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Exact Analytical Algebraic Expressions for Mathematical Modeling of Face Milling Spiral Bevel Gears on a Five-Axis CNC Machine

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Extended Abstract

Spiral bevel gears are widely used in gearbox, differential and other heavy load intersecting axis transmission because of its high efficiency, low noise, large contact rate, and high life cycle, etc. Its processing methods are mainly divided into face milling type and face-hobbing type, in which face milling type is discontinuous cutting, and face-hobbing type is continuous cutting, due to the complexity of the shape of these two methods are often used in the processing of specialized machines such as Gleason, Oerlikon, Klingelnberg, and this type of specialized machines are expensive and can only process a single product, which is a big burden for small-scale manufacturers of bevel gears. if this processing method can be applied to general-purpose models five-axis machining machine, it will be able to reduce a great deal of cost, and 5-axis machining machine can be more flexible processing of most products.

Since the geometry of face- hobbing tools is more complex than face-milling tools, this study focuses on the fabrication and cutting methods of face-milled tools.

In this study, a mathematical modeling and tool design method for face milling spiral bevel gears is proposed and applied on a five-axis machine. The method is divided into four stages. In the first stage, the design of the tooth shape and bevel gear tool parameters is carried out, where it should be noted that the tool diameter affects the tooth depth[1]. In the second stage, based on the tool parameters set in the first stage, a virtual flat-topped production wheel is created and the positional relationship between the bevel gear cutter and the bevel gear is established based on the homogeneous coordinate transformation [2], which has also been used in previous studies [3,4]. In the third stage, a mathematical model of the face milling spiral bevel gear is developed using the principle of conjugate surface theory, and then the motion trajectory of the bevel gear tool during cutting is derived from the mathematical model developed in the second stage. In the fourth stage, the derived mathematical model is used to build the five-axis machining machine coordinates using homogeneous coordinate transformation, which is a procedure to generate the NC codes for various five-axis machining machines, and at the same time, the CNC machine simulation software VERICUT was used to simulate the tool paths, and finally the bevel gears and tools were actually processing on the 5-axis machine to verify the feasibility of this method. The results show that this method can effectively machine the spiral bevel gears on a general-purpose five-axis machine with less cost and time compared to a dedicated machine.

References

[1] S.P. Radzevich , Gear Cutting Tools: Fundamentals of Design and Computation, CRC Press,2010
[2] F.L. Litvin, A. Fuentes, Gear Geometry and Applied Theory, Cambridge University Pressy,2004.
[3] F.L. Litvin and Y. Gutman, "Methods of synthesis and analysis for hypoid gear-drives of Formate and Helixform, " ASME J. Mech. Des. 103, 83-113 ,1981
[4] Z.H. Fong and C.B. Tsay, A mathematical model for the tooth geometry of circular-cut spiral bevel gears," ASME J. Mech. Des. 113, 174-181 ,1991.