CAD/CAM RESEARCH ON RADIAL NON-CIRCULAR GEARS

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Abstract: Based on the comparison with the traditional normal non-circular gears, a new type of radial non-circular gears and its generation method are discussed, and the thought for tooth-by-tooth modification is introduced. In this paper, the whole process from the mathematical analysis to CAD/CAM Integration is discussed, which has an extensive application in the field of flow meters.

Key words: Radial Non-circular Gears; Tooth-by-Tooth Modification; Injection Mold; CAD/CAM Integration.

1. INTRODUCTION

The non-circular gear, widely applied in automation and instrumentation, is a kind of driving component used to transmit variable motions. Non-circular gears can substitute for the linkages and cams in many fields because of the following merits[1-3]: (1) Non-circular gears are more compact and work well; (2) It is easier to guarantee the change drive with a regular pattern by non-circular gears than by other mechanisms.

In the positive-displacement flow meters, non-circular gears are always used as the central parts to measure the expensive liquid medium, such as oil and natural gas. Because of the accuracy of this kind of flow meter, it is extensively used in various industrial fields, such as petroleum, chemical industry, medicine and energy. And the design and manufacture of non-circular gears has being studied. Tong S H[4] investigated the generation of identical non-circular pitch curves, Chien-Fa Chen[5] and Biing-Wen Bair[6] studied the elliptical gears with circular-arc teeth and Chang S L[7] focused on the tooth profiles generated by rack cutter. In this paper, a particular type of radial gears is introduced, which has shown excellent advantages in the

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minute-flux meters and other occasions. Hence, the CAD/CAM research on radial non-circular gears is of central importance.

2. THE ANALYSIS OF RADIAL NON-CIRCULAR GEARS

Traditional non-circular gears are basically normal gears[1, 2], that is, all teeth are arranged in the normal direction of the pitch curve, as displayed in Figure 1. However, the novel radial non-circular gears are quite different in that the teeth are arranged in the radial direction of the pitch curve, as shown in Figure 1. Both of these types of gears meet the demand of engagement, and their pitch curves are coincident. The difference lies in the generation mechanism and the arrangement method of the gear teeth. Compared with traditional normal gears, the improved radial gears have some excellent characteristics:

1. The accuracy and the sensitivity of the flow meters are greatly enhanced. In positive displacement flow meters, under the pressure difference between the entrance and the outlet, the torque is produced to make the gears rotate continually[8]. Because certain pressure acting on the teeth of radial gears could produce more force moment than that on the teeth of normal gears, the reaction to the minute flux is quit sensitive.
2. The security and the stability of the flow meters are improved. The contact ratio of a couple of radial gears is higher than that of normal gears, which minimizes the probability of latch and improves the ability to adapt to the variation of temperature.

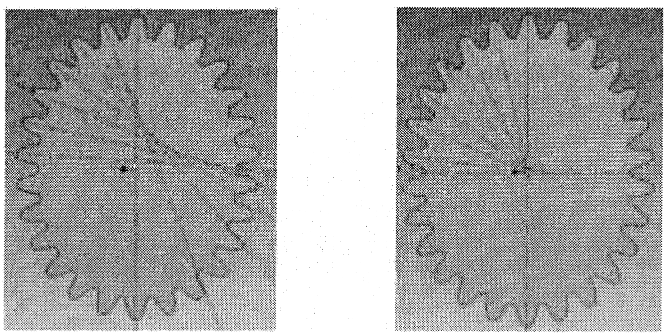


Figure 1. Normal Gears (Left) and Radial Gears (Right)

3. DESIGN OF RADIAL GEARS

The toughest part of the design of radial non-circular gears lies in the generation of the tooth profile, the involute between the addendum circle and the dedendum circle. In the paper, the method of equivalent pitch radius and tooth-by-tooth modification is introduced to develop the mathematical model of the tooth profiles.

3.1 Method of Equivalent Pitch Radius

This method is that the radius vector of every equant point* on the pitch curve is regarded as the pitch radius, called equivalent pitch radius[1, 9]. Therefore, according to the different radius vector, the corresponding tooth profile is generated. As in Figure 2, Cartesian coordinate system is established, in which the origin is set in the geometric center of the gear, and axis y is in the direction of radius vector of every equant point. Thus, the standard tooth profile is generated by the following equation (1):

$$\begin{cases} x = \dfrac{R_J}{\cos a_2}\sin\left[\dfrac{0.25\pi m}{R_d} + (\tan a_1 - a_1) - (\tan a_2 - a_2)\right] \\ y = \dfrac{R_J}{\cos a_2}\cos\left[\dfrac{0.25\pi m}{R_d} + (\tan a_1 - a_1) - (\tan a_2 - a_2)\right] \end{cases} \qquad (1)$$

In Eq.(1), parameter m is the module, R_j the base radius, R_d the equivalent pitch radius, a_1 the pressure angle of the crossing point of involute and pitch curve and a_2 the pressure angle of any point required.

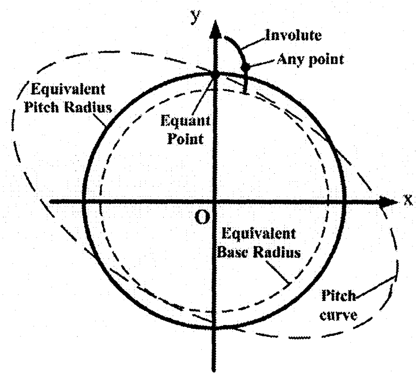
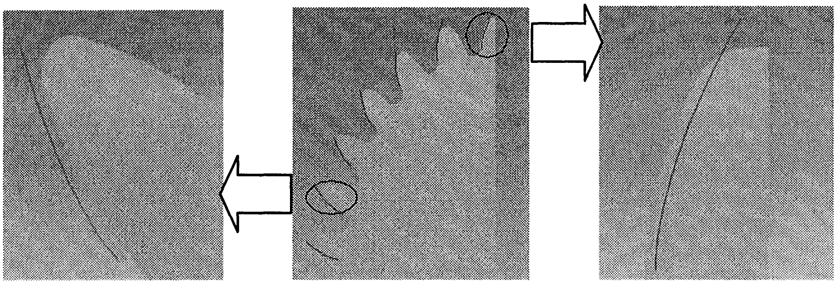


Figure 2. Method of Equivalent Pitch Radius

*equant point: On the pitch curve, the arc length between the gear teeth is identical, and the crossing point of the center line of every gear teeth and the pitch curve is called equant point.



(1) (2) (3)

Figure 3. Tooth-by-tooth Modification

3.2 Tooth-by-Tooth Modification

Tooth-by-tooth modification is defined as the gear shift with different coefficients which are determined by the equivalent pitch radius of every gear tooth. The standard of comparison is $\pi m/2$, in which m stand for the module of the gear. When the equivalent pitch radius is greater than $\pi m/2$, the positive-shifted modification is applied, as shown in Figure 3(1). On the contrary, if the equivalent pitch radius is less than $\pi m/2$, the negative-shifted modification is used, as shown in Figure 3(3). After the modification, the used part of the involute is changed, but the center distance and the anticipated drive ratio of the gear pair are invariable[9]. The thought for tooth-by-tooth modification is put forward to eliminate the meshing interference, a phenomenon that the tooth face of one gear exceeds the specified kinematic boundary and interferes with the tooth face of the mating gear. But via tooth-by-tooth modification, the gear teeth near the major axis are wider and those near the minor axis are narrower, which guarantees the exact engagement of the couple of gears.

4. CAD/CAM INTEGRATION

Based on the design method above, the parameterized 3-dimensional model of radial non-circular gear can be established using Pro/E[10]. And the drive process can be simulated[11], as shown in Figure 4.

The traditional manufacture method of gear shaping and hobbing is unlikely to be utilized to produce radial gears. In this paper, the injection model is introduced, which guarantees not only the quality of products, but also the mass-production. And the injection model can be cut by transferring the CNC code obtained automatically via the NC module of Pro/E to the linear cutting machine directly.

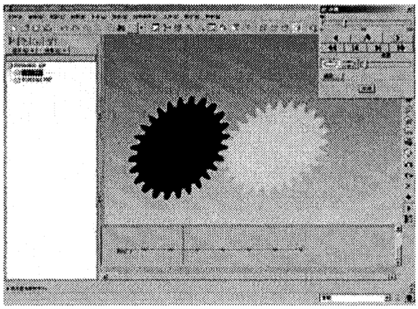


Figure 4. Dynamic Simulation of Radial Gears

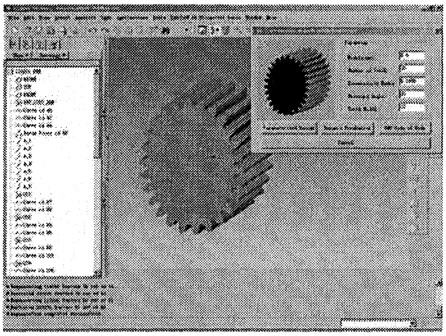


Figure 5. Interface of CAD/CAM Integration

Through Pro/TOOLKIT[12, 13] and VC++, the compiled application code, shown in Table 1 can be linked to the library files of Pro/TOOLKIT, and the executable program, so-called the exclusive design module will be started when Pro/E is opened. So the developed module can meet the demand of special design and manufacture of radial non-circular gears efficiently. The mutual interface of the integration system of radical non-circular gears is shown as Figure 5.

Table 1. The Compiled Application Code (part)

BOOL CDlg8_2::OnInitDialog()	if (status==PRO_TK_NO_ERROR)
{ CDialog::OnInitDialog();	{ProMdlToModelitem(model,
MoveWindow(600,50,450,300,TRUE);	&modelitem);
ProMdl model;	....
ProModelitem modelitem;	if (status==PRO_TK_NO_ERROR)
ProName ParamName;	{ProParameterValueGet(&param, &value);
ProParameter param;	m_B=value.value.d_val; }
ProParamvalue value;	}
ProError status;	UpdateData(false);
status=ProMdlCurrentGet(&model);	return TRUE;
	}

5. CONCLUSIONS

The concise modeling and the manufacture of gears have been the tough issue in CAD/CAM field, not to mention non-circular gears. In this paper, the following conclusions are drawn.

1. In the field of flow meters, normal non-circular gears can be replaced by radial gears, which have an extensive application. The model of modified tooth profiles complies with the theory of gearing, and the method of establishing and simulating the model is clear.
2. Tooth-by-tooth modification is a feasible method to eliminate the meshing interference. This method can be used not only in radial gears but also in normal gears in order to improve the condition of gear drive.
3. The radial gears can be produced by the injection model, which can be cut according to the CNC code generated automatically.
4. Secondary development of Pro/E can be achieved by Pro/TOOLKIT. And the developed CAD/CAM integration module of radial non-circular gears can make design and manufacture more accurate and efficient.

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