

# Utilization of cluster analysis in the multi-dimensional evaluation of mould surface quality in product correlation

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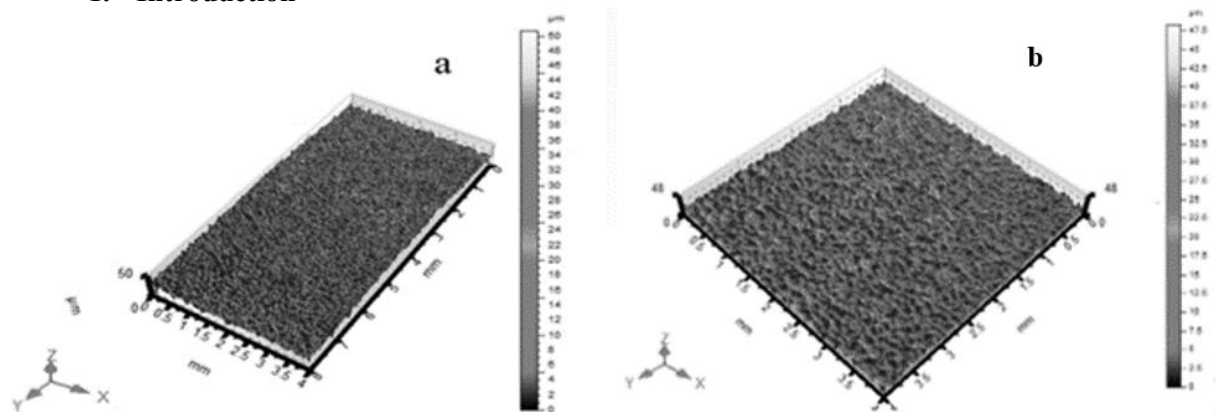
**Abstract.** Quality assessment of mould surfaces, of the products they produce is often done in both scientific and industrial practice separately and without considering the links of the individual descriptive parameters.

The present article will describe how to find amplitude, frequency parameters that will be grouped into so-called parametric sets. Each parameter set will be characterised by its values for both the mould and the product it produces.

The final step is to apply cluster analysis and to determine the similarity of the individual sets of parameters between the form and its product.

Therefore, the presented methodology will provide complex correlation evaluation of products and mould not by individual parameters but within the whole set of parametric sets.

## 1. Introduction



**Figure 1** 3D surface a) form, b) product

A classic approach to assessing compliance is to use hypothesis testing, individual parameters independent of each other. This, however, leads to the following problem, for example, I do not ignore the match of the  $R_p$  and  $R_v$  parameter between the form and the product, but I will reject the match between Parameters  $R_z$ , which is the sum of  $R_p$  and  $R_v$ . The same problem is even when using 3D parameters, such as  $SP$ ,  $S_v$  and  $S_z$  [1].

However, scientific practice requires a much more complex approach, such as solving the question of the consistency between the set of  $R_a$ ,  $R_z$ ,  $R_p$  and  $R_v$  parameters between form and product.



Here is the possibility to directly visualise the form (the form is small, and the weight is low) and it is rarely possible to capture this form. After the mould and product have been developed at an equivalent site, it can be said that the parameter has very different results [1,3].

Looking at the statistical results obtained directly through the TalyMap program, we see differences in diameters and direction. The deviations generally differ in tenths of microns to units of micrometres. However, we are not able to determine with what probability the results have been determined, whether they contain gross errors, whether the skewness or spike of the individual parameters differs significantly from one another and above all the data come from the normal distribution [1,4].

This type of results, which is often presented at scientific conferences, can only be considered as indicative in view, similar to 3D graphics scenes.

If we evaluate the parameters precisely in the sense of mathematical and statistical rules, we find that the parameters of skew and spikes fluctuate at a 95% confidence level between insignificant and significant differences from the normal distribution. Normality is often not observed at all. Such types of heterogeneous data cannot be solved using classical averages and direction. Deviation (as is often the case), but it is necessary to use data transformations that give much more accurate results [1,8].

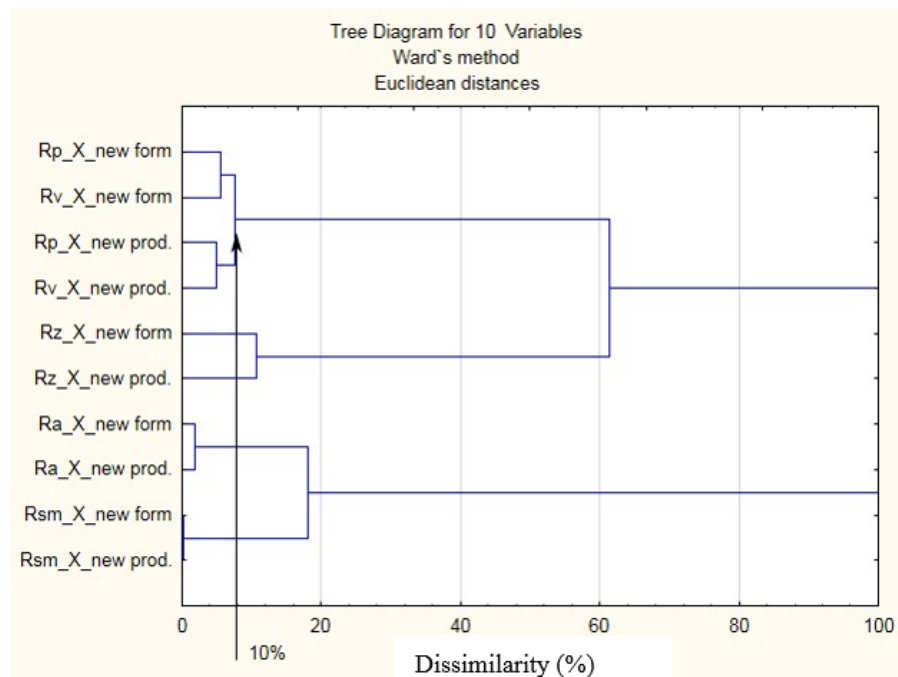
## **2. Material and method**

If we want to evaluate complex amplitude and frequency parameters, between form and its product, it is appropriate to use multidimensional statues, methods, in particular, factor analysis and cluster analysis.

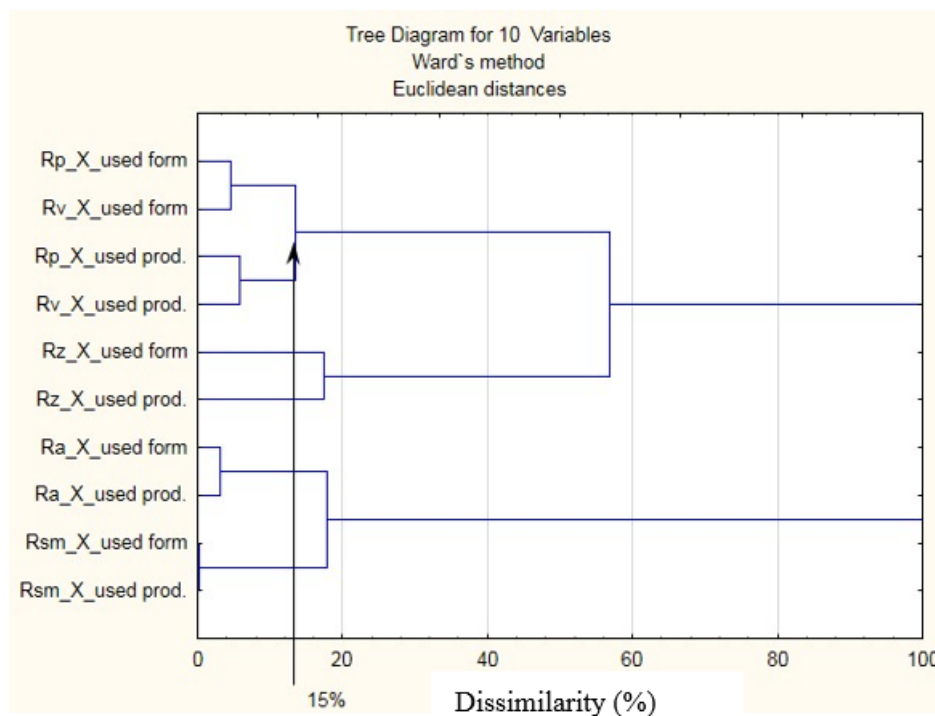
Subsequently, the use of factor analysis, in particular, the diagram of the footnote of own numbers. On this diagram, it is quite clear that when using the Kaiser criterion, only two factors will be sufficient to describe all parameters, as is evident from the graph of factor loads. Thus, using factor analysis, namely the Varimax method, we can state that the parameters describing the surface quality of the mould and the product form 2 separate clusters that differ in their external correlation.

Both clusters are factor-net - they have a high projection value in the factor axis and the minimum projection value in the axis of the opposite factor [1,2].

Finally, after factor analysis, we can assert that for the description of 8 surface quality parameters it is sufficient to describe only two factors [1,5].



**Figure 2** cluster analysis for the new form and its product



**Figure 3** cluster analysis for the form used and its product

This problem helps us solve cluster analysis, specifically Ward's method, using the so-called Euclidean distance calculation.

Clusters were found between the parameters describing the surface quality of the new mould and the product of the mould.

It is possible to state, based on the distance matrix, the degree of similarity of the individual parameters describing the quality of the mould surface and the product formed from that place.

As a measure of quality, the increasing or decreasing value of Euclidean distances, which is dimensionless, can be used between individual parameter aggregates.

It is also possible to see here for a better understanding of the binding of individual parameters merged into corresponding clusters.

For example, it can be seen that the cluster of parameters  $R_p$  and  $R_v$  measured on the product of the new form is similar to the cluster of parameters  $R_p$  and  $R_v$  in the new form.

This disparity is expressed either by dimensionless numbers or by percentage. Looking at our dendrogram, we can say that the unity of the first and second clusters of the new form and its product is approximately 10%. (90% similarity for  $R_p$  and  $R_v$ ) (see fig.2).

In the case of a product of the mould used, this same cluster is dissimilar to 15% (see fig.3), and it can be stated that the parameters  $R_p$  and  $R_v$  of the mould and product used are less similar to those of  $R_p$  and  $R_v$  in the new form of product

Similarly, the percentage disparity is expressed for the other clusters.

### 3. Conclusion

Using cluster analysis, specifically Ward's method, using the so-called Euclidean distance calculation, clusters were found between the parameters describing the surface quality of the new mould and the mould used and the products formed in these forms.

Within individual clusters, we can say that the parameters  $R_p$ ,  $R_v$  and  $R_a$  respectively form similar clusters based on the calculation of distance by the Euclidean method.

The similarity of parameters based on arithmetic averages and parameters generated by summaries, expressed by the distance in the assessment of the worn form and the product from this worn form.

Parameters  $R_z$ , which are the function of parameters  $R_p$  and  $R_v$ , form a separate cluster that is unlike the parameters  $R_a$  and  $R_{sm}$ , which are the function of arithmetic means.

Based on the distance matrix, it is possible to state the degree of similarity of the individual parameters describing the surface quality of the new mould and the resulting product (4.3) and the surface of the mould and product used (4.4).

As a measure of quality, the increasing or decreasing value of Euclidean distances, expressed as a percentage, between individual parameter aggregates can be used.

Factor analysis has shown that the product varies from one form to another, but the differences have not been proven. It has only been demonstrated that there is a higher correlation between product and form related parameters.

This means that the methodology recommended by prof. Whitehouse is no longer sufficiently prominent and only applies to surfaces that are scanned in the form of separate cuts (contact profilometer).

For spatial (non-contact) scanning, this method is inadequate because we evaluate several parameters that have arisen in a different mathematical way.

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