Proceedings of the 3rd International Conference on Mechanical Engineering and Mechatronics
Prague, Czech Republic, August 14-15, 2014
Paper No. 78

Assessing Spur Gear Quality Using Virtual Rolling Gear Testing Machine

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***Abstract* -** Composite error in gears is a main parameter to evaluate the grade of the manufactured gears. Composite errors are usually determined through the use of rolling tester machine. This requires the existence of the master gear for each tested gear which is economically unfeasible. Again, most of the gears are having addendum modification which means the existence of the perfect profile which matches the profile of the master gear with the modification. Thus the problem became extremely impossible to test the gears by the technique of single flank method on the rolling testing machine. This was replaced by testing the pair of meshed gears with a specified tooth engagement. It is then a burden to determine the quality of individual gear. The present paper faces this problem by proposing a methodology for producing virtual master gears and to use this methodology for computer utilization for indirect assessment based on the virtual gears model (VGM) so that composite and run out errors can be assessed without the need of actual master gears or the need of special gear measuring machines. Software written using Microsoft Visual Studio – C# version 2010 was designed to generate the perfect or the master gear profile. The model has been used to measure various gears and their measured values were analyzed and the quality was determined.

Keywords: Virtual master gear, Composite gear errors, Rolling tester machine, Gear measurement and addendum modifications.

1. Introduction

The inaccuracies of manufacturing process result in deviation between the ideal shape of the gear and the actually produced one. Gear errors are classified into individual errors and composite error. Determination of either of them depends on the method of inspection, namely, analytical (all the individual elements of the gear teeth are checked) and functional (tangential composite and radial composite inspection). All the traditional techniques involve the use of special measuring equipment for both techniques. This method is basically hardware- based, relying on the motion of specially designed mechanisms. Thus, for different sizes and types of gears, different measuring machines should be used, imposing economical burden for the industry. Besides, measuring some errors require the presence of a master gear. The manufacturing of such gear with high precision is very difficult and expensive especially when different sizes and types of gears are required to be inspected.

Those are beyond the capability of great region of the gear users, either for cost or time consumed. Researcher tried to apply non-traditional means to achieve the errors.

Some researchers tried to use other measuring machines such as coordinate measuring machine (CMM) as shown by Tamura and Liu (1997), Suh, et al. (2002) and by Sammar and De Chiffre (2000) to avoid the use of the special measuring machines. All methods were purely software-based and were claimed that they are capable of measuring various errors including tooth profile error and tooth trace error, which cannot be measured by the conventional methods.

This is, again requires the existence of a machine such as the CMM. Therefore, there is a need to find an alternative way to check the composite error of gears which does not depend on a special type of hardware or master gears. Thus an algorithm for indirect measurement based on the virtual gears model (VGM) is required so that error measurement can be carried out in computers. The present study proposes taking the measurement on classical measuring machine such as the cam tester and comparing them with the generated master profile or the perfect profile with any addendum modification to determine the out of run and the composite errors.

2. Theoretical Approach

2.1. Generating the Master and the Perfect Gear

Several approaches were used in literature for generating the profile of involute gears. In the present work the parametric equations with matrix transformation, fig 1, are used as shown by Koura et al. (2011), Chien and Chumg (2004), Fong et al. (2002) and Kuo and Hsin (2010). From this figure, the following relationships stand:

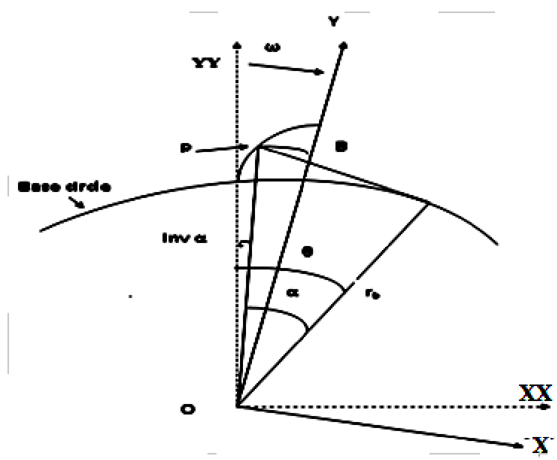


Fig. 1. Generation of gear profile.

X_i offset in x of point "i" = $((R_p*\sin(\theta_i)) - (((R_p*\theta_i) - B) * \cos(\alpha) * \cos(\theta_i - \alpha)))$ (1)

Y_i offset in y of point "i" = $((R_p*\cos(\theta_i)) + (((R_p*\theta_i) - B) * \cos(\alpha) * \sin(\theta_i - \alpha)))$ (2)

Where i is any point on the profile with coordinates (X_i, Y_i)

α pressure angle

R_p radius of pitch circle = $(m * Z) / 2$ (3)

B half the tooth thickness at pitch circle = $(\pi * m / 4) + m * k * \tan(\alpha)$ (4)

θ_i rotation angle for matrix transformation = $(B/R_p) + \tan(\alpha) - \sqrt{((R_i^2 / R_b^2) - 1)}$ (5)

R_b radius of base circle = $R_p * \cos(\alpha)$ (6)

In case of generating master gear, k is taken to be zero.

2.2. Run Out and Composite Errors

The composite error and the run out error were deduced based on readings r_i (op in fig 2) and φ_j (angle xop in fig 2) stored in a data source file. The readings "r_i" represent the radii at the contact points between the ball end of the probe of the measuring device and the gear tooth at the pitch circle diameter. Hence,

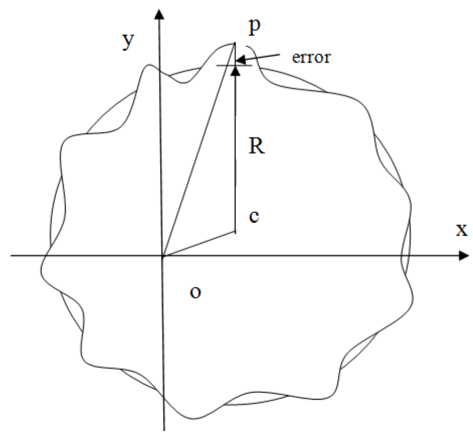


Fig. 2. Composite & run out errors.

Composite errors (e_i) = $r_i - (\Sigma r_j / Z) - c * \cos(\varphi_j - \beta)$ (7)

β (angle xoc) = $\tan^{-1}(\Sigma(r_i * \cos(\varphi_j) / \Sigma(r_i * \sin(\varphi_j))$ (8)

Eccentricity (c) = $2 * \text{sqrt} (\Sigma (r_j * \cos(\varphi_j) / Z)^2 + (\Sigma (r_j * \sin(\varphi_j) / Z)^2)$ (9)

3. Proposed Software

The software developed for generating the master tooth profile (module 1) and importing the measured data, then processing it (module 2) are written in Visual Microsoft C# - version 2010. The block diagram representing the flow chart for the 1st module is presented in fig 3.

The block diagram for the proposed software for module 2 is shown in fig.4. Three data sources are linked to the software. Those are the source that stores the measured data for the total composite error, the source that saves the interpolated points (output of module 1) of the master or perfect profile of the tested tooth and the source that contains the quality data for the run out and composite errors (Indian Standard).

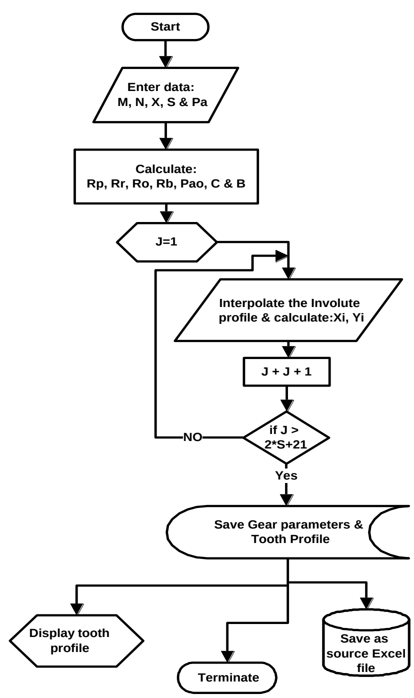


Fig. 3. Flow chart for module 1.

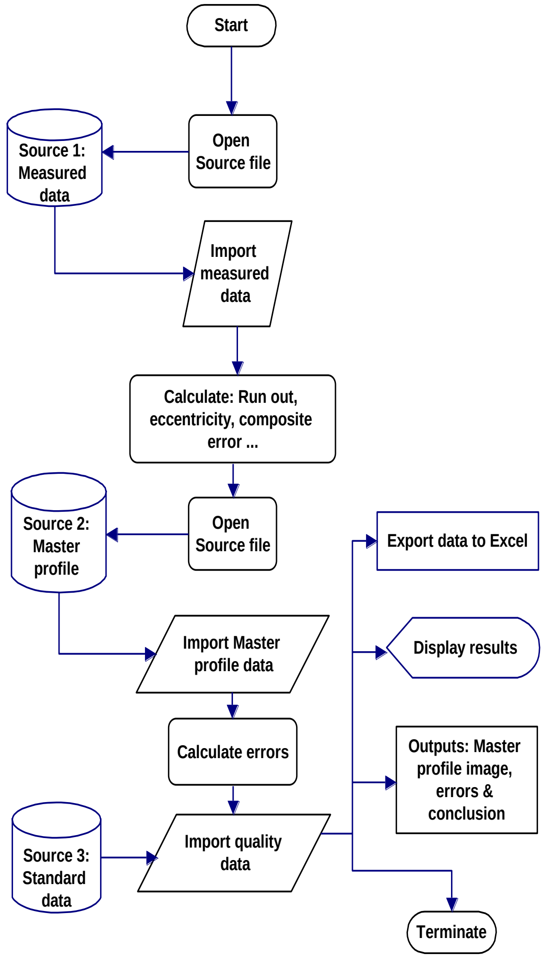


Fig. 4. Flow chart for module 2 – composite error.

4. Experimental Procedure

Two sets of tests were planned to be carried out. The 1st set, table 1, is for the generation of the master or the perfect profiles. All gears will be having 20 º pressure angles.

Table 1. Tests for the generation of the master or perfect profiles.

tests	module	teeth	X1	X2	X3	X4	X5
Test 1 – 3	3	36	-0.4		0		0.4
Test 4 – 8	7	18	-0.4	-0.2	0	0.2	0.4

The 2nd set will be the tests for assessing the run out and composite errors. This will be done on two gears having modules of 3 and 7 with 36 and 17 teeth respectively. The two gears are having no addendum modification (i.e. X =0). Gear having module 3 was manufactured on a reasonably accurate hobing machine using steel material, while the second gear was made of aluminum and was dismantled from running engines during maintenance.

Although, the readings may be taken by any suitable measuring machine as long as the measured radii "r_i" and the angle "φ_j " were saved in a source data file. In the present paper the readings were taken on a cam shaft tester, fig 5, with a spherical probe touches the pitch circle at both flanks. At the specified angles the radial readings were triggered and saved in a Microsoft Excel file working as the source file.

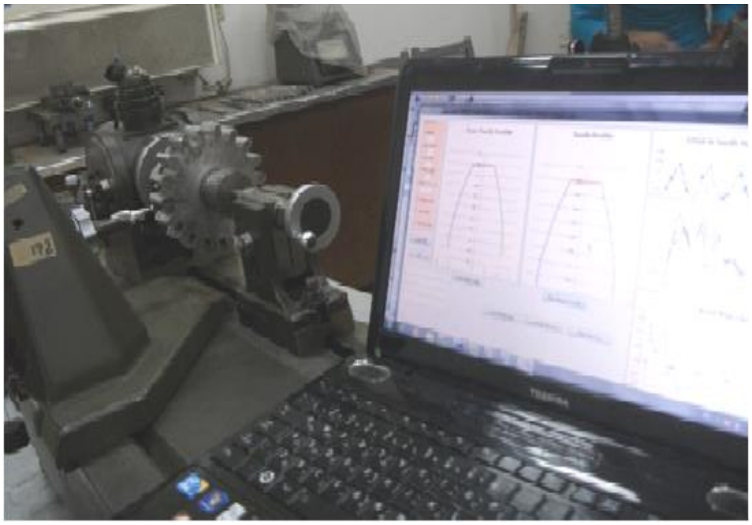


Fig. 5. Cam Shaft tester.

5. Results

The results include both the output of the software for the first set and the output of the virtual rolling tester for the second set. Fig 6 shows the main screen displayed as running the software.

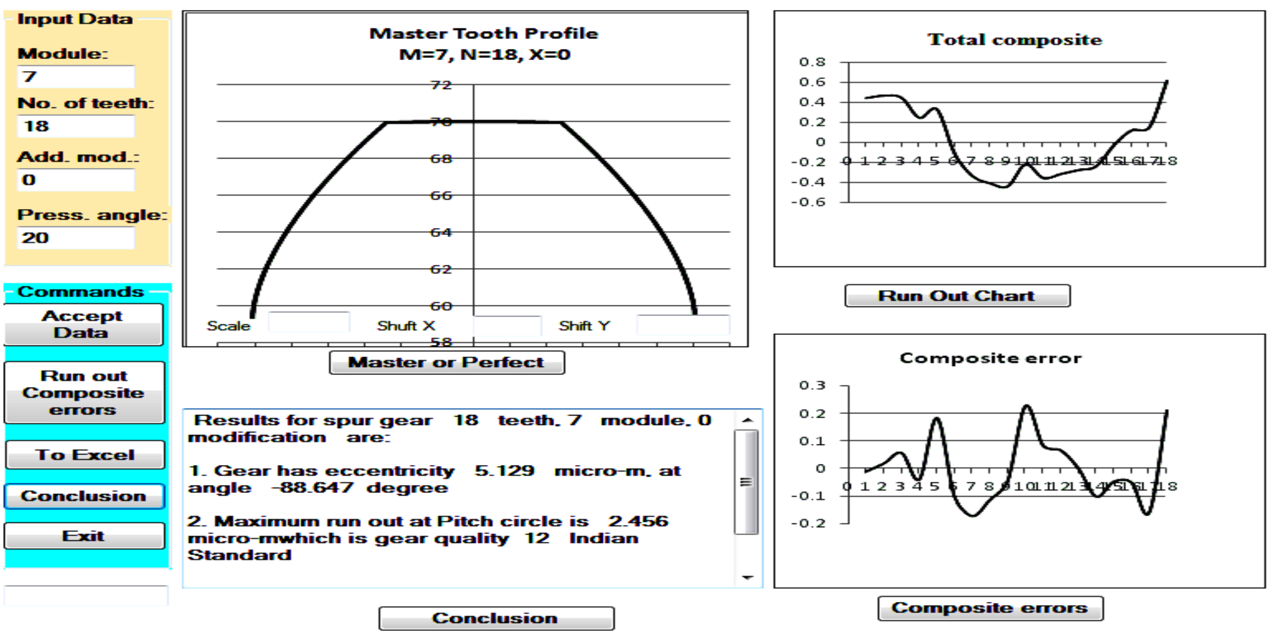


Fig. 6. Software main screen.

5.1. Generating the Master Profile and Perfect Profile

Fig 7 shows the generated master profile and perfect profiles for the different addendum modifications.

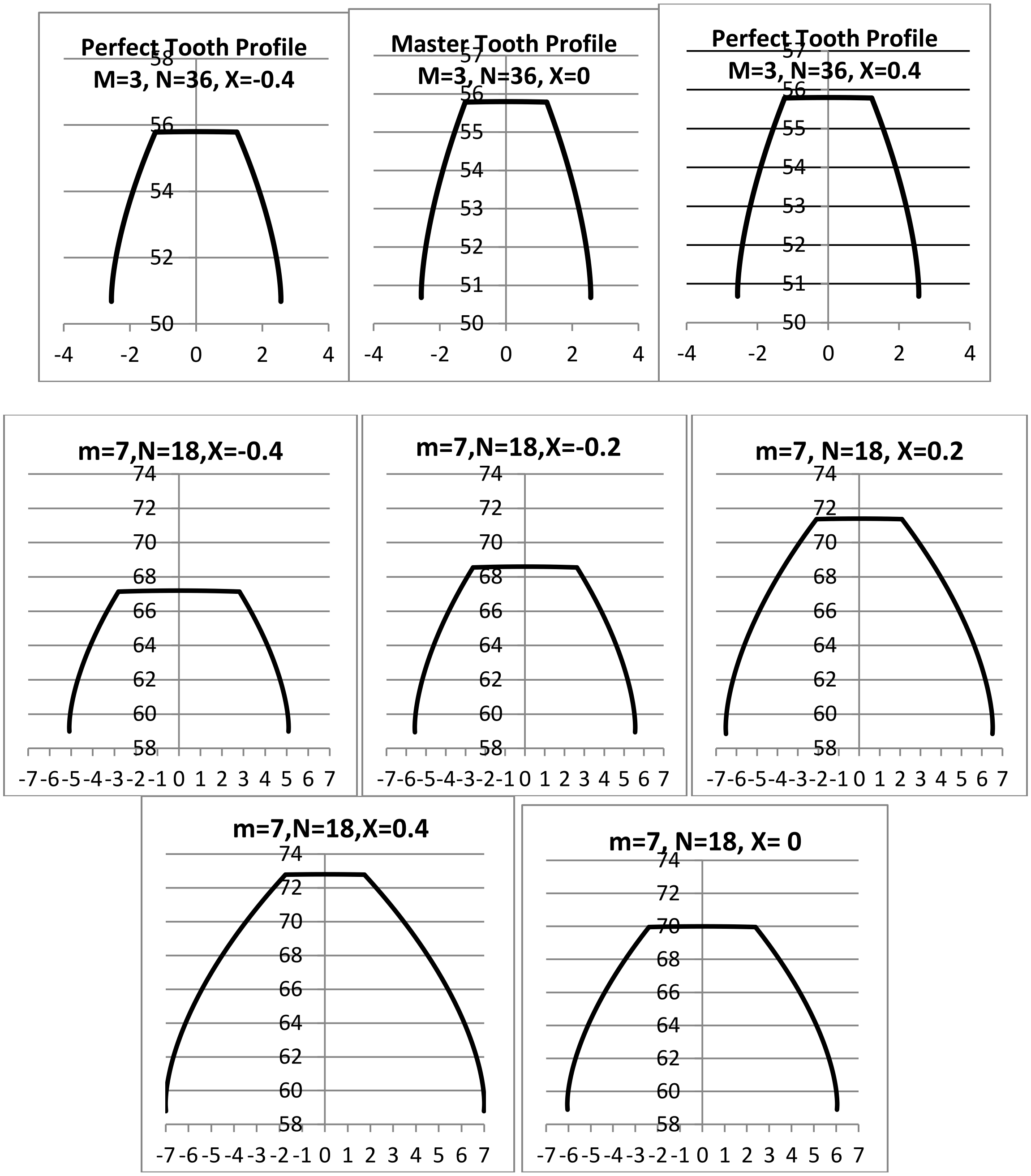
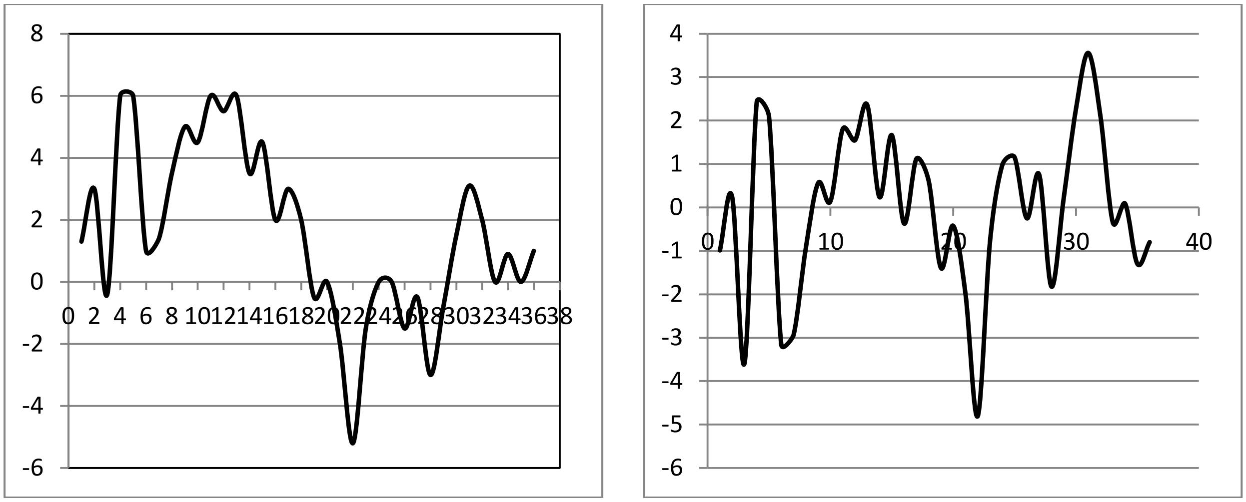


Fig. 7. Master & perfect profile gears.

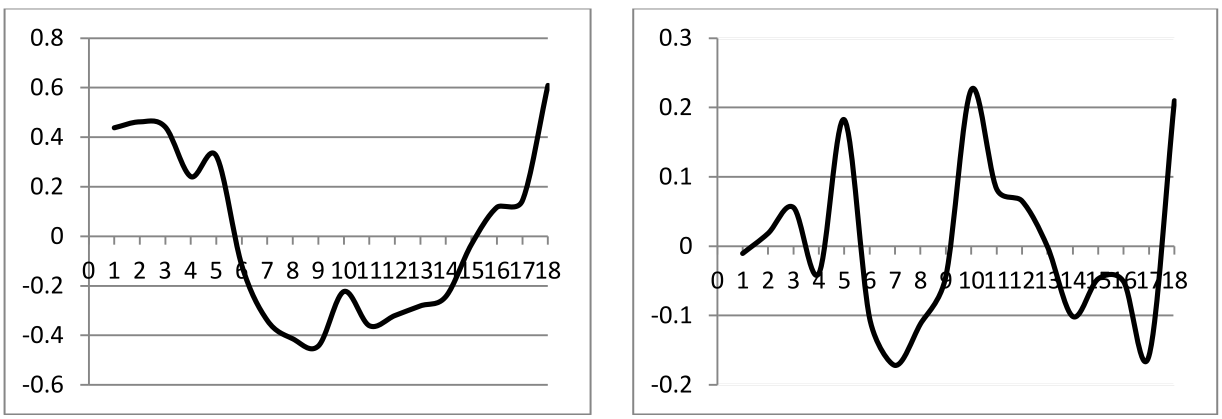
Variations in the tooth shape with the addendum modifications are quite clear, particularly at the root and tip widths.

5.2. Composite Errors

The output of the software for the run out error is shown in fig 8 for the three tests.



a) Total Composite & composite for module 3, 36 teeth (μm).



b) Total Composite & composite for module 7 , 18 teeth (mm).

Fig. 8. Software output.

The run out, eccentricity, composite errors and the quality of the gears based on the Indian standard were obtained as displayed on the main screen, fig 6.

6. Conclusion

The proposed software has proved its full capability for:

- Developing the profile of any master spur gear. This, also, can facilitate the use in manufacturing purposes and producing templates,
- Developing the profile of perfect spur gear with any addendum modification which will help in the design purposes, stress analysis beside determining the error of the measured gears,
- Replacing the rolling testing machine with a corresponding virtual machine for duel flank determination of run out , eccentricity and composite errors,
- Assessing the quality of measured gear.

References

Tamura H., Liu. Z, (1997) Measurement of helical gear using coordinate measuring machine, Journal of Japan Society of Mechanical Engineering, Vol.63, pp.252–258, 1997.

Suh S.H., Lee E.S., Kim H.C, Cho J.H., (2002) Geometric error measurement of spiral bevel gears using a virtual gear model for STEP-NC, International Journal of Machine Tools & Manufacture, Vol.42, pp.335-342.

Maria Pia Sammartini , Leonardo De Chiffre, (2000) Development and validation of a Precision Engineering and Nanotechnology, Vol. 24, pp. 302-309.

Koura M.M., Zamzam N.M., Rizk M.A. & Sayed T.H., (2011) Software for generating Modified helical gears, Engineering research Journal, University of Helwan, ISSN 1110-5615, V 132, December 2011

Chien-Fa Chen, Chung-Biau Tsay, (2004) Computerized tooth profile generation and analysis of characteristics of elliptical gears with circular-arc teeth, Journal of Materials Processing Technology, Vol. 148, pp.226–234.

Fong Zhang-Hua , Chiang Ta-Wei, Tsay Chieh-Wen, (2010) Mathematical model for parametric tooth profile of spur gear using line of action", Mathematical and Computer Modelling, Vol. 36, pp. 603-614, 2002.

Kuo Jao Huang, Hsin Wei Su, (2010) Finite elements in analysis and design, Elsevier 46, 2010 pp 1106 – 1113.