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USE OF MATHEMATICAL STATISTICS FOR QUALITY CONTROL OF SURFACE LAPPING AND DETECTION OF FRAUD: A CASE STUDY

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ABSTRACT

Advancing international cooperation makes mutual trust and detection of unfair practices increasingly significant. This article attempts to make a case that a series of rejections of purchased products within the framework of commercial transactions between two enterprises was based on manipulation with numerical data. This case study provides an example how mathematical statistics can be used not only for quality control (e.g. lapping of plastic surfaces) but also for detection of unfair practices in the international trade. In general, mathematical statistics is applicable for this purpose, because artificial manipulations with numerical data or specimens can cause deviations from usual distribution patterns of numerical values.

Keywords: lapping; plastic; quality control; mathematical statistics

INTRODUCTION

Forthcoming globalization and broadening international economic relations make mutual trust and detection of unfair practices increasingly important. Previously we reported about this kind of problems in the international trade with medical products (Jargin, 2008). Fraud (Becker et al., 2010), is increasingly widespread in the international economic relations, along with development of modern technology and global communications, which results in the loss of billions of dollars worldwide each year (Richard and Hand, 2002). Although prevention is always preferable, perpetrators are adaptive and find ways to circumvent preventive measures. Methods of fraud detection come to the foreground if prevention fails. Mathematical statistics is one of the tools for detection of unfair practices; it has been applied against money laundering, credit card and telecommunications fraud (Becker et al., 2010), computer intrusions (Richard and Hand, 2002), etc. Eradication of unfair practices is

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complicated additionally by the shortage of laws and regulations recognized by all parties. Fraud detection is an evolving field of applied science; and different statistical methods have been used for that. Among those methods, the following ones should be mentioned in the first place: statistical classification (Hand, 1981; McLachlan, 1992) such as linear discriminant analysis and logistic discrimination (Richard and Hand, 2002; Lachenbruch, 1974). In particular, classification of data as true or fabricated has applications in fraud detection and verification of data samples (Hill, 1999; Kouritzin et al., 2008). More powerful tools e.g. neural networks (Ripley, 1996; Fanning et al., 1995; He et al., 1997) have also been applied for this purpose (Richard and Hand, 2002). However, a more simple approach, such as recalculation and verification of claimed levels of significance (P-values), coefficients of linear correlation or other statistical indices, can also be helpful for detection of manipulations with numerical data or specimens (Jargin, 2009). Another area, where mathematical statistics has been applied, is detection of medical and scientific fraud or scientific misconduct (Ranstam et al., 2000; von Elm, 2007). Previously we reported on manipulations with statistics in medical research (Jargin, 2009). Fraud in medicine is of special significance because it can undermine free health care or medical insurance systems, available to wide sections of the population, overloading insurers with forged bills. Fraud in medicine includes prescription of drugs, therapies or examinations, which are not indicated to a patient according to the principles of evidence-based medicine (Bailey et al., 2011), or registration with the health care authorities of drugs, equipment, diagnostic and therapeutic methods, effectiveness of which has not been proven (Jargin, 2010 a-c). Finally, plagiarism is also an unfair practice; and statistical methods can be applied for its detection (Richard and Hand, 2002). Previously we reported on several cases of plagiarism and misquoting in professional literature (Jargin, 2010d; 2011). This article attempts to make a case that a series of product rejections within the framework of commercial transactions between an enterprise from Russian Federation (below referred to as the Enterprise) and a foreign firm (Manufacturer) was based on manipulations with numerical data or specimens.

The Enterprise regularly purchased from the Manufacturer lapped plastic grids, which are the components of measuring devices produced in Russia under the Manufacturer's license. Several lots of the grids were rejected by the Enterprise, the declared grounds being poor quality of lapping resulting in insufficient flatness of the lapped surface. Corresponding quantities of the grids were delivered by the Manufacturer additionally at no cost. We performed statistical evaluation, demonstrating that the grids out of tolerance were not, as claimed, picked up from the boxes by chance, but most probably were searched out selectively. Another possibility would be trimming or fabrication of the numerical data.

Statement of Inconsistency No. 1.

The statement of inconsistency, issued by the Enterprise, characterizes a rejected lot of 25,000 lapped grids delivered in 18 containers. The rejection of the lot was based on the flatness measurements performed on 72 specimens: 4 specimens selected from each of 18 containers. Selection of the specimens was claimed to be random. According to the usual packaging procedure, distribution of the grids was random as well, being independent of any particular features of the product. The measurements were performed on the basis of 20 points determined by 3-dimensional laser scanning. The index of flatness, characterizing quality of lapping, was defined as a distance from the most protruding point on the surface to the imaginary plane construed on the basis of 20 reference points, determined by the scanning, according to the principle of the minimal sum of all distances from the plane to the points.

For the purpose of the statistical evaluation, the data were subdivided into 18 groups according to the number of containers. The purpose of the evaluation was to determine a probability of the given diversity of the flatness indices, provided that all grids were selected from the containers randomly. The calculations were performed using the GraphPad InStat version 3.00 for Windows, GraphPad Software Inc., San Diego, California, USA. Taken together, the 72 values of all grids were distributed normally ($P > 0.1$) i.e. compatible with the Gaussian distribution, which was confirmed by the Dallal and Wilkinson approximation to the Lilliefors' adaptation of Kolmogorov-Smirnov test (Dallal and Wilkinson, 1986; Dudewicz and Mishra, 1988) using the same software.

Statistical evaluation included the one-way analysis of variance (ANOVA), based on the assumption of normal distribution of the values. Furthermore, a nonparametric Kruskal-Wallis test was applied to the same data. Nonparametric procedures have less power in hypothesis-testing than the parametric ones, if assumption of distribution normality is not violated (Dudewicz and Mishra, 1988). Accordingly, although the Kruskal-Wallis test is less powerful, it permits avoiding the assumption that the data are sampled from a normally distributed totality. The P-values, calculated both by ANOVA and the Kruskal-Wallis test, answer the question, what is the probability that random sampling of the grids from containers would result in the mean values, characterizing the grids in singular containers, as far apart as given.

Results of the one-way ANOVA: the P value is < 0.0001, considered extremely significant. Accordingly, it is extremely improbable that the observed differences in the mean values are due to a coincidence of random sampling.

Results of the Kruskal-Wallis test: the P value is < 0.0005, also extremely significant. Therefore, the variability of the mean values of the flatness indices is significantly higher than it could be expected to be by chance. If all the specimens belong to the same sample i.e. had been manufactured from the same material by identical technological procedures, the probability that the specimens were selected from the containers randomly would be less than 0.05 %. Accordingly, the null hypothesis, implying that there are no significant differences between grids from different containers, was tested by the ANOVA and a non-parametric method (Damon and Harvey, 1987).

The results of the evaluation permitted rejecting the null hypothesis with a high level of probability. Therefore, an alternative hypothesis should be accepted, i.e. that there were significant differences between the containers. Considering that all grids were manufactured of the same material by identical processing, these differences could have been caused either by data fabrication or by intentional searching out of defective grids.

Statement of inconsistency No. 2.

The Statement of inconsistency No. 2 describes a rejected lot of 67,500 lapped grids delivered in 18 containers (the figures are in the Appendix). The rejection of the lot, as in the first case, was based on the surface flatness measurements performed on 36 specimens: 2

specimens taken from each of the 18 containers. Selection of the grids was declared to be random. The measurement procedure was the same as above. Taken together, all 36 flatness values were distributed normally (Gaussian distribution) according to Dallal and Wilkinson (1986) approximation to the Lilliefors' adaptation of Kolmogorov-Smirnov Test ($P > 0.1$). As only two specimens were selected from each box, the ANOVA and the Kruskal-Wallis test were only marginally efficient. Nevertheless, the results were similar to those presented above for the Statement of inconsistency No. 1.

Results of the one-way ANOVA test: $P = 0.0106$, considered significant. Accordingly, the variation of the mean flatness indices is significantly higher than it could be expected by chance. Kruskal-Wallis test: $P = 0.0682$, which is near to the generally accepted level of statistical significance ($P = 0.05$).

To provide more evidence, another approach was used, based on the following. Among the main factors defining quality of lapping are processing time, a force applied to the polishing instrument, its rotation speed, contact temperature, as well as characteristics of the abrasive, in particular, its grit i.e. average size of abrasive grains (Ermakov, 1982; Pilinsky and Donets, 1986; Obeid, 2005a,b). Protrusions and other surface irregularities, significantly bigger than the grains of the abrasive, are being cut off in the process of lapping. Other parameters (processing time, speed etc.) being equal, roughness of the lapped surface depends on the grain size of the abrasive (Obeid, 2005a,b). Consequently, a distribution curve of surface flatness indices, characterizing randomly selected grids, must have a maximum, defined by the grit, with the slopes on both sides of the maximum. Accordingly, the following correlations between frequencies of the flatness indices and the absolute values of those indices should be expected (provided that the grids had been taken at random): a positive correlation from the minimal up to the mean value and a negative correlation from the mean value to the maximal one. Two sets of grids were used for this purpose: the first set of 36 specimens selected from the totality of 67,500 grids (Statement of inconsistency No. 2); and the second set of 150 grids, used as a control, randomly selected from boxes of an accepted lot of grids, where all measurements were performed by the Manufacturer.

1st set. 36 grids from the totality of 67,500 grids. The mean value of the flatness index is 0.0158 mm, standard deviation is equal to 2.

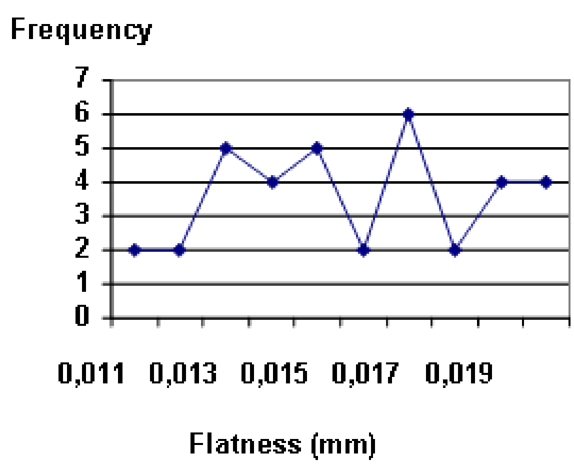

Figure 1. Flatness indices and their absolute frequencies determined on 36 grids from the rejected lot.

Further, the distribution curve shown on the Diagram (Figure 1) was subdivided into 2 parts before and after the mean flatness value. Coefficients of linear correlation between the absolute values of the flatness indices and their frequencies were calculated separately for the first and the second part of the curve. For the first part of the curve, the coefficient of linear correlation was r = 0.26, which is a weak correlation, statistically insignificant for the given number of correlation pairs (n =10).

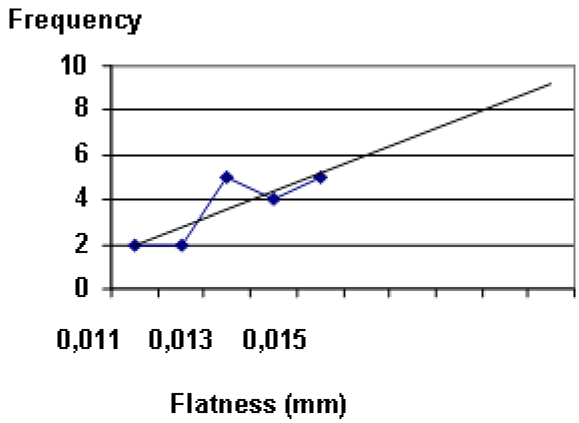

Figure 2. First part of the curve shown on the diagram 1: a weak positive correlation between the flatness index values and their absolute frequencies: r = 0.26 (statistically insignificant).

For the second part of the curve, the coefficient of linear correlation is r = 0.094 (i.e. the expected negative correlation was not confirmed).

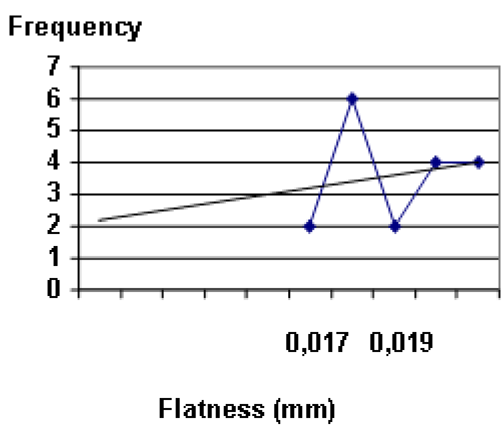

Figure 3. Second half of the diagram 1: weak statistically insignificant correlation between the flatness index values and their frequencies (r = 0.094).

2nd set (control). Mean flatness index = 0.0105, standard deviation = 0.85. The calculated coefficients of linear correlation for the first (ascending) and the second (descending) parts of the curve were, correspondingly, r_1 = 0.9178 and r_2 = -0.921, which means that, as expected, the strong and statistically significant correlations were found both for the first and for the second parts of the curve.

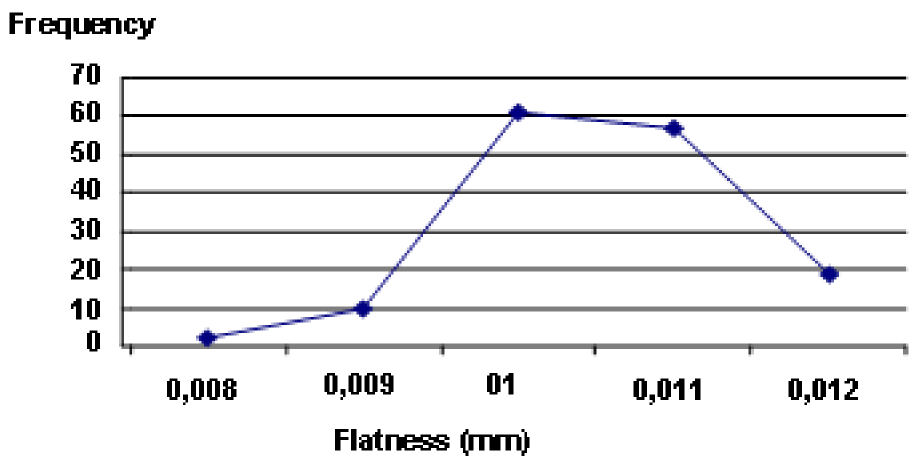

Figure 4. Flatness indices and their frequencies among 150 grids from an accepted lot.

CONCLUSION

The numerical data, presented in both inconsistency statements as a reason for rejection of the purchased lots of plastic grids, are inaccurate and probably have been modified artificially. Should control measurements confirm that the values were accurate, it would mean that selection of the grids was not random and, probably, occurred with deliberate searching out of specimens out of tolerance. This case study demonstrates that mathematical statistics can be used for detection of unfair practices in the international trade. In conclusion, mathematical statistics is useful for this purpose, for example, for classification of sequences as real or faked (Kouritzin et al., 2008), because artificial manipulations with numerical data or specimens might cause mismatch and deviations from usual distribution patterns.

APPENDIX

The Statement of Inconsistency (translation from Russian)

Comment: This Statement was referred to as the Statement of Inconsistency No. 2 in the text of this article. Names of the enterprises and dates were removed to prevent recognition.

1. Data on the inconsistent items

Entrance inspection
Product denomination: Lapped Grid
Quantity: 67.500 pieces. Quantity inspected: 36 pieces.

2. The substrate of the inconsistency

Description of the inconsistency

Requirements of the Normative Document	Inspection Results
General flatness of the lapped surface - 12 μm	Measured by means of the device “Mistral” two specimens from each of 18 packages 13 μm - 5 pieces 14 μm - 4 pieces 15 μm - 5 pieces 16 μm - 2 pieces 17 μm - 6 pieces 18 μm - 3 pieces 19 μm - 3 pieces 20 μm - 4 pieces (4 pieces within norm limits < 12 μm)
No defects are admissible	2 pieces - chipping on the lower surface

Resolution on the Rejection of Components and Materials

The lot is to be returned to the Manufacturer as inconsistent with Technical Conditions.

Lapped Grids

Measurements of the general flatness performed on 2 specimens from each package.

The measurements have been performed by means of the Measuring Device “Mistral” using 20 points

Package-No.	Specimen No. 1	Specimen No. 2	Measurements according to the charts of the Manufacturer
1	0,017	0,019	
2	0,020	0,014	0,011
3	0,019	0,019	
4	0,017	0,018	
5	0,015	0,016	
6	0,016	0,015	
7	0,017	0,013	
8	0,015	0,011	
9	0,013	0,014	
10	0,013	0,015	
11	0,017	0,019	
12	0,020	0,020	
13	0,014	0,017	0,012
14	0,017	0,018	
15	0,015	0,020	
16	0,014	0,012	0,010
17	0,012	0,013	
18	0,011	0,013	

REFERENCES

Bailey, C.S., Fehlings, M.G., Rampersaud, Y.R., Hall, H., Wai, E.K., Fisher, C.G. (2011), "Industry and evidence-based medicine: Believable or conflicted?" *Canadian Journal of Surgery*, 54(5), 321-326.

Becker, R.A., Volinsky, C., Wilks, A.R. (2010), "Fraud detection in telecommunications: history and lessons learned", *Technometrics*, 52(1), 20-33.

Bolton, R.J., Hand, D.J. (2002), "Statistical Fraud Detection: A Review", *Statistical Science* 17(3), 235-255.

Dallal, G.E., and Wilkinson, L. (1986). An analytic approximation to the distribution of Lilliefors' Test statistic for normality. *American Statistician* 40 (4), 294-296.

Damon, R.A., Harvey, W.R. (1987), "*Experimental design, ANOVA, and regression*", New York: Harper and Row.

Dudewicz, E.J., Mishra, S.N. (1988), "*Modern mathematical statistics*", New York: John Wiley and Sons.

Ermakov, Yu.M. (1982), "*Perspectives of effective application of abrasive treatment*", Moscow: NIIMash. (in Russian).

Kouritzin, M.A., Newton, F., Orsten, S., Wilson, D.C. (2008), "On detecting fake coin flip sequences", In: Ethier, S.N., Feng, J., and Stockbridge, R.H., Editors. Markov Processes and Related Topics: A Festschrift for Thomas G. Kurtz. Beachwood, Ohio: Institute of Mathematical Statistics, 107-122.

Jargin, S.V. (2011), "Overestimating Chernobyl's consequences: motives and tools", *Disaster Medicine and Public Health Preparedness*, 5, 175-176.

Jargin, S.V. (2010a), "Shock wave therapy of ischemic heart disease in the light of general pathology", *International Journal of Cardiology*, 144(1), 116-117.

Jargin, S.V. (2010b), "Radioprotective properties of water with low content of stable isotopes: critical evaluation" *Fiziologia-Physiology*, 20.4(68), 30-40.

Jargin, S.V. (2010c), "Testing of anti-atherogenic drugs and food components on cell cultures: assessment of reliability", *Puerto Rico Health Sciences Journal*, 29(1): 86-87.

Jargin, S.V. (2010d), "Plagiarism in radiology: A substitute for importation of foreign handbooks", *Journal of Medical Imaging and Radiation Oncology*, 54(1), 50-52.

Jargin, S.V. (2009), "Manipulation with statistics in medical research", Dermatopathology: Practical and Conceptual, 15(1), 21. Available at: http://derm101.com/abstract/32761

Jargin, S.V. (2008), "Barriers to importation of medical products in Russia", *Lancet* 372(9651), 1732.

Fanning, K., Cogger, K.O., Srivastava, R. (1995), "Detection of management fraud: a neural network approach", *Proceedings the 11th Conference on Artificial Intelligence for Applications.* IEEE Computer Society Press, 220-223.

Hand, D. J. (1981), "Discrimination and Classification", Chichester: John Wiley and Sons.

He, H.X., Wang, J.C., Graco, W, Hawkins, S. (1997), "Application of neural networks to detection of medical fraud". *Expert Systems with Applications*, 13, 329-336.

Lachenbruch, P. A. (1974), "Discriminant analysis when the initial samples are misclassified. II: Non-random misclassification models", *Technometrics*, 16(3) 419-424.

McLachlan, G. J. (1992), "*Discriminant analysis and statistical pattern recognition*", New York: John Wiley and Sons.

Obeid, A. (2005), “Dynamics evaluation of the surface roughness of glass VK7 and TF1 in the process of surface lapping”, *Opticheskii Zhurnal*, 72(12), 79-82. (in Russian)

Pilinsky, V.I., Donets, I.P. (1986, “*Productivity, quality and effectiveness of high-speed grinding*”, Moscow: Mashinostroenie. (in Russian)

Ranstam, J., Buyse, M., George, S.L., Evans, S., Geller, N.L., Scherrer, B., Lesaffre, E., Murray, G., Edler, L., Hutton, J.L., Colton, T., Lachenbruch, P. (2000),” Fraud in medical research: an international survey of biostatisticians”, ISCB Subcommittee on Fraud. *Controlled Clinical Trials,* 21(5), 415-427.

Ripley, B. D. (1996), “*Pattern recognition and neural networks*”, Cambridge University Press.

von Elm, E. (2007), “Research integrity: collaboration and research needed”, *Lancet,* 370, 1403-1404.