,0317	0,6379	0,3872	0,1409	0,2674	92,0
10.000 (D)	0,1509	-0,1853	0,4645	0,2066	5,9151	0,4953	1,5497	0,9597	0,5952	0,2206	0,2953	90,5
15.000 (E)	0,2412	1,2060	1,0013	0,3433	6,9614	0,6126	2,6104	1,6139	0,9848	0,2708	0,5372	96,7
DIN 1.2080Boronized (B)												
Number of Cycling	R_a (µm)	R_{sk} (µm)	R_q (µm)	R_p (µm)	R_{ku} (µm)	R_v (µm)	R_t (µm)	R_z (µm)	R_c (µm)	W_a (µm)	P_a (µm)	mr_2%
0 (A)	0,1186	-0,2438	0,2994	0,1487	2,9472	0,3491	0,8191	0,6484	0,4029	0,0918	0,2067	91,5
1.000 (B)	0,3893	-0,4734	0,8773	0,4864	3,0716	1,2340	2,6520	2,1114	1,2892	0,1751	0,8087	90,2
5.000 (C)	0,4179	-0,2835	1,0512	0,5267	3,2405	1,2747	3,1395	2,3260	1,4475	0,2824	0,7597	89,7
10.000 (D)	0,3490	-0,8655	0,7139	0,4510	4,1199	1,2101	2,6667	1,9241	1,2614	0,2527	0,5632	88,2
15.000 (E)	0,3497	-0,4440	0,7353	0,4402	3,2825	1,0733	2,5697	1,9085	1,1571	0,3134	0,5864	81,7
DIN 1.2787 (C)												
Number of Cycling	R_a (µm)	R_{sk} (µm)	R_q (µm)	R_p (µm)	R_{ku} (µm)	R_v (µm)	R_t (µm)	R_z (µm)	R_c (µm)	W_a (µm)	P_a (µm)	mr_2%
0 (A)	0,0062	-0,4816	0,0146	0,0079	4,2077	0,0169	0,0478	0,0315	0,0217	0,3037	0,0399	91,3
1.000 (B)	0,0092	-0,0478	0,0241	0,0117	3,5178	0,0250	0,0725	0,0491	0,0322	0,0762	0,0407	85,3
5.000 (C)	0,0465	1,4975	0,1987	0,0735	8,8431	0,1325	0,6495	0,3312	0,2448	0,3689	0,1114	94,5
10.000 (D)	0,1314	0,7897	0,4434	0,1756	5,0083	0,2997	1,1282	0,7432	0,5255	0,6126	0,2292	96,7
15.000 (E)	0,1603	0,4455	0,4734	0,2031	3,4642	0,3483	1,2467	0,8217	0,5238	1,4531	0,2636	95,9

Determined roughness characteristics of surfaces at selected intervals are given in Table 1. Very result in every cell is an arithmetical average of ten, five of at x, 5 of at y direction, measurement results.

There are many research works evaluates the surface roughness parameters determined by different operations using statistical techniques. Some of these works include modeling of surface roughness. Lots of surface roughness alteration parameters of thermally cycled machined surfaces have to be evaluated statistically in order to be used correctly. Chappard et all. (2003) have measured the R_a parameters of differentially machined Ti samples that are used as metal implants by using a tactile profilometry and a scanning electron microscope and have researched the statistically evident correlation between the results. As Muralikrishnan and Raja (2004), have mentioned that surface texture measurements are intended to aid in process diagnostics or functional prediction. They have developed an advanced surface texture analyze system that can analyze multiple profiles and develop cause–effect models for process diagnostics and functional prediction. They have used many different filtering techniques in analyze system and many statistical tests such as t-test and F-test in modeling and process monitoring supplied by clustering the surface texture parameters.

In this work the obtained data have been evaluated statistically by using SPSS 13.0 (Statistical Package for Social Science). Statistical distributions of the obtained data are shown in Table 2. Statistical comparison tools (*t*-test and F-test) are often useful to evaluate the significance of the differences among the groups have also been used. In addition "Analysis of Variance" (ANOVA) technique has been used to analyze whether the Ra parameters are statistically different from each other at different cycles.

Table 2. Statistical distribution of measurement data

	AA	AB	AC	AD	AE	BA	BB	BC	BD	BE	CA	CB	CC	CD	CE
Ra	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Rsk	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
Rp	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0
Rq	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
Rku	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1
Rv	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Rt	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0
Rz	1	0	1	1	1	1	1	1	1	1	1	1	0	1	0
Rc	1	0	1	1	1	1	1	1	0	1	1	1	0	1	1
Wa	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
Pa	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
mr2%	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

1: Normal distribution, 0: Other distributions.

1.2080 Material: Determined R_a parameter measurement values at (0-1.000), (1.000-5.000), (5.000-10.000) and (10.000-15.000) cycles indicates statistically significant difference from each other in %95 confidence interval.
1.2080 Boronized Material: Determined R_a parameter measurement values just at (0-1.000), (5.000-10.000) cycles indicates statistically significant difference from each other in %95 confidence interval.
1.2787 Material: Determined R_a parameter measurement values at (0-1.000), (1.000-5.000) and (5.000-10.000) cycles indicates statistically significant difference from each other in %95 confidence interval.

The measurement results taken according to the measurement direction didn't show significant difference in t-test. Clustering the data supplied by F-test.

4. CONCLUSION

In this experimental work the parameters which could effect the glass container manufacturing moulds performances during process are determined by precision measurement techniques and evaluated. Considering the hypothesis "mould surface roughness parameter value is acceptable" the Likert scale is being created and given in Table 3.

Using the boronized 1.2080 steel as a glass manufacturing mould, it was observed that some of the surface roughness parameters were higher than the other specimens. Contrary to this, in some parameters, affirmative values that increase performance have been monitored.

The number of parameters and their varieties whose alterations are pursued and evaluated, can be increased according to the usage features that are expected from work pieces. Manufacturers could privatize this Table by determining the importance level of related parameters for their manufacturing field.

Table 3. Evaluation with Likert scala

Percentage (%)	Surface Parameter	DIN 1.2080	DIN 1.2080 Boronized	DIN 1.2787
15,00%	R_a	4	3	5
10,00%	R_{sk}	2	5	1
5,00%	R_p	4	2	5
12,50%	R_q	4	2	5
10,00%	R_{ku}	1	5	2
5,00%	R_v	4	1	5
5,00%	R_t	4	1	5
5,00%	R_z	4	1	5
5,00%	R_c	4	1	5
15,00%	W_a	5	5	1
12,50%	*mr2%*	2	1	4
100%	Total Score	**38**	**27**	**43**
	Total Weighted Score	**3,40**	**2,88**	**3,58**

5: Strongly agree, 4: Agree, 3: Neither agree nor disagree, 2: Disagree, 1: Strongly disagree.

In this experiment, parameters scored by considering the predict lifetime for mould and the quality of glassware. The statistical test results are going to serve as the basis of the modelling between the number of cycling and mould surface roughness parameters.

REFERENCES

[1] ISO 4288: 1996, Geometrical Product Specifications (GPS) -- Surface Texture: Profile Method - Rules and Procedures for the Assessment of Surface Texture.

[2] ISO 14660-1: 1999, Geometrical Product Specifications (GPS) -- Geometrical Features -- Part 1: General Terms and Definitions.

[3] Akdogan A.N., Durakbasa M.N., Osanna P.H., Yurci M.E., "Identifying Mould Surface Texture Parameters Experimentally with the Help of Precision Measurement Techniques", ICPM 2005, III. International Congress of Precision Machining, October 18-19, Vienna, Austria.

[4] Myshkin N.K., Grigoriev A.Y., Chizhik S.A., Choi K.Y., Petrokovets M.I., (2003) "Surface Roughness and Texture Analysis in Microscale", Wear, 254:1001-1009.

[5] Meric, C., Sahin, S., Backir, B. ve Koksal, N.S., (2005), "Investigation of the Boronizing Effect on the Abrasive

Wear Behaviour in Cast Irons" Materials and Design, Article in Press.

[6] Chappard, D., Degasne, I., Hure, G., Legrand, E., Audran, M. ve Basle, M. F., (2003), "Image Analysis Measurements of Roughness by Texture and Fractal Analysis Correlate with Contact Profilometry", Biomaterials, 24:1399-1407.

[7] Muralikrishnan, B. ve Raja, J., (2004), "Inference Engine for Process Diagnostics and Functional Correlation in Surface Metrology", Wear, 257:1257-1263.