International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 02 Issue: 01 | Apr 2015 www.irjet.net p-ISSN: 2395-0072

ANALYSIS OF NEW MACHINING METHODS OF SKEW BEVEL GEARS USING GENERATION LINE

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Abstract —*According to generating principle of spiral bevel gear and space meshing theory, formation theory of generation line of tooth surface about skew bevel gears is studied. A new processing method of tooth surface with the generation line as chord of face circular cutters is put forward. Moving process model of milling processing with skew bevel gears is built, and profile of the gears can be machined using three axes linkage method based on the model. Ma- chining test of the gears is carried out on experiment plat- form designed. Furthermore, 3D points cloud model of tooth surface are calculated in light of mathematical model of the tooth surface which has been established, and datum of mesh nodes on actual tooth surface are collected. Then surface errors are evaluated by normal vector equation of the tooth surface which has been developed. Finally, this method is proved to be effective and feasible.*

Keywords- Skew bevel gears. Generation line. Mathematical model of tooth surface. Machining experiments.

1. INTRODUCTION

Spiral bevel gears are needed to transfer power and motion between intersecting axes and are widely used in the equipments of aviation, navigation and national defense and mechanical products such as vehicles, ma- chine tools, engineering mechanics. Skew bevel gears are as a part of spiral bevel gears and have all advantages of spiral bevel gears. In the field of gear manufacture at present, design and manufacture process of tooth surface about spiral bevel gear are very complex and the control of quality is very difficult. So spiral bevel gears are a research focus in gear manufacture field.

Accordance with the principle of gear engagement, tooth surface of spiral bevel gear should be tooth surface with spherical involute. However, the existing processing technology is performed by using engineering approximation method. So there are theoretical errors on the tooth surfaces. First, transmission ratio is not constant; Second, modification and adjustment of tooth surfaces are complex; Finally, designing and manufacturing need to take a longer period and gears cannot be interchanged unless in the same batch. Therefore, in order to reduce to effect of the error, the parameters of machine tools and cutting tool need to be modified and improved continuously.

The new method that is put forward can be used to process ideal spherical involute spiral bevel gears that the transmission ratio is constant and gears can be inter changed even in different batches. This method makes thecalculation and adjustment of machine tools settings

2. MACHINE TOOL DESIGN OF SPIRAL BEVEL GEARS

Initial position relation of chord of circular milling cutters and work piece are determined, through adjust position of worktable X,Y direction and degree of Z direction as well as change angle of inclined rotary table C and level rotary table B based on base cone angle δb. When spiral bevel gears are processed, the work-shaft and level rotary table rotate with angular velocity ωt and ωb respectively to satisfy the equation 4 that ensure the strict proportion of the tool shaft and the work piece movement so as to realizetooth surface spread correctly. Movement of the tool shaftand work piece is as above mentioned. Meanwhile, Y axis move with angular velocity based on equation 5 to avoid overcut and complete feed drive. Therefore, therelation of three Axes linkage is composed with work- shaft. Level rotary table rotation and Y axis motion to realize milling of skew bevel gears.

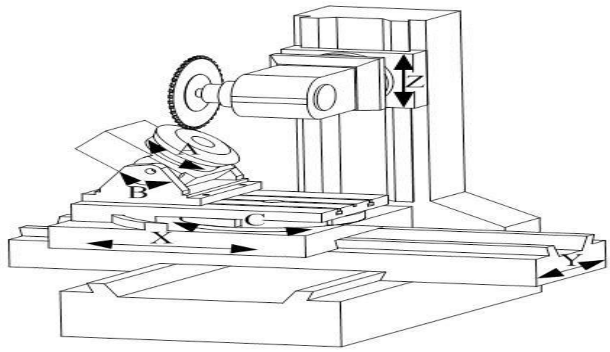

FIG1:3D model machine

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Initial position of machine tool is adjusted according to parameter of gear manufactured, including pressure angle αp, pitch angle δ, mean spiral angle β, base cone angle δb,root cone angle δf face cone angle δa, face width b . Finally, NC program is designed to accomplish cutting process of gears.

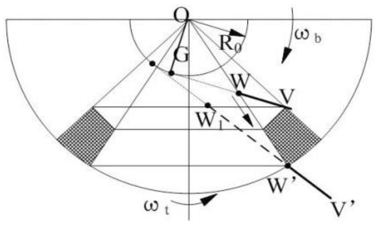

FIG-2: Analysis of cutting movement

3. EXPERIMENTAL VERIFICATION OF MILLING AND DETECTION

In this milling experiment, the material of milling cutterdesigned is cemented carbide, cutter Diameter is 350mm, when gearwheel is processed, milling cutter move fromsmall end to big end first so that one side of tooth surface can completed. Another side however from big end to small end. On the contrary, when pinion was processed, milling cutter move from big end to small end so that one side of tooth surface can complete. Another side butfrom small end to big end.

In this milling experiment, the material of milling cutterdesigned is cemented carbide, cutter Diameter is 350mm, tooth number is 12, length of cutter tooth is 13mm, the rake angle of main cutting edge is 5°, Celief angle of pair cutting edge is 6°. The material of pair skew bevel gearsis aluminum alloy. Main parameter of pinion and gear- wheel is given in table 1.

TAB-1: Cutting Processing of Gearwheel

Modeling parameters	**pinion**	**gear-wheel**
Tooth number z	14	65
Big end module m/mm	6	6
Root cone angle δ_f/°	11.2171	11.2171
Big end pitch circle diameter D/ mm	84	390
Base cone spiral angle β_b/°	35	35
Pitch cone angle δ/°	12.1549	77.8451
Pressure angle a_p/°	22.5	22.5
Root cone angle δ_f/°	11.2171	11.2171
Face cone angle δ_a/°	14.5833	78.6156
Base cone angle δ_b/°	11.2171	64.5777
Face width b/mm	60	60
Cutting area μ/°	9.3744	9.5027
Adjusting angle of cutting area ψ/°	0	54.0892
Generatrix of big end about base cone L_{b1}/mm	199.4992	117.1003
Radius of Tangent Circle about Toothed Portion R_0/mm	97.2207	49.9587
The Length of generation line [C]r/mm	52.2233	81.0328
Center distance of cutting edge L_N/mm	173.0410	170.245

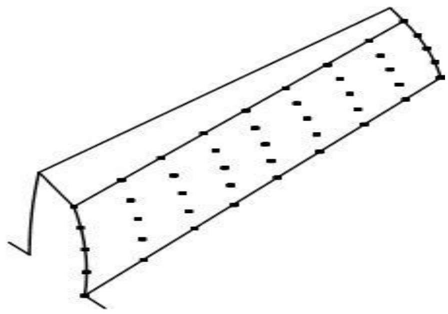

FIG-3: Detection point

Based on the mathematical model of tooth surface about skew bevel gears, accurate 3D point cloud model ofbevel gears are built in mat lab. Meanwhile, plan the measuring path on the ideal tooth surface and establish theories coordinate system that is in keeping with measuring coordinate system. Then, the datum of mesh nodes on the actual tooth surface are collected by coordinate measuring machine, and so these data of discrete points of actual tooth surface are introduced into mat lab system. According to coordinate transformation, spatial position error of discrete points between actual tooth surface and ideal tooth surface is calculated. Finally, tooth surface error of skew bevel gears is evaluated by means of difference surface.

Measuring probe of 3D coordinate measuring machine presets a certain position of initial measuring point in normal direction on the basis of the vector formula 12. Measuring element mesh nodes on convex and concave ofspiral bevel gears are measured in normal direction. The datum of all tooth in turn collected average a set of numbers.

The maximum positive deviation about convex of gearwheel is less than 0.0379mm, maximum negative deviation while 0.0491mm. Similarly, the maximum

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positive deviation about concave of gearwheel is less than0.0289mm, maximum negative deviation while 0.0390mm.The trend of error: convex from small end to big end shown an increasing tendency, maximum deviation is present to top of small end. Concave from small end to bigend shown an increasing tendency.

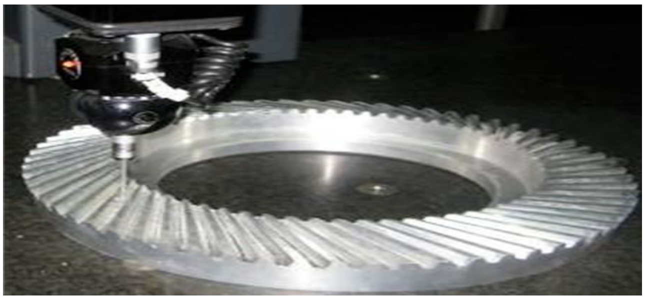

FIG-4: Detection of Gearwheel

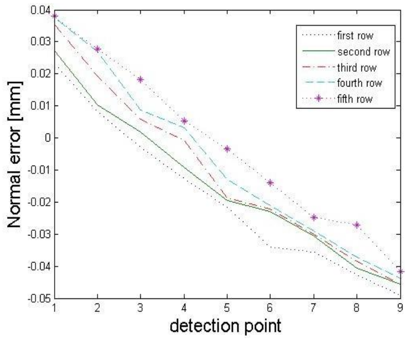

FIG-5: Convex error of gearwheel

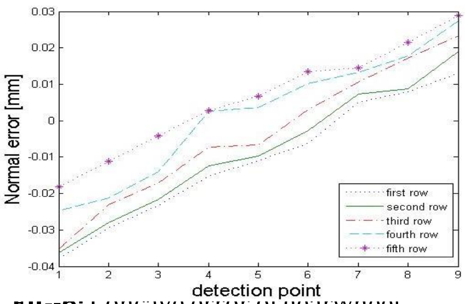

FIG-6: Concave error of gearwheel

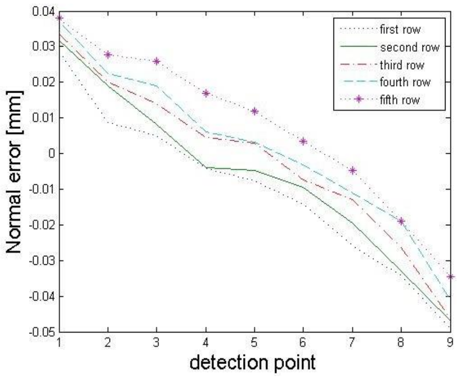

FIG-7: Concave error of pinion

The maximum positive deviation about convex of pin-ion is less than 0.0370mm, maximum negative deviation while 0.0482 mm, similarly, the maximum positive deviation about concave of pinion is less than 0.0467mm, maximum negative deviation while 0.0358 mm. The trendof error: convex from small end to big end showed an increasing tendency, maximum deviation is present to topof small end. Concave from small end to big end showed an increasing tendency, maximum deviation is present to top of small end.

4. CONCLUSION

Generation line cutting methods is used for skew bevel gears. Namely, the generation line is as chord of face circular milling cutters, the tracing that generation ling spread involute helicoids is just the cutting trace chord of face circular milling cutters. Skew bevel gears without theoretic errors are machined using three axes linkage by this method. The cutting motion and control is greatly simplified by utilizing this method. Machining experiments of a pair of mesh gear are performed by generation line processing method. And then, the measurement and evaluation of the pairs are completed. Detection results: the maximum positive deviation about convex of gearwheel is less than 0.0491mm. The maximum positive deviation about convex of pinion is less than 0.0482mm. The experimental results show that this method is feasibleand effective.

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