Computer Analysis of the Worm and Gear Meshing

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Abstract

The design and simulation of meshing of a gear drive is presented. Generally worm-gear is generated by the hob which is identical to the worm. This process guarantees the conjugation between the worm and the gear but results in a line contact at every instant which is very sensitive to misalignment. The localization of bearing contact is necessary to reduce the sensitivity of the worm-gear drive to misalignment. Practically this localization is achieved by application of an oversized worm type hob to cut the worm-gear. The oversized hob approach is very practical and effective to localize bearing contact but can not provide the conjugation between the worm and the modified worm-gear. This work proposes an analytical procedure to make the worm surface conjugate to the worm-gear which is cut by the oversized hob. The developed computer program allows the investigation of the influence of misalignment on the shift of the bearing contact and the determination of the transmission errors, the contact ratio and the principle curvatures. The developed approach has been applied for single-enveloping worm-gear drives .

Keywords

Gear drive ; Worm gear ; contact surface; generatrix line

1 INTRODUCTION

A worm drive is a gear arrangement in which a worm, which is a gear in the form of a screw, meshes with a worm gear. The worm and gear drive is the simplest way to obtain a large speed reduction with high torque in a compact space.
Generally worm-gear is generated by the hob which is identical to the worm. This process guarantees the conjugation between the worm and the gear but results in a line contact at every instant which is very sensitive to misalignment that we evoid by localizating the bearing contact.
This localization is achieved by using an oversized worm type hob to cut the worm-gear. This approachis pratical and effective but can't provide the conjugation between the worm and the modified worm-gear. This work proposes an analytical procedure to make the worm surface conjugate to the worm-gear which is cut by the oversized hob. The flank's surface of the thread's groove is an helical surface generated by helical motion of straight line secant to the worm's axis. The obtained bearing surfaces has been resized and cleaned for the analysis in the second part of this work.

2 OBJECTIVE

The aim of this work is to

- Mentioning, comparaison and the evaluation of usable methods of creating the CAD model of a worm and gear set
- The verification of possibility to generate exact 3D modelsof the worm and gear set by simulation of it's manufacturing process.

- The verification of created 3D model of the worm and gear set to be used for FEM analysis
- Examination of the FEM model for FEM analysis
- Modeling of loading of curved teeth with regard to the non uniformity of the load distribution along the tooth flank.
- The comparaison of results of isued from the FEM analysis with existing methods according to ISO 6336.

3 THE WORM AND GEAR SET MODELLING

3.1 WORM AND WORM WHEEL DEFINITION

First of all the basic dimensions of the wrom have been choosen.
The machining technology of the worm has been described in my previous plublication. The thread grove is machined with a conical tool wich axis is skew to the worm axis. The inclination in equal to the spiral angle. It is also comon to use for worms with biger dimensions the so called shank-type gear shaper cutter, a conical tool with axis perpendicular to the machined worm axis. The worm thread shape slightly differs from the theoritical shape machined by turning. We obtain a correct meshing when the tool used to machine the gear has the same shape as the worm.

Choosen dimensions

$Z_1 = 1,$
$Z_2 = 36$
$Mn = 10$
$D_1 = 100$

Calculated dimensions

$i = \frac{Z_2}{Z_1}$, $\sin\gamma = \frac{m_n * Z_1}{D_1}$, $D_2 = \frac{m_n * Z_2}{\cos\gamma}$, $D_{a1} = D_1 + 2 * m_n$, $Ca = 0.25 * m_n$,
$D_{a1(tool)} = D_1 + 1.25 * 2 * m_n = D_{a1} + 2 * Ca$, $D_{a2} = D_2 + 2 * m_n$, $D_{f1} = D_1 - 2.5 * m_n$,
$D_{f2} = D_2 - 2 * 1.25 m_n$

$$D_2 = \frac{10 * 36}{\cos 5.739170477} = 361.813613493, \ D_2 = 361.818613493mm$$
$$D_{a2} = 361.813613493 + 2 * 10 = 336.813613493, \ D_{a2} = 336.813613493mm$$
$$D_{a1} = 100 + 2 * 10 = 120, \ D_{a1} = 120mm$$
$$\sin\gamma = \frac{10 * 1}{100} = 0.1, \ \gamma = 5.739170477^\circ$$
$$Ca = 0.25 * 10, \ Ca = 2.5mm$$

$$i = \frac{36}{1} = 36,,$$

$$D_{a1(tool)} = 125mm$$

$$D_{f1} = 100 - 2.5 * 10 = 75$$

$$D_{f1} = 75mm$$

,

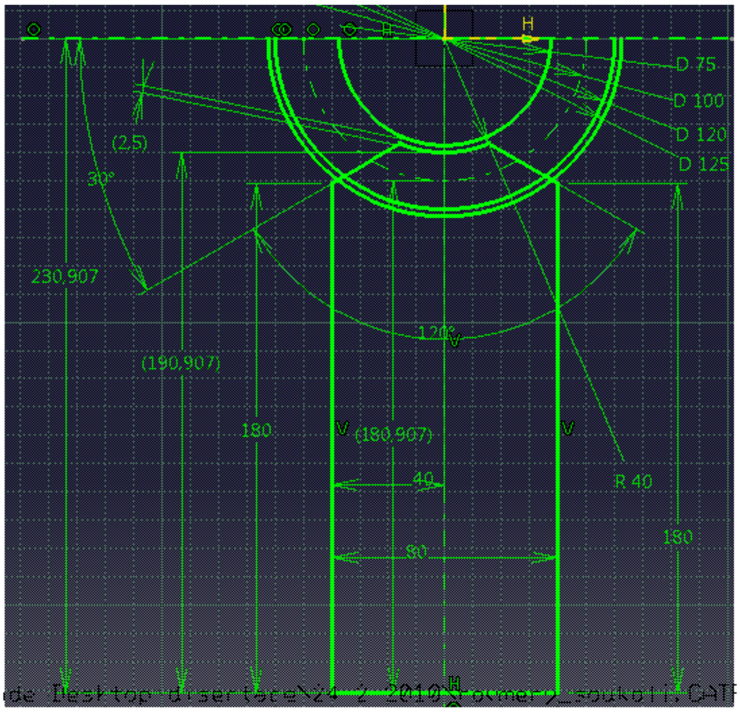
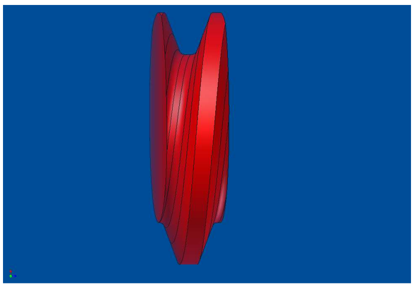


Figure1

3.2 WORM AND GEAR MESHINING

In figure 2 we can see a model of a one tooth single threaded worm (m=10, d_1 =100 mm, α_n=20°). The worm shape is obtained by slinding a tooth section along the the spiral generative around the worm axis.

The described technology means the machining of the worm thread grove with a conical tool which axis is skew to the machined worm axis. The inclination is equal to the spiral angle. It is also comon to use worms with biger dimensions, the so called shank-type gear shaper cutter, a conical tool with axis perpendicular to the machined worm axis. The worm thread shape slightly differs from the theoritical shape machined by turning.



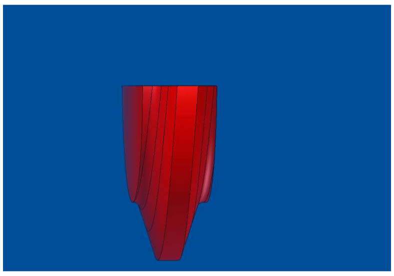


Figure2 a

Figure2 b

The tool (Figure3) for the wheel machining is derived from the worm. The head diameter of the tool is increased by the functional clearance Ca (figure4).

The step for the tool's substraction from the blank in inclined by 5 degrees and the axial displacement by 1/72 time the lead of screw thread.

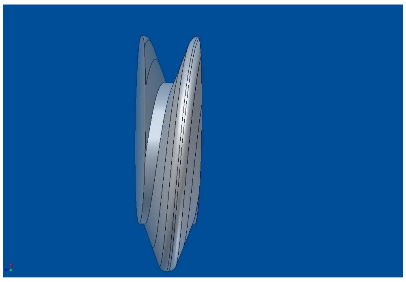


Figure3 a

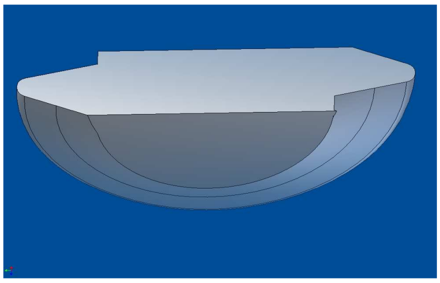


Figure3 b

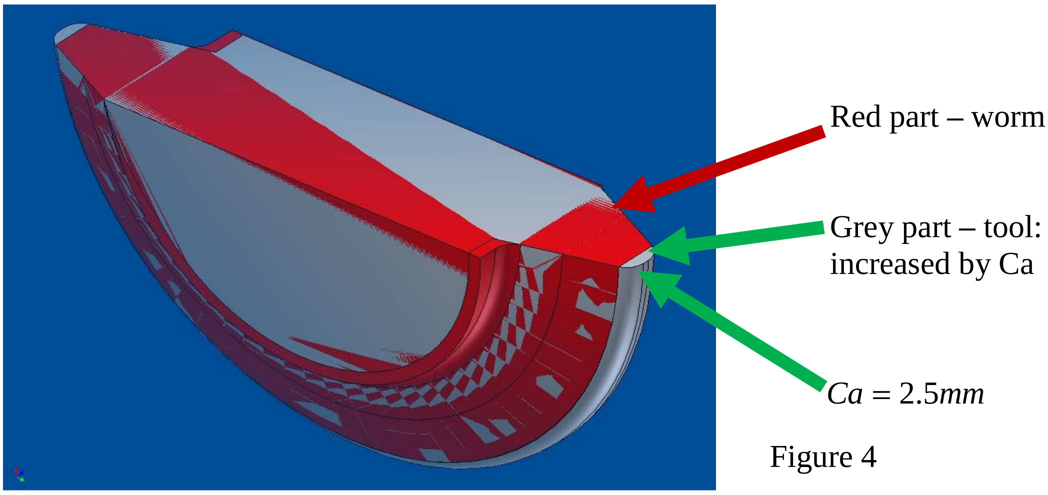


Figure 4

The model of the gear is obtained by the animation of the generation of the machining of the gear blank with worm tool. To achieve a rapid animation of the wheel machining it is possible to use only a half part of one thread of the wormtool and instead of the worm rotation, translate the half thread and substract from the wheel. The tool's axis skew to the wheel blank axis and is progressively subtracted from the blank. The blank rotates and the tool advances. During the tool preparation for the worm's machining, the tool's head circle must be tangent to the wheel root diameter.

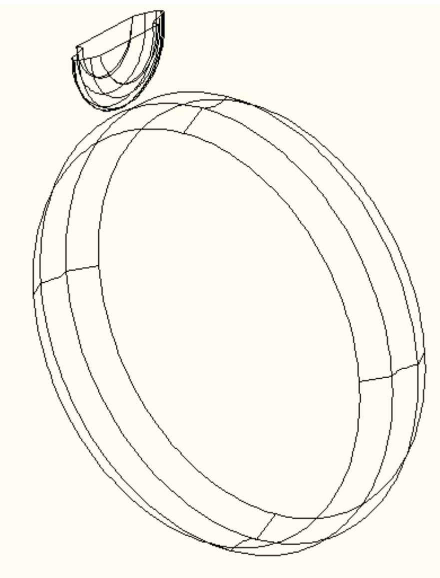


Figure 5a

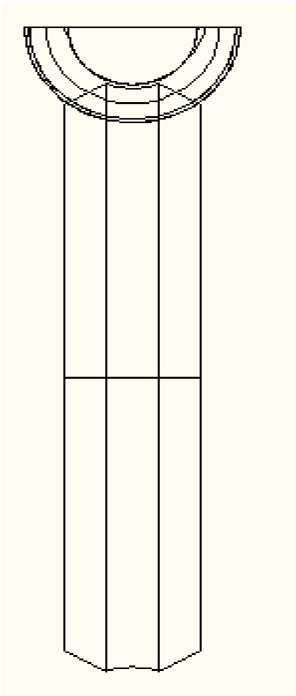


Figure 5b

The substraction of the tool from the wheel is obtained by lunching the programme below in AUTOLIPS:

```
;wheel  modul 10 teeth number 36, m=10  z=36
;worm nominal diameter D1 = 100 mm
; climbing angle gama = 5,739 deg
;wheel nominal diameter D2 = 361.814 mm
; centre-to-centre distance a = 230.907 mm

(defun prime ( )
(setq MODUL 10.0 D2 361.814 ZUBU 36 )
( setq
  ;MODUL    10.0
  ;      ZUBU    36.0
  ;     GAMA    5.739
       PREVOD 36.0
       TGGAMA  0.1005038
       R2       (/ D2 2)
       OPAK    20
       X0     0    ;pocatecni poloha pred odvalovanim
       KROK     15.7872
 )
( print "Vyber polotovar kola " )
( setq SEL1 ( ssget ))
( print "Vyber zub sneku " )
( setq SEL2 ( ssget ))
( setq N OPAK                              ;pocet opakovani kroku

       ;BETA ( * BETA ( / PI 180.0 ))             ;polomer roztecne kruznice
       ;R ( / ( * MODUL ZUBU )(* 2.0 (cos BETA)))
       BOD2 ( list KROK 0.0 0.0)
       BOD0 ( list 0.0 0.0 0.0 )              ; stred kola
       ALFA -5.0
       ;ALFA ( / KROK R2 )
       ;ALFA ( / ALFA PREVOD )
       ;ALFA ( / ALFA TGGAMA )
       ;ALFA ( * ALFA ( / -180.0 PI ))
        X KROK )
;( command "_move" SEL2 "" BOD0 BOD2 )
( repeat N
      ( setq BOD1 ( list X 0.0 0.0))
      ( command "_copy" SEL2 "" BOD0 BOD1 )
      ( setq SEL3 ( ssget "_L" ))
      ( command "_rotate" SEL1 "" BOD0 ALFA )
      ( command "_subtract" SEL1 "" SEL3 "" )
      ;( setq SEL1 ( ssget "_L" ))
      ( setq X ( + X KROK ))
); konec repeat N
); konec defun
```

The result of this apoperation is a groove which appear on the blank. This groove is the space between two teeth figure 6. This groove volume will be substracted 36 times by 10 degrees to obtain the wheel complete shape.

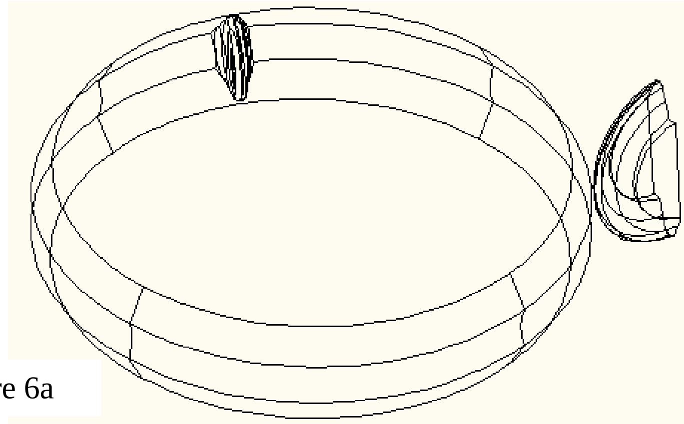


Figure 6a

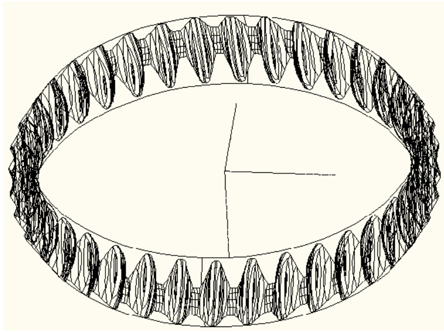


Figure 6b

The next part of this work is to determinate the exact profile of the worm and gear set and generate the the solide model.

The second chapiter will deal with the application of the FEM methode on the model with respect to the correct meshing of finite elements and with respect of their quantity. Static analysis with clasic methods have two procedures: the contact and beding calculation. Because the contact tasks are very complicated to solve with FEM, we consider the teeth are subjected only to bending deformation . The input parameters for FEM analysis are the size, the distribution and the point of application of forces. Another aim of this thesis is to determinate the point of application of the forces on the flank curved surface.

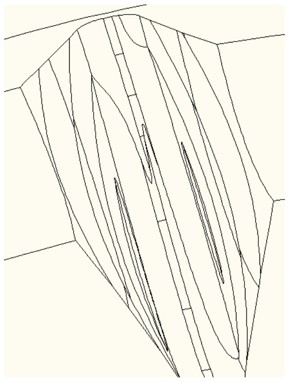
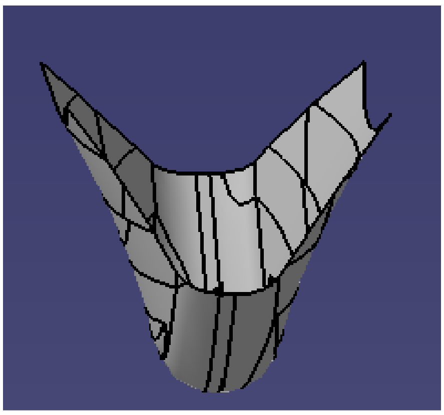


Figure 6c

For the perposes of static analysis, it is neccessary to clean the surface to have the groove made of continual and regular surfaces before the complete wheel gereration. As the matter of fact, the obtained groove surface consites of several irregular curved surfaces figure 7. These kind of surfaces are not suitable for the meshing.

Figure 7b



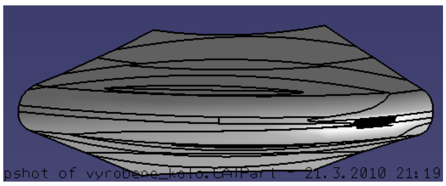


Figure 7b

During the process of creating the model, it is possible to make any changes or ajustements on the geometry of the accurate profile. Some of them may concern only 2D profile of the tooth, other the 3d profile. The teeth can be made separatly and and put together to create the wheel. But it is faster to make one groove surface and substrate it's volume frome the grear blanc to obtaine the wheel. To cleaning the surface, we need to add point elements on the boundarys of the small surfaces and we joing the points to obtain new boundary curves that will be used to generate new surfaces. The old groove surfaces will be removed and replaced them by the cleaned one (figure8).

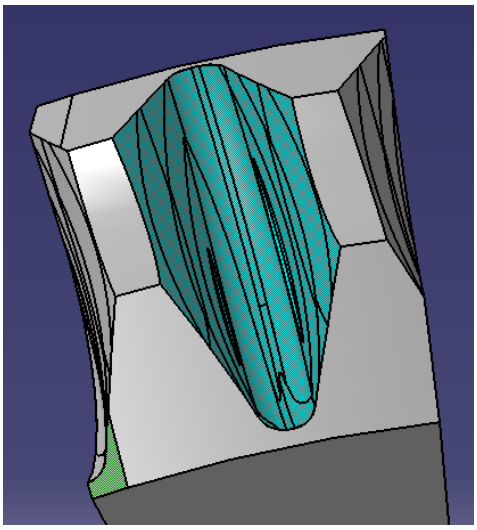


Figure 8a

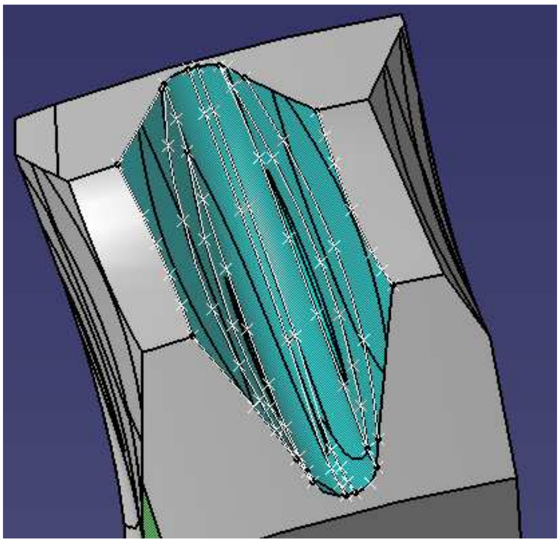


Figure 8b

The figure 9 shows the cleaned surface of the groove. We obtain the whole model on cleaned wheel by

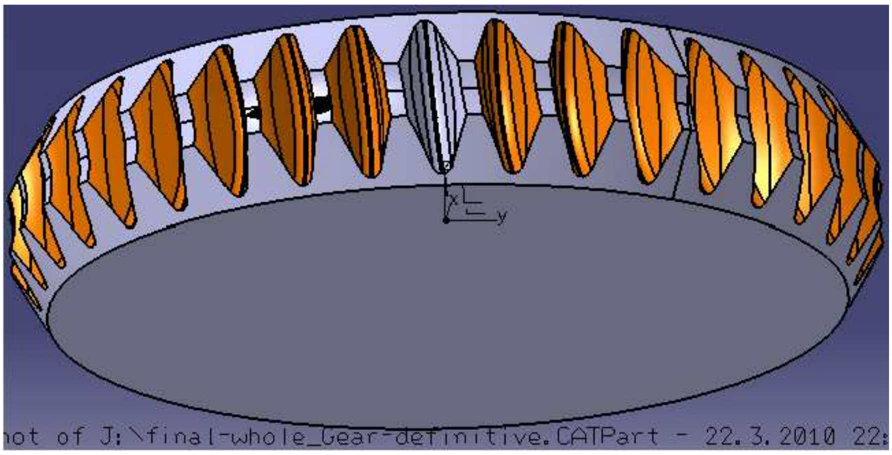


Figure 9a

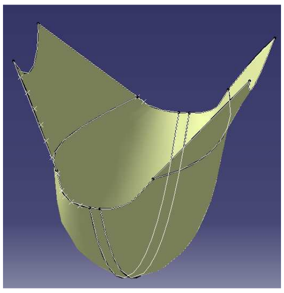


Figure 9b

4 KONTAKT SURFACE MODELING

For the application of the force on the contact surface, we need first to determinate the exact position of the contact surface on the teeth curved flank.
The contact surface was determinated by providing the clash analysis on the worm and gear set in meshed position.
The Inventor system allow such a colision analysis of assemblis and views the intersection surface of clashed components. This intersection surface was isolated and it's shape has been reproduced on the tooth flank to make the contact surface. On this surface, we will apply the load in our next publication for FEM analysis.

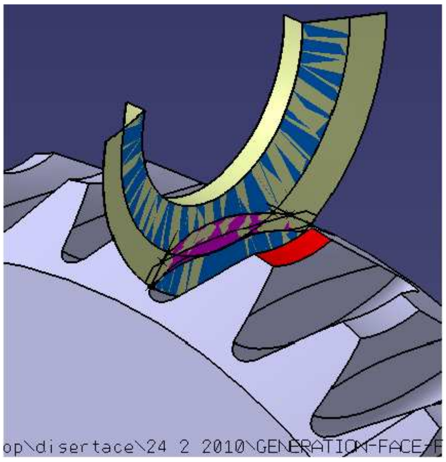


Figure 10a

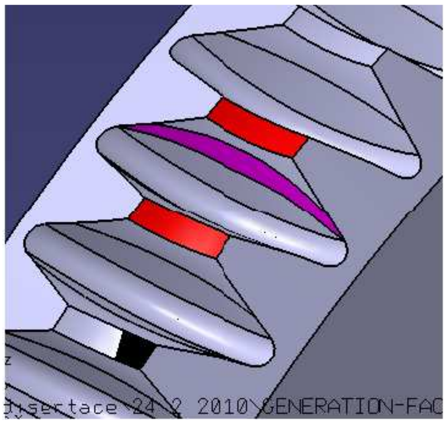


Figure 10b

5 CONCLUSION

The worm gear modeling by the simulation of it machining in CAD system appears to be the more efficient methode to obtain a correct shape profile. They are other methodes:

- The direct generation of the shape in CAD systems.This methode is not suitable because it needs to simplify the gear shape.
- The mathematical definition of the shap whsch is very complicated due to the amount of matematical equations to solve.
- The matematical simulation of the machining is another possible methode but it needs to daterminate all the coordinate of all point defining the tooth shape.

The developed computer program allows the investigation of the influence of misalignment on the shift of the bearing contact and the determination of the transmission errors, the contact ratio and the principle curvatures. The developed approach has been applied for single-enveloping worm-gear drives. The developed theory must be illustrated with a numerical approach which will invoke the meshing stiffness calculation which is an important factor used in modelling of gear transmission errors and wear, as load sharing has to be taken into account.

6 AKNOWLEDGEMENT

Many thanks to Mr J. Bečka for his help and advice.

7 REFERENCE

[1] Jan Bečka; Modelování a vypočty ozubených kol na PC Praha 2003– vydavatelství ČVUT