QUALITY LOSS FUNCTION FOR MACHINING PROCESS ACCURACY

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"An article of good quality performs its intended functions without variability, and causes little loss through harmful side effects, including the cost of using it." Genichi Taguchi

Abstract. *The main goal of the paper is to propose new quality loss models for machining process accuracy in the classical case "zero the best", MMF and Harris type. In addition a numerical example illustrates that the choose regression functions are directly linked with the quality loss of manufacturing process. The proposed models can be adapted for the "maximal the best" and "nominal the best" cases.*

Key words: *quality loss function; accuracy, MMF and Harris models*

1. Introduction

"Each machining operation creates a feature which has certain geometric variations compared to its nominal geometry. One needs to estimate accuracy of various manufacturing processes in order to verify whether or not a given process plan will produce the desired design tolerances. In machining, various factors such as deformation of the workpiece and tool, vibration, thermal deformation, inaccuracies of machine tool, etc., affect the machining accuracy "[12]. Therefore it is an important factor of manufacturing process quality, with big influences on costs and needs an association between the accuracy and costs. The Taguchi's methods in the engineering area were an inflexion point in the quality development in research and design. "The quality loss function gives a financial value for customers' increasing dissatisfaction as the product performance goes below the desired target performance."[6] The quality quantification paradigm proposed by Taguchi is based on two fundamentals concepts: the quality loss function and the signal/noise ratio [7]. The rationale of Taguchi's loss function is that all the characteristics having different units of measurement and varying magnitude of scale can be converted into a single value, loss score. Another advantageous property of the loss function is that it becomes increasingly large as the value deviates from the target value [3]. There are many loss functions (cost functions) proposed and studied in the scientific papers, as models for different industrial and economical processes. The quality loss functions try to estimate the loss of the quality in financial terms [9]. Briefly speaking those functions transform quality losses in costs.

A quality loss function describes a dependency between a quality index (loss of quality) and costs. The especially simple functions proposed by Taguchi, starting with the very well known quadratic model, have guaranteed a wide spreading of applications. Those models have usually little connections with the variation of the quality characteristics.

Depending of type of quality characteristic there are three categories of quality loss models [7]:

the-smaller-the-better (*S*-type)
the-larger-the-better (*L*-type)
the-nominal-the-best (*N*-type.)

In the case of *S*-type loss functions, quality losses appear due to highest-as intended outcomes. In the *L*-type quality losses appear due to lower -as intended outcomes [1]. In the *N*-type case, the target specification is fixed. Taguchi postulated the quality loss to be zero if and only if the product is on target, increasing function with growing the distance from the target, and can be different to the left or to the right of target point. For *N*-type loss functions Taguchi used quadratic approximation for the loss function, as model for measuring losses of society including the loss of the producer and that of the customer [1]. The success of this modeling is once mainly given by the simple mathematical formulations, easy to apply. On the other side this is a boorish fitting: a deficiency of a consistent link with the analyzed process and the unbounded values at the end of the interval.

2. Study case

In view of given an example it will be used as per ISO 1708 – 1997: Reception conditions for normal lathes of general use – the precision control the P1 checking: the cutting of the cylindrical sample parts fixed in the chuck, where one of values taken into consideration is the constancy of the processed diameters, namely the difference among the diameters processed at the ends of the sample part, measured in the same axial plan [5]. The standard provides for this check a tolerance of 0.02mm for precision lathes and 0.04mm for other types of lathes (in the calculations presented here below this last higher value will be taken into account). This problem ranges in the set of lost functions zero centered, from theoretical reasons. This shows that the variable x, which is the registered deviation, has zero as its target value [5].

An example of classical Taguchi function who stats these nonmathematical conditions in analytical language, noted L(x), is:

$$L(x)=K(x-0)^2 \qquad (1)$$

where: x is the quality characteristic; 0 - target value; K – quality loss coefficient, depending on the analyzed problem.

Regression is a conceptually simple technique for investigating functional relationship between output and input decision variables of a manufacturing process and may be useful for process data description, parameter estimation, and control [2]. An important application of regression analysis is concerned with the economic aspects of the manufacturing processes [4].

The regression curves obtained from the numerical data were applied for the estimation of machining accuracy.

The distribution analysis of experimental data points indicated that curve profiles can be described more adequately different of the degrees of curvature of the curves.

In this paper were used the following functions:

Harris model

$$y = \frac{1}{a+bx^c}$$

For the experimental data it results:
a = 114,66 *b* =-127,98, *c* = 0.03654

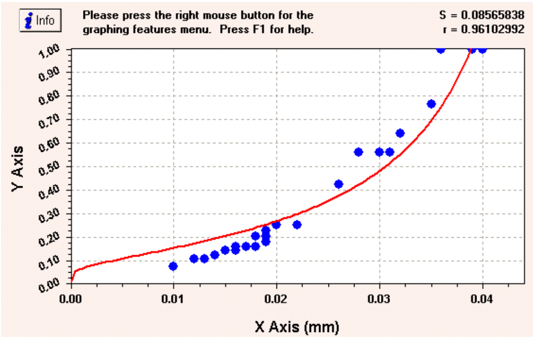

Fig. 1.*The empirical failure function Harris for the experimental data*

MMF model

$$y = \frac{ab + cx^d}{b + x^d}$$

For the experimental data it results:
a = 0.0108; *b* = 0.0077; c=13.5155;
d=2.2810

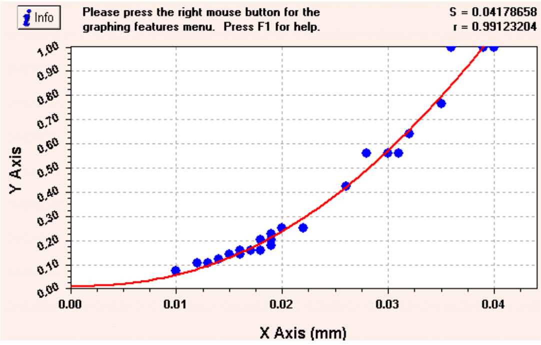

Fig. 2.*The empirical failure function MMF for the experimental data*

The different values for r (correlation coefficient) and s (experimental standard deviation):
r=0.961; s=0.0856 for Harris model; r=0.991; s=0.0418 for MMF model
give an clear advantage for MMF model, that should be adopted as quality loss function.

3 **Conclusions**

In the paper following issues will be pursued:
the study of the link between machining accuracy and costs;
the comparative analysis of the proposed models for experimental data;
the identification of most adequate stochastic law.

The best results were obtained with the adaptive MMF model, since, for example, the values of the correlation coefficient are in most of the cases closed to one. Hence the modeling by truncated shifted models on a given interval represent adequate quality loss functions for " zero the best" case.

The studied case for machining accuracy presents a process with convex curvature, which is properly for the machine-tools with medium accuracy.

The analyzed laws prove their efficiency if are applied in the design stage. To conclude, in this paper we proposed adaptive stochastic distributions for describing the loss functions in the usual manufacturing models [5]. The results that we obtained show that our approach has practical application in the design of actual strategies, allowing, moreover, for prediction of production costs [10].

The results can be extended in the n-dimensional space, taking into consideration multidimensional variables with/without the potential interactions, which can cause a fraction of quality loss too [5], [8]. The results should be applied in the reliability area too [11].

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