Generating ideal reference geometry for cutting edges

Abdullah Karatas\textsuperscript{1} and Jörg Seewig\textsuperscript{1}

\textsuperscript{1}University of Kaiserslautern, Department of Mechanical and Process Engineering, Institute for Measurement and Sensor-Technology, Gottlieb-Daimler-Str., Building 44, D-67663 Kaiserslautern, Germany
E-mail: karatas@mv.uni-kl.de

Abstract. In the last years, many different techniques for rating cutting edges were presented. Nevertheless an automatic measurement and indication of quality from cutting edges was covered less attention. Although the state of cutting edges is very important in many cases during the manufacturing process. An automatic indication of quality can roughly be realised in three steps. The step, generating an ideal reference geometry from measured data, will be discussed in this paper. Therefore different types of splines and a robust filtering method is used. The other two steps, mainly measuring and estimating quantification parameters, were discussed in diverse sources.

Keywords: Cutting edge, ideal reference geometry, robust Gaussian filter, Splines

1. Introduction

Due to improvements in the field of measurement techniques and manufacturing methods characterization of cutting elements comes to the fore. Different techniques for characterising and rating cutting edges were presented, e.g. in [1] and [2], however no standard to characterise cutting edges exists so far [3]. Besides, approaches for an automatic estimation get less attention. To realise this, three main steps are necessary. In the first step, measured data are required. Since an areal-measured topography is needed, an optical measurement system is a good choice. To estimate qualified parameters in the third step a ideal reference for cutting edges is necessary. If there is an ideal reference available a simple least square optimization problem for the orientation between the measured and reference data is solved. Therefore, the ideal geometry and the measured data can be compared with each other since both data share the same position and orientation. If an ideal reference geometry is not available, the measured data will be used to generate automatically an ideal reference which is the main topic of this paper. For the last step, estimating significant parameters, several publications are available [4], [5], [6], [7].
Generating ideal reference geometry for cutting edges

(a) The rounded area of a cutting edge and its ideal reference is pictured. Areas with defects are located and corrected.

(b) One large defect of a cutting edge was detected by the algorithm. Significant parameters can be estimated in the following step.

(c) Ideal reference geometry and measured data for a larger dataset. The cutting edge does not continue as a straight line and has a more complex geometry.

Figure 1: Examples of measured data and ideal references for cutting edges. In fig. 1a the rounded area of a cutting edge is shown. In fig. 1b a large defect is pictured and in fig. 1c measured data and the reference geometry for a larger dataset.

2. Generating ideal reference geometry

To describe the generation of ideal reference geometries for cutting edges some basic fundamentals in interpolation methods and robust filtering are essential. For a detailed description of the using tools, mainly different types of splines and the robust Gaussian filter of 2nd order, [8], [9] and [10] are recommended. Besides the used robust Gaussian regression filter of 2nd order is in its current definition an ISO standard [11]. To generate an ideal reference geometry for cutting edges measured data $X, Y, Z \in \mathbb{R}^{m \times n}$ are required where $m$ are the number of measurements in $y$ and $n$ the number of measurements in $x$ direction, see fig. 1. Not all measured data are complete and are therefore undefined expressions. To fill up these, a cubic hermite spline is applied. Therefore the implementation from MATLAB was used [12]. The advantage of this method is the independence of an additional parameter and a more realistic curve progression. Furthermore it is an interpolation method and the original measured data are unmodified. To compensate small noise components a robust Gaussian regression filter of 2nd order for all $(x_j, z_j)$-planes with $j = 1, \ldots, n$ was used next. Therefore a small nesting index for the Gaussian regression filter was chosen. Thus the contour can be followed with all existing defects. Afterwards, if defects exist, areas, start and endpoints of defects are detected for all considered planes, see fig. 2 and in particular fig. 2b. To optimise the algorithm and searching speed, the start and endpoint are searched near the maximum value of $z_j$ in the $(x_j, z_j)$ plane. Using this, the index value for all planes are noticed. An overview therefore is pictured in fig. 2. In fig. 2a a
Generating ideal reference geometry for cutting edges

(a) Cutting edge in the \((x, z)\)-plane without a defect. Start- and endpoint will not be defined.

(b) Cutting edge in the \((x, z)\)-plane with a defect. Start and endpoint will be defined.

(c) Cutting edge in the \((x, z)\)-plane without a defect but an arbitrary contour line.

Figure 2: Cutting edge for an arbitrary \((x, z)\) plane

cutting edge in the \((x_j, z_j)\) plane with no defects is pictured, where in fig. 2b an other \((x_{\tilde{j}}, z_{\tilde{j}})\) plane with defects and defined starting and ending point is shown, in which \(j, \tilde{j} \in \{1, 2, \ldots, n\}, j \neq \tilde{j}\). The index information for start and endpoints of defects allows a transition between the nesting index of the Gaussian regression filter of 2nd order and is used for all \((y_i, z_i)\) planes with \(i = 1, \ldots, m\). Therfore complex and arbitrary contour lines can be followed, see fig. 2c. For areas with strong defects a higher nesting index for the Gaussian regression filter was chosen. In the last step a bicubic smoothing spline with a fixed smoothing parameter was selected. These allows a smooth surface for the reference geometry since only cuts along the \((x_j, z_j)\) respectively \((y_i, z_i)\) plane are considered before.

3. Results and Summary

To verify this approach measured data of different cutting edges were tested, see. fig. 3. Cutting edges with varying form and partially heavy damages can be seen e.q. in fig. 1a, fig. 1b and fig. 3. The damages were detected and the ideal reference geometry was created. In fig. 1c a bigger range of the measured data and of the reference geometry is pictured. The presented cutting edge does not continue as a straight line and has not negligible damages. Also therefore the algorithm generates an ideal reference geometry. In fig. 3 different types of cutting edges and there generated ideal reference are pictured especially fig. 3a and fig. 3b are different types of cutting edges where one continue as a straight line. In fig. 3c the measured data have many undefined expressions. Nevertheless, for all different types and existing undefined expressions an ideal reference can be generated. Afterwards a estimation of significant parameters for cutting edges can be realised. The view of all \((x, z)\) planes is neccessary since the pass between areas with and without damages needs different nesting indices for the robust Gaussian regression filter. Therefore an arbitrary contour can be followed with a small nesting index where for areas with damages a larger nesting index for the robust Gaussian filter of 2nd order is chosen, see fig 2. A good example for an arbitrary contour is shown in fig. 2c. In summary, a combination of different spline types and robust Gaussian filtering of 2nd order can successfully generate an ideal reference geometry by
Generating ideal reference geometry for cutting edges

(a) Measured data of a cutting edge with a complex contour and defects and its generated ideal reference geometry.

(b) Measured data of a cutting edge with larger defects and its generated ideal reference geometry.

(c) Measured data of a cutting edge with many undefined expressions and its generated ideal reference.

Figure 3: Different types of cutting edge and there automatically generated ideal references geometry.

only using the measured data.

References

[1] Prantl M, Danzl R and Helmli F 2009 Optische 3D Messung der Schneidkantenverrundung F. Tikal (Eds.), Schneidkantenpräparation, Ziele Verfahren und Methoden (Kassel University Press, Kassel) pp 163-179.
[2] Hainich R 2009 Optische Messtechnik von Schneidkanten F. Tikal (Eds.), Schneidkantenpräparation, Ziele Verfahren und Methoden (Kassel University Press, Kassel) ISBN 978-3-89958-494-3, pp 146-162.
[3] Bauer C and Hahne S 2017 Komplexe Geometrien mit nur einem optischen Messsystem vermessen Gröger S and Weißgerber, XIV. Internationales Oberflächenkolloquium - XIV. International Colloquium on Surfaces (Universitätsverlag der TU Chemnitz) pp 145-154.
[4] Robert Bosch GmbH 2015 Prüfung von Werkstückkanten mit unbestimmter Form Bosch-Norm N42AP 621, Gerlingen, Firmenschrift
[5] Denkena B and Biermann D 2014 Cutting edge geometries CIRP Annals Manufacturing Technology pp 631-653
[6] Yussefian N and Koshy P 2013 Parametric characterization of the geometry of honed cutting edges Precision Engineering pp 746-752
[7] Zind S and Dültgen P 2012 Kantenspezifikation durch Volumenelemente XIII. Internationales Oberflächenkolloquium: 1. IMSAS-Treffen, Hrsg.: Gröger S and Dietzsches M, Universitätsverlag Chemnitz, pp 79-86
[8] Dahmen W and Reusken A 2006 Numerik für Ingenieure und Naturwissenschaftler (Berlin: Springer)
[9] Boor C de 1978 A Practical Guide to Splines (New York: Springer)
[10] Seewig J 2005 7th International Symposium on Measurement Technology and Intelligent Instruments, J. Phys: Conf. Series 13 pp 254-257
[11] ISO 16610-31 Geometrische Produktspezifikation (GPS) - Filterung - Teil 31: Robuste Profilfilter: Gausche Regressionsfilter ISO International Organization for Standardization.
[12] The Mathworks Inc. Documentation for Matlab. 2017 URL: https://de.mathworks.com/help/matlab/ref/pchip.html (visited on 05/03/2018).