

***CAD/CAM of Sculptured Surfaces
on Multi-Axis NC Machine
The DG/K-Based Approach***

© Springer Nature Switzerland AG 2022

Reprint of original edition © Morgan & Claypool 2008

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means—electronic, mechanical, photocopy, recording, or any other except for brief quotations in printed reviews, without the prior permission of the publisher.

CAD/CAM of Sculptured Surfaces on Multi-Axis NC Machine: The DG/K-Based Approach

Stephen P. Radzevich

ISBN: 978-3-031-79311-0 paperback

ISBN: 978-3-031-79312-7 ebook

DOI: 10.1007/978-3-031-79312-7

A Publication in the Springer series

SYNTHESIS LECTURES ON ENGINEERING #8

Lecture #8

Series ISSN

ISSN: 1939-5221 print

ISSN: 1939-523X electronic

CAD/CAM of Sculptured Surfaces on Multi-Axis NC Machine

The DG/K-Based Approach

Stephen P. Radzevich

Eaton | Automotive, Innovation Center
Southfield, Michigan

SYNTHESIS LECTURES ON ENGINEERING #8

ABSTRACT

Many products are designed with aesthetic sculptured surfaces to enhance their appearance, an important factor in customer satisfaction, especially for automotive and consumer electronics products. In other cases, products have sculptured surfaces to meet functional requirements. Functional surfaces interact with the environment or with other surfaces. Because of this, functional surfaces can also be called dynamic surfaces. Functional surfaces do not possess the property to slide over itself, which causes significant complexity in machining of sculptured surfaces. The application of multi-axis numerically controlled (NC) machines is the only way for an efficient machining of sculptured surfaces. Reduction of machining time is a critical issue when machining sculptured surfaces on multi-axis NC machines. To reduce the machining cost of a sculptured surface, the machining time must be as short as possible.

KEYWORDS

sculptured surface, generating surface of a cutting tool, surface generation, NC machine, kinematics of surface generation, DG/K-based method, indicatrix of conformity

Dedication

Dedicated to friends of mine.

Preface

Many products are designed with aesthetic sculptured surfaces to enhance their appearance, an important factor in customer satisfaction, especially for automotive and consumer electronics products. In other cases, products have sculptured surfaces to meet functional requirements. Examples of functional surfaces can be easily found in aero-, gas-, and hydrodynamic applications (turbine blades); optical (lamp reflector), and medical (parts of anatomical reproduction) applications; manufacturing surfaces (molding die, die face), etc. Functional surfaces interact with the environment or with other surfaces. Because of this, functional surfaces can also be called *dynamic surfaces*.

Functional surfaces do not possess the property to slide over itself. This causes significant complexity in machining of sculptured surfaces. The application of multi-axis numerically controlled (NC) machines is the only way for an efficient machining of sculptured surfaces.

Reduction of machining time is a critical issue when machining sculptured surfaces on multi-axis NC machines. To reduce the machining cost of a sculptured surface, the machining time must be as short as possible. Definitely, this is the case where the adage “Time is money!” applies. Generally speaking, the optimization of surface generation on multi-axis NC machine results in time savings. It is the right point to recall the shrewd observation¹ that “gaining time is gaining everything!”

This book is the author’s attempt to cover briefly the modern theory of surface generation with focus on optimal machining of sculptured surfaces on multi-axis NC machine.

¹John Shebbear, 1709–1788.

Contents

1.	Introduction	1
2.	Analytical Representation of Sculptured Surfaces	5
3.	Kinematics of Sculptured-Surface Machining	11
3.1	Local Reference System	11
3.2	Elementary Relative Motions.....	13
3.2.1	Generating Motions of the Cutting Tool	14
3.2.2	Motions of Orientation of the Cutting Tool	19
3.2.3	Coordinate System Transformations: Their Impact on Fundamental Forms of the Surfaces.....	23
4.	Analytical Description of the Geometry of Contact of the Sculptured Surface and of the Generating Surface of the Form-Cutting Tool.....	29
4.1	Local Relative Orientation of Surfaces P and T	29
4.2	Dupin's Indicatrix	33
4.3	Rate of Conformity of Surfaces P and T at the CC-Point.....	33
4.4	Directions of the Extremal Rate of Conformity of Surfaces P and T	39
4.5	Implementation of Plücker's Conoid.....	39
4.6	$AN_R(P)$ -Indicatrix of Surface P	41
4.7	Relative Characteristic Curves.....	41
5.	Form-Cutting Tools of Optimal Design	45
5.1	On the Principal Concept of Profiling Form-Cutting Tools for Sculptured-Surface Machining.....	45
5.2	\mathbb{R} -Mapping of Part Surface P on Generating Surface T of the Form-Cutting Tool.....	49
5.3	Reconstruction of the Generating Surface T of the Form-Cutting Tool	52
5.4	An Algorithm for the Computation of the Design Parameters of the Form-Cutting Tool.....	52

5.5	Selection of the Form-Cutting Tools of Rational Design.....	54
5.6	Form-Cutting Tools Having Continuously Changeable Generating Surface....	56
6.	Conditions of Proper Sculptured-Surface Generation.....	57
6.1	Optimal Workpiece Orientation on the Worktable of Multiaxis NC Machine	57
6.2	A Set of Necessary and Sufficient Conditions of Proper Part Surface Generation.....	60
6.3	Global Verification of Satisfaction of the Conditions of Proper Sculptured-Surface Generation	65
7.	Predicted Accuracy of the Machined Sculptured Surface	67
7.1	Components of the Resultant Deviation of the Machined Surface from the Desired Surface.....	67
7.2	Local Approximation of the Contacting Surfaces	69
7.3	Configuration of the Approximating Torus Surfaces.....	71
7.4	Predicted Elementary Surface Deviations	73
7.5	Total Displacement of the Cutting Tool with Respect to the Sculptured Surface.....	75
7.6	Efficient Ways for Increasing Accuracy of the Machined Sculptured Surface.....	83
7.7	Principle of Superposition of the Elementary Deviations	84
8.	Optimal Sculptured-Surface Machining	85
8.1	Criteria of the Optimization	85
8.2	Synthesis of Optimal Operations of Sculptured-Surface Machining	89
8.3	An Example of Implementation of the <i>DG/K</i> -Based Method of Sculptured-Surface Machining.....	100
	Notation.....	103
	References	107
	Bibliography	111
	Author Biography	113