Preface

In recent years, the demand of micro-components and tiny parts has increased rapidly due to the growing trend of miniaturization. Technological advances have aided the production of miniaturized devices by making it possible to create high-quality micro-parts. Miniature gears are an important and an extensively used micro-component with widespread applications. These applications range from MEMS-NEMS, miniature pumps, miniature motors, timer mechanisms to robots, home appliances, electronics, cars, and even aircrafts.

The main purpose of the use of miniature gears was the transmission of motion and/or power. The functional performance, reliability, and service life of machines and devices depend largely on the manufacturing quality, i.e., dimension, form, and surface quality of the miniature gears employed. The size of these gears ranges from 0.1 to 10 mm in outside diameter. High manufacturing quality of gears ensures smooth, accurate, and noise-less operation. This necessitates highly precise and accurate processes to manufacture these gears. Conventional processes (i.e., hobbing, stamping, die-casting, powder-metallurgy, and extrusion) are productive and give good surface finish, but they yield poor quality (DIN standard 9–12) in terms of micro-geometry/form features. Consequently, secondary finishing and sizing operations are required to manufacture net-shaped miniature gears. The inclusion of secondary operations heavily increases the cost of gear manufacture, lengthens the production chain, and consequently causes high environmental footprint.

Recently, spark-erosion-based processes such as spark erosion machining (SEM)\wire-SEM (WSEM) and their micro-versions have been explored to overcome the limitations of the conventional processes for miniature gear manufacturing. The research work detailed in this book aims to explore and establish WSEM as a near-net-shape process to manufacture high-quality fine-pitched miniature spur gears with improved dimensional accuracy, micro-geometry, and surface quality. This involved properly planned detailed experimental investigations in four stages, careful analysis and interpretation of the results, development of models for micro-geometry, surface roughness and gear cutting rate using regression analysis and artificial neural network (ANN), and multi-objective optimization of the WSEM

process parameters (for high-quality miniature gears and productivity of WSEM process) using response surface modeling-based desirability analysis and back propagation neural network integrated genetic algorithm techniques.

Significant achievements of this research work are: (i) attainment of gear quality up to DIN standard 5 which is much superior than produced by any conventional manufacturing process for the miniature gears; (ii) average roughness up to 1.05 μm and maximum roughness up to 6.34 μm with good running-in properties; (iii) good surface integrity aspects having crack-free microstructure and very thin recast layer; (iv) establishing superiority of WSEM over hobbing for manufacturing of high-quality miniature gears; and (v) establishing WSEM as a near-net-shape manufacturing alternative to the conventional processes for miniature gears.

This will significantly improve the operating performance (noise-less and accurate transmission) and enhance the service life (better tribology aspects and wear characteristics) of the miniature gears.

This work certainly opens up many avenues for future research on miniature gear manufacturing by wire spark erosion machining (WSEM). Some worth-mentioning are: exploring WSEM for manufacturing high-quality miniature helical, bevel, internal, and planetary gears; investigating other commonly used miniature gear materials such as stainless steel, bronze, aluminum; investigating the effects of WSEM process parameters on noise, vibration, and wear rate of the miniature gears; employing WSEM for gear tooth modifications such as tip correction, root alteration, and crowning.

This book is a good source of information on miniature gears, wire spark erosion machining, and its capability to manufacture net-shaped or near-net-shaped miniature gears. It enables the researchers and engineers by providing them a vast knowledge of the above-mentioned fields, which certainly helps them to explore future avenues in manufacturing high-quality miniature gears for wide application requirements.

It opens with Chap. 1 introduces miniature gears and discusses various parameters to determine their quality and service life, and conventional processes to manufacture them. Chapter 2 presents an insight into wire spark erosion machining process and a detailed review of past work done on manufacturing miniature gears using spark erosion and wire spark erosion machining processes. It also mentions the research gaps evident from this review and furthermore describes the identified research objectives of the present work. Chapter 3 describes the planning, design, details, and procedure of experimental investigations for different stages, i.e., trial, pilot, main, and confirmation experiments. It also describes evaluation procedure of the measures of gear quality and WSEM productivity. This chapter also mentions the methods and tools employed for analysis of the experimental data. Chapter 4 presents the experimental results, their analyses, and conclusions for each experimental stage. Chapter 5 describes the modeling by regression analysis and artificial neural network, and optimization of WSEM process by desirability analysis and genetic algorithm. A comparative study between WSEM and hobbing to manufacture miniature gear of the same specifications is given in Chap. 6, which also highlights the significant achievements and conclusions from the present research work.

Finally, the chapter and conclusively the book end up with stating the avenues for future research.

We hope the book could disseminate the knowledge of wire spark erosion machining of gears and fulfill the requirements of the researchers, engineers, and academicians indulged therein.

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