

e=MSC<sup>x</sup>

ENGINEERING. EDUCATION. ENTERPRISE.  
2009 VPD  
VIRTUAL  
PRODUCT  
DEVELOPMENT  
CONFERENCE

# Integrating ADAMS Software into an Upper Division Mechanical Design and Analysis Course

Xi Wu, Assistant Professor, **California Polytechnic State University**

Dewen Kong, Professor, Jilin University

Jim Meagher, Professor, California Polytechnic State University



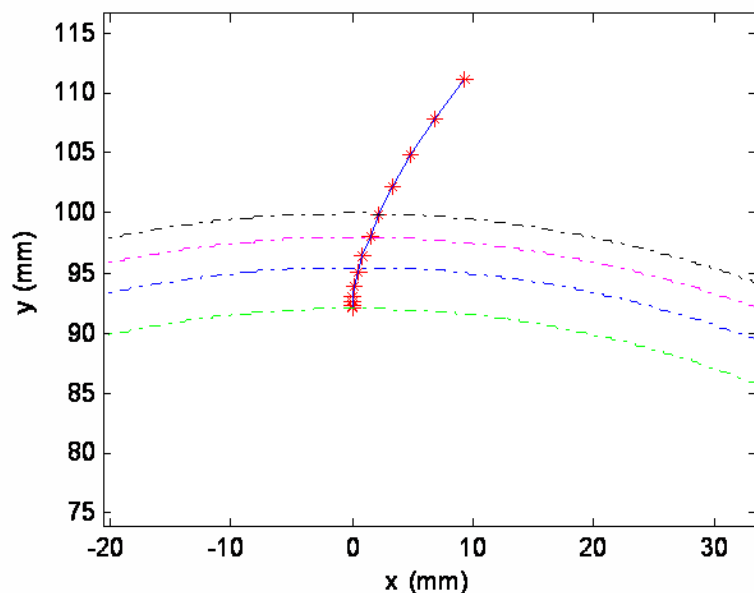
MSC<sup>x</sup> Software



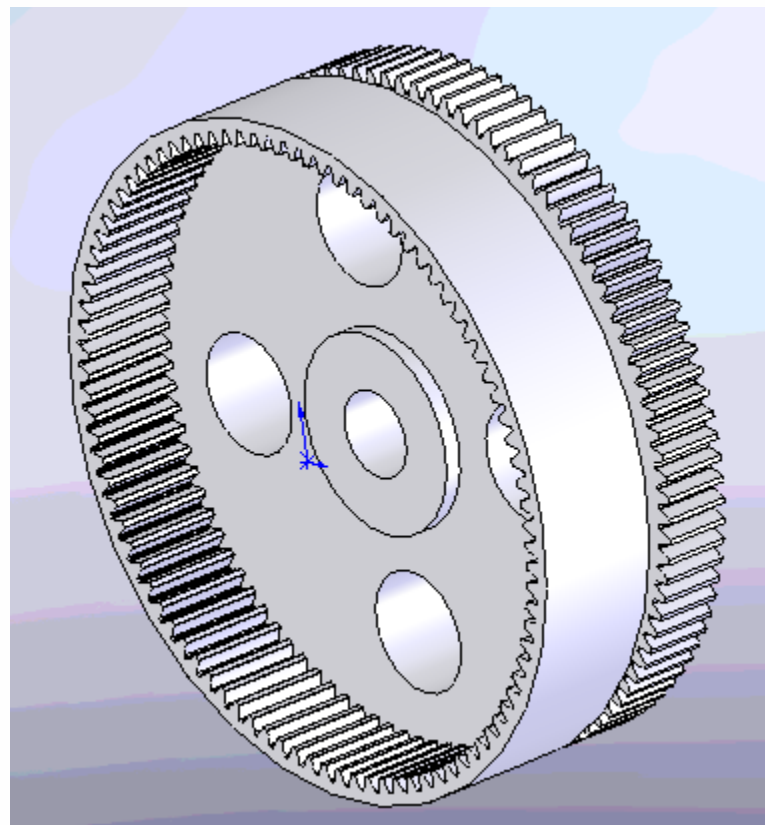
# Outline

- Introduction to rotating machinery design and analysis course: ME518.
- Gear profile design using MATLAB and CAD program.
- Crank-slider mechanism and two-stage gear box.
- Three types of planetary gear transmission systems.
- Comparison of the ADAMS simulation results with theoretical results.
- Vibration signals synchronous with gear mesh frequency and input speed.
- Changes in vibration signatures due to damage in transmission components.

# Gear Tooth Profile Design

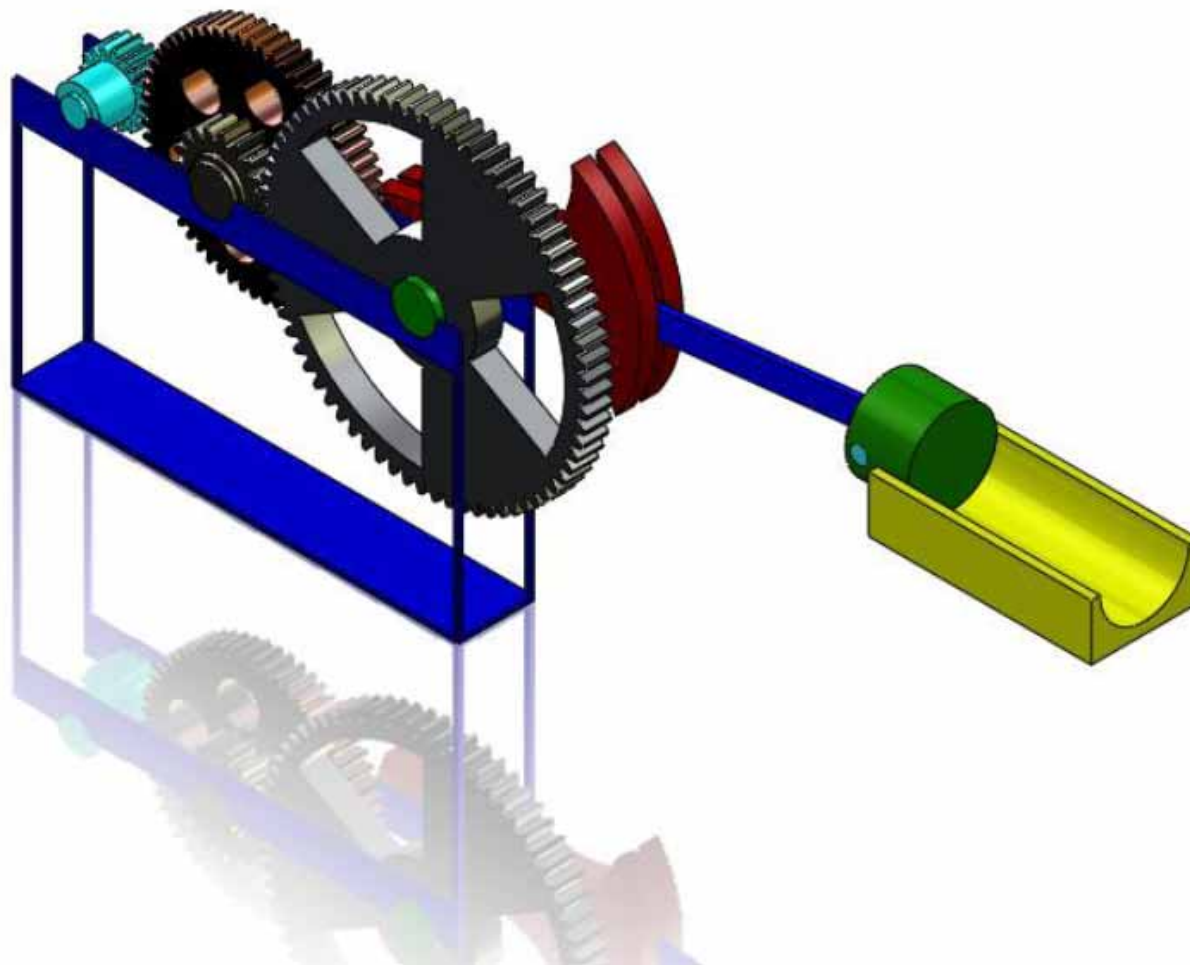


MATLAB plot for gear tooth profile



Note: In order to generate external tooth and internal tooth, respectively, the profile should be rotated different angles in different directions.

# Crank Slider Mechanism Assembly I



Design goal:

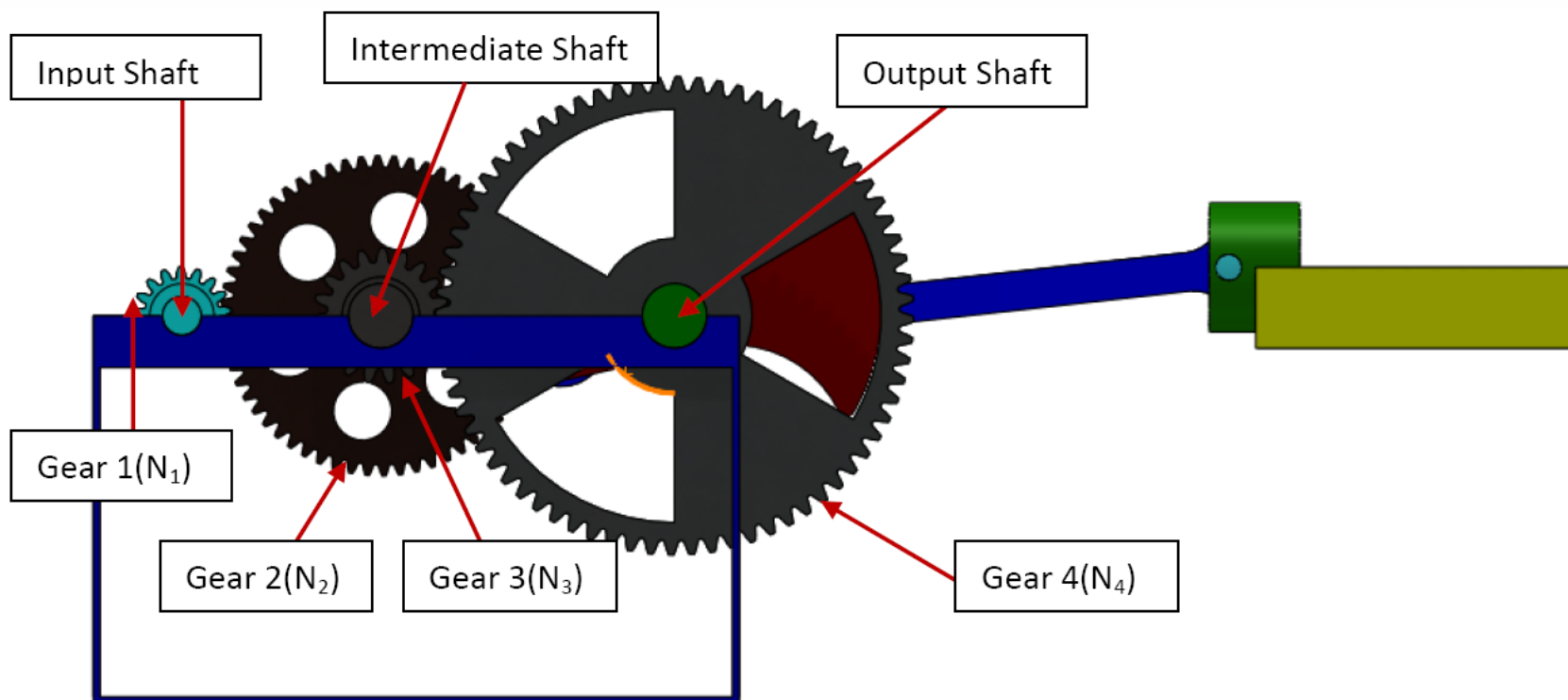
input power:  $P_1=22\text{kW}$ ;

input angular velocity:

$n_1=1500\text{ rpm}$ ;

gear ratio:  $i=13.375$ ;

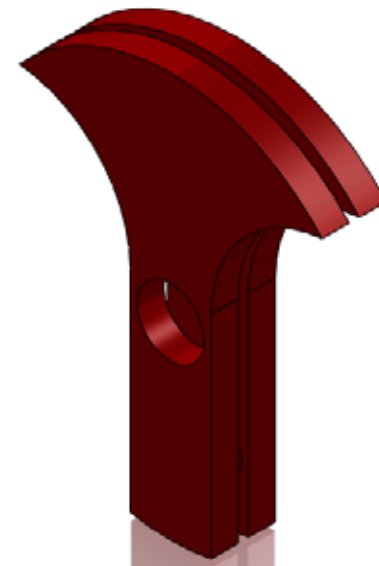
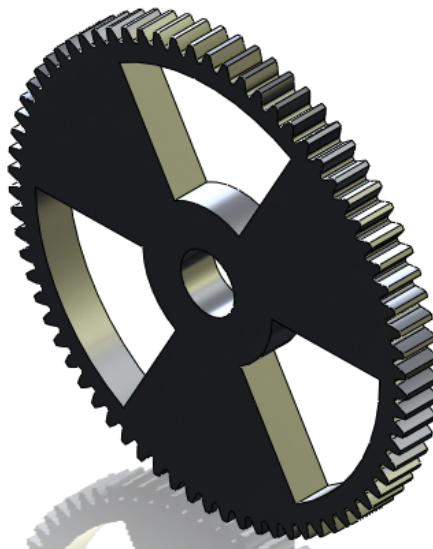
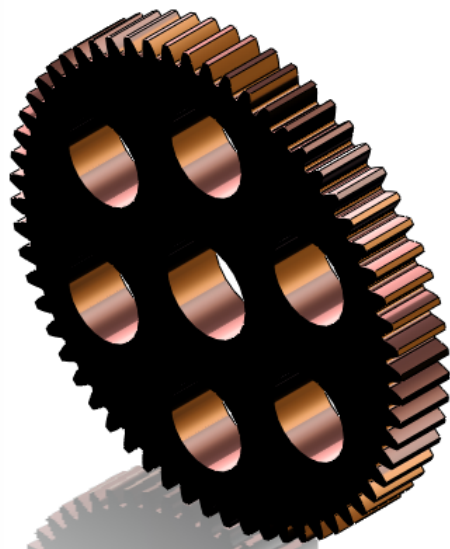
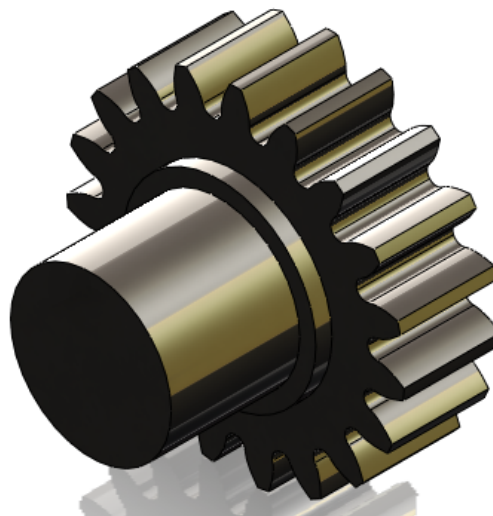
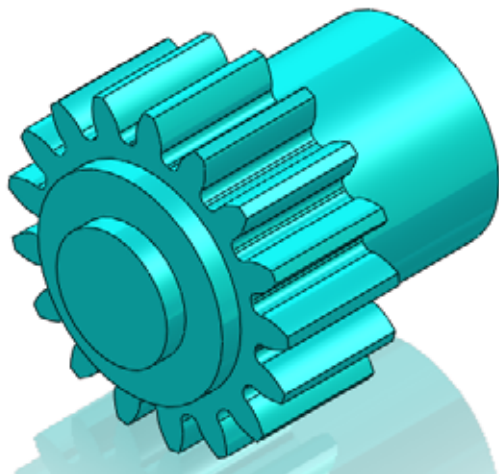
# Crank Slider Mechanism Assembly II



Number of teeth:  $N_1=17$ ,  $N_2=60$ ,  $N_3=19$ ,  $N_4=72$

Gear Modules:  $m_1 = 4$ ,  $m_2 = 5$

# Crank Slider Mechanism Components

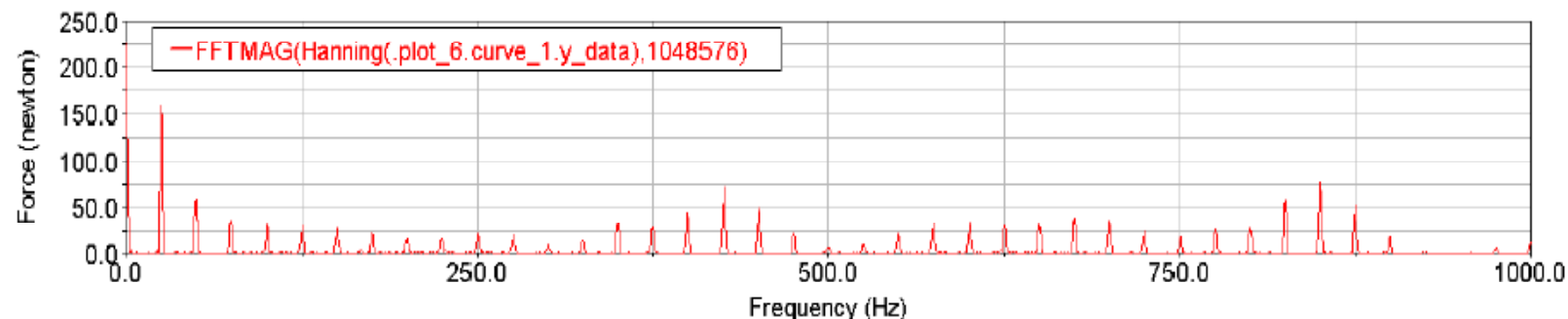
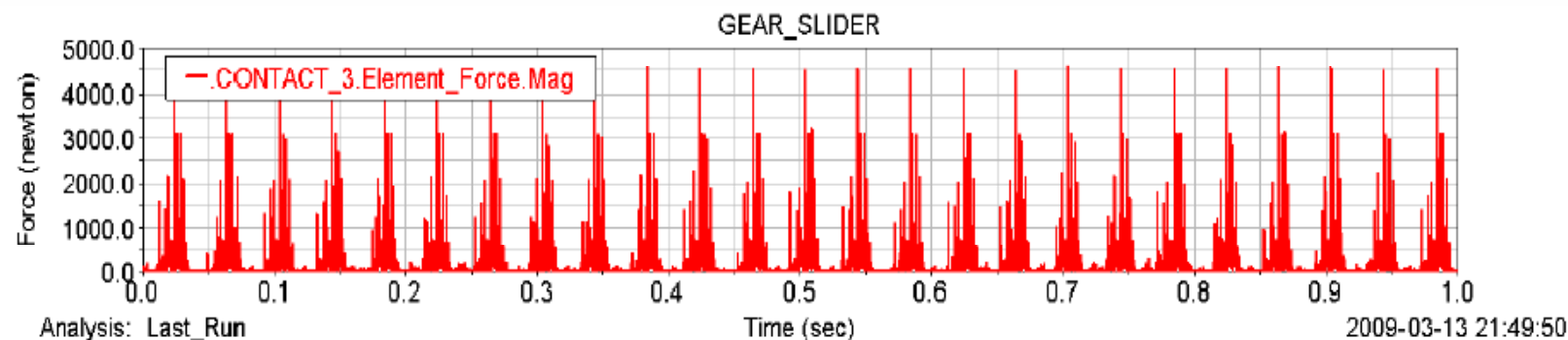


# ADAMS Simulation Result I



Time base and FFT plots of the contact forces in gear pair 1-2 for a healthy crank-slider mechanism

# ADAMS Simulation Result II



Time base and FFT plots of the contact forces in gear pair 1-2 for a crank-slider mechanism with a damaged pinion tooth.



# Practical Gear Box Design

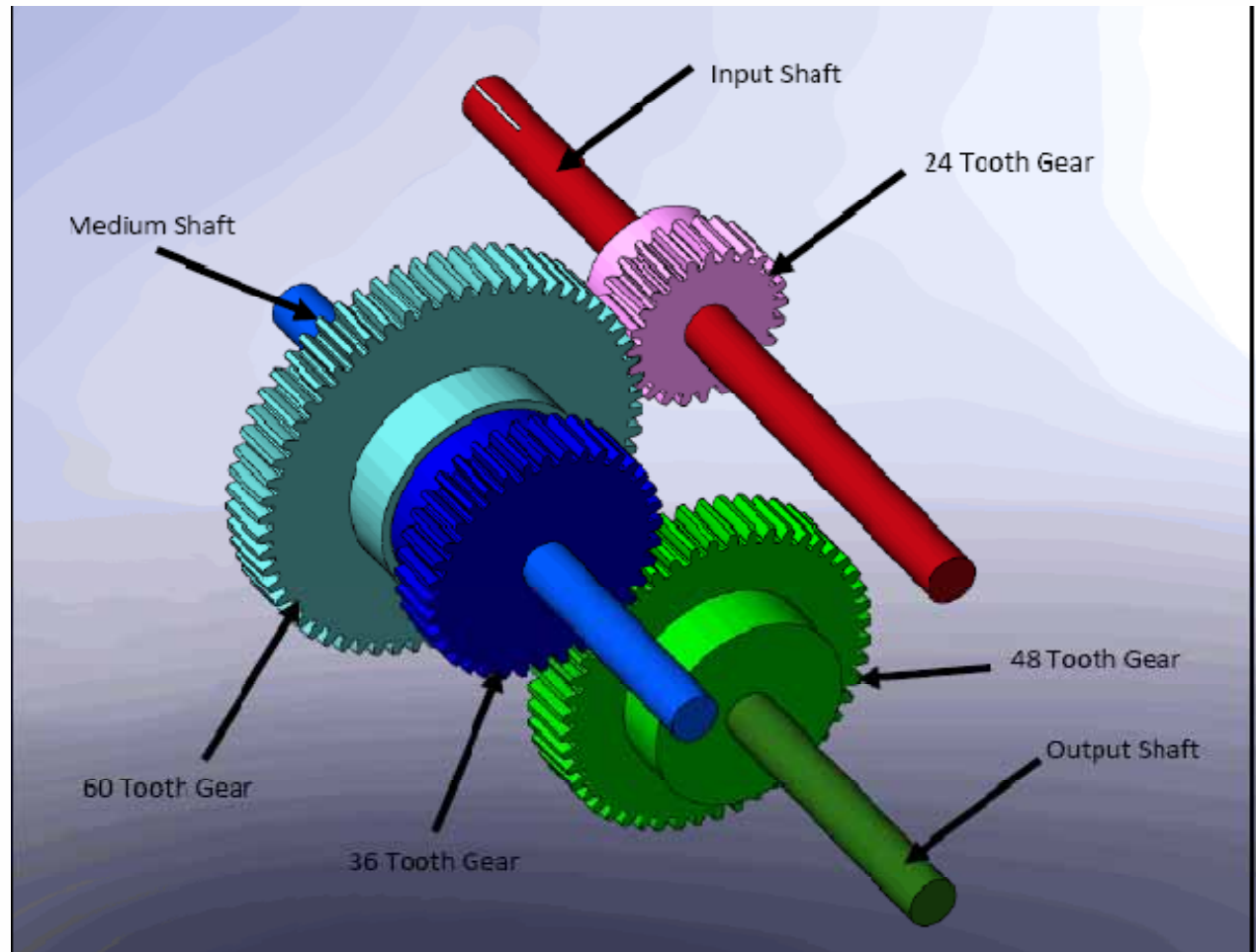
This is a practical gear train in vibration Lab.

Design parameters:

Face width:  $\frac{3}{4}$  in;

Diametral Pitch: 12  
teeth/inch;

Pressure Angle:  $14.5^\circ$

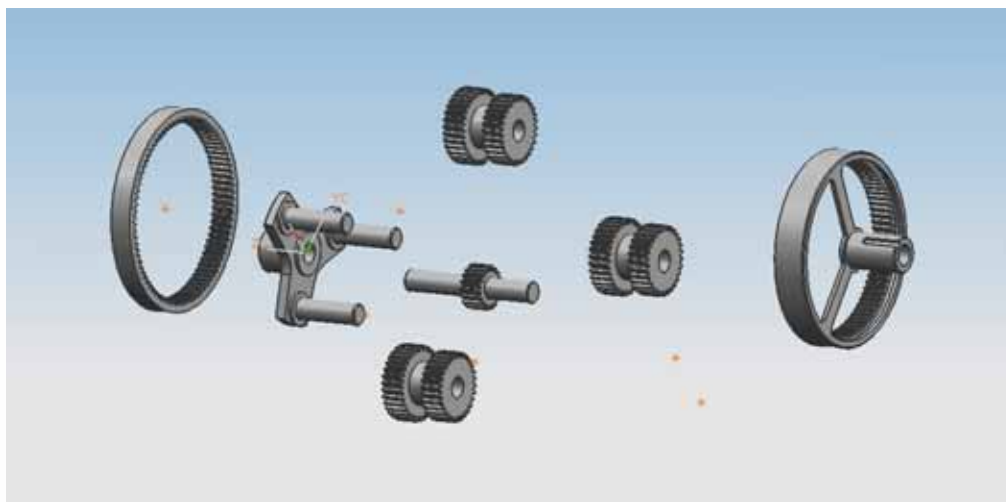
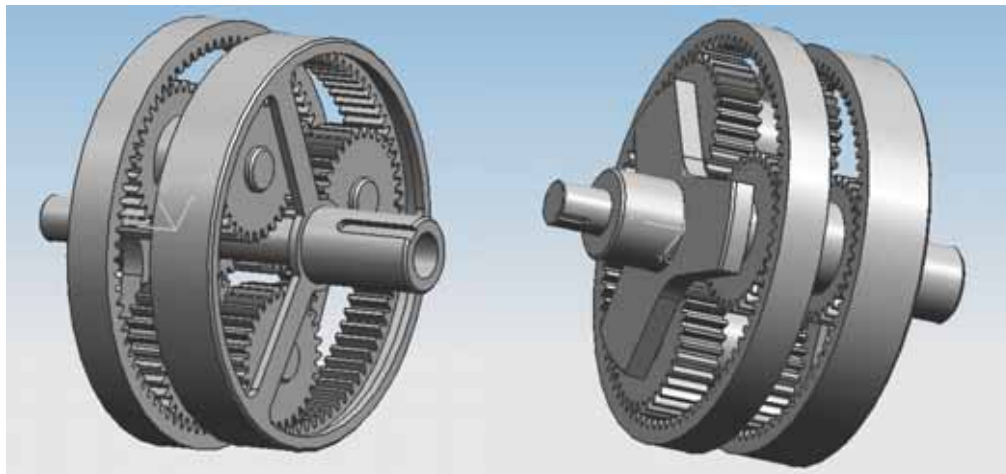


# Planetary Gear Transmission I



Design Goal:

input power  $P_1=22\text{kW}$ ;  
input angular velocity;  
 $n_1=1500\text{ rpm}$ ;  
gear ratio:  $i=99$ ;



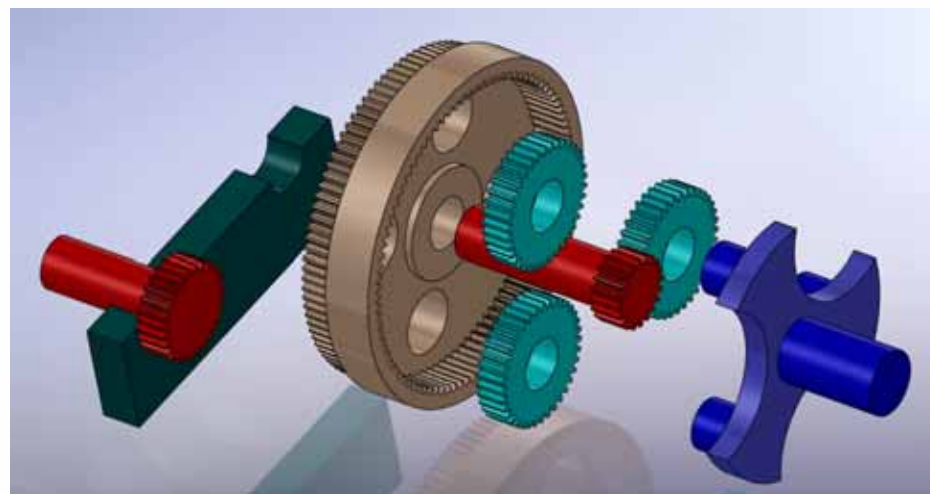
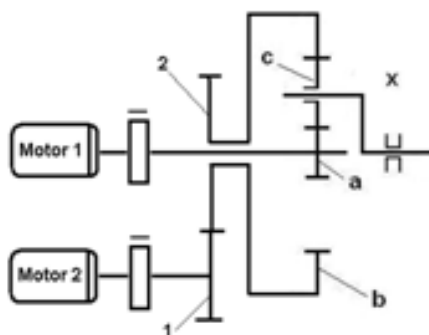
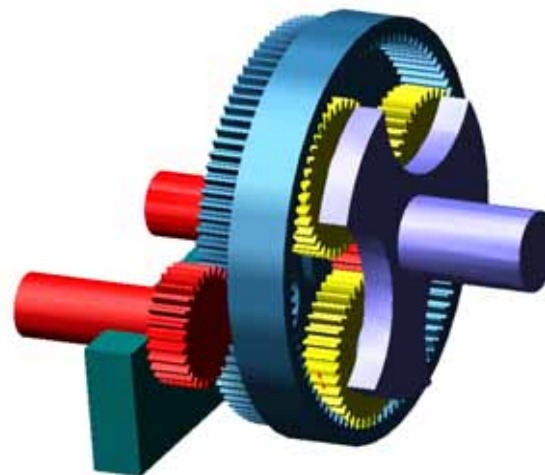
# Differential Driving System

Design Requirement:

$P_1=7.5\text{kW}$ ;  $n_1=980\text{ rpm}$   
for motor 1;

$P_2=5.5\text{kW}$ ;  $n_2=750\text{ rpm}$   
for motor 2;

$z_1=28$ ,  $z_2=98$ ,  $z_a=20$ ,  
 $z_c=37$ ,  $z_b=94$ ;

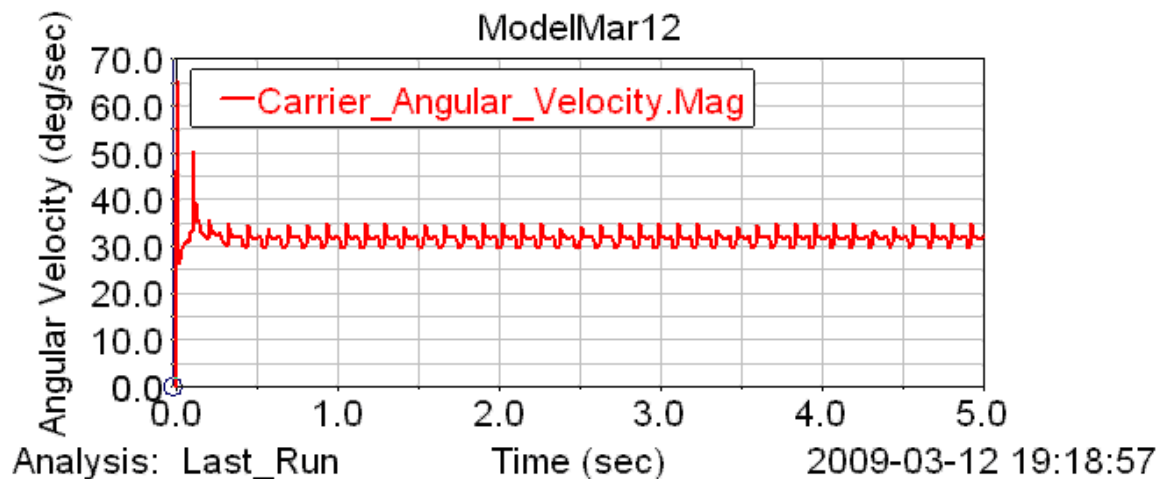
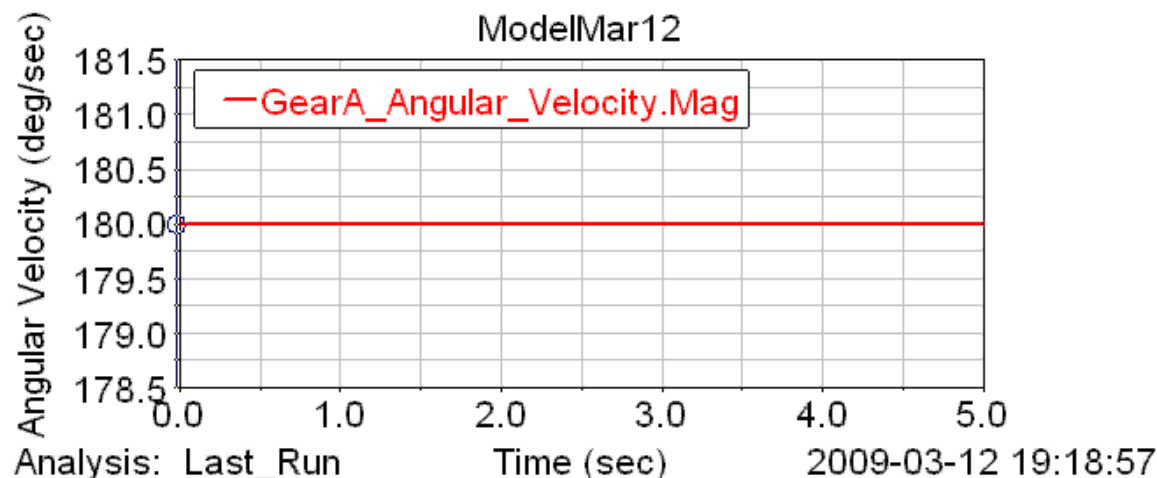


# ADAMS Verification I

Case 1. Sun gear a operates at 180°/sec;  
Theoretical carrier output is

$$n_x = \frac{n_1}{i_{ax}^b} = \frac{180}{5.7} = 31.57^\circ/\text{sec}$$

ADAMS carrier output:  
31.52°/sec



# ADAMS Verification II

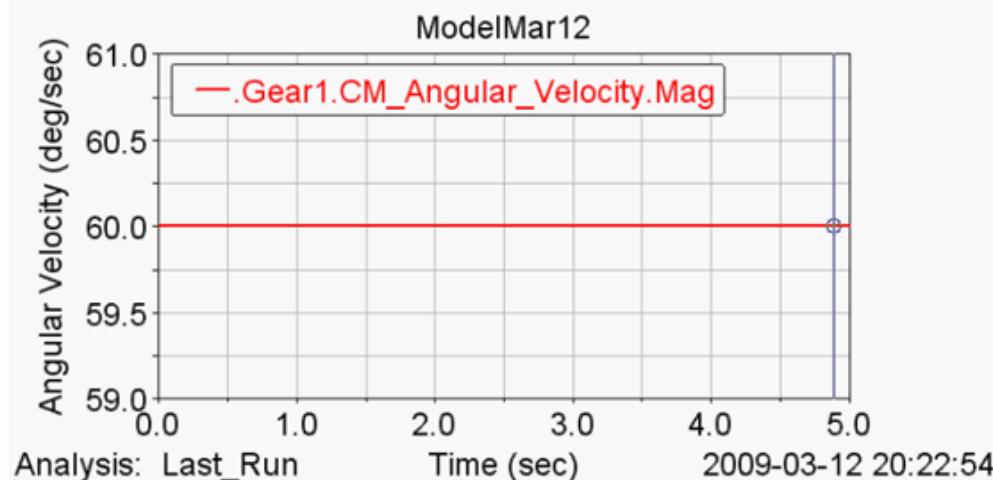
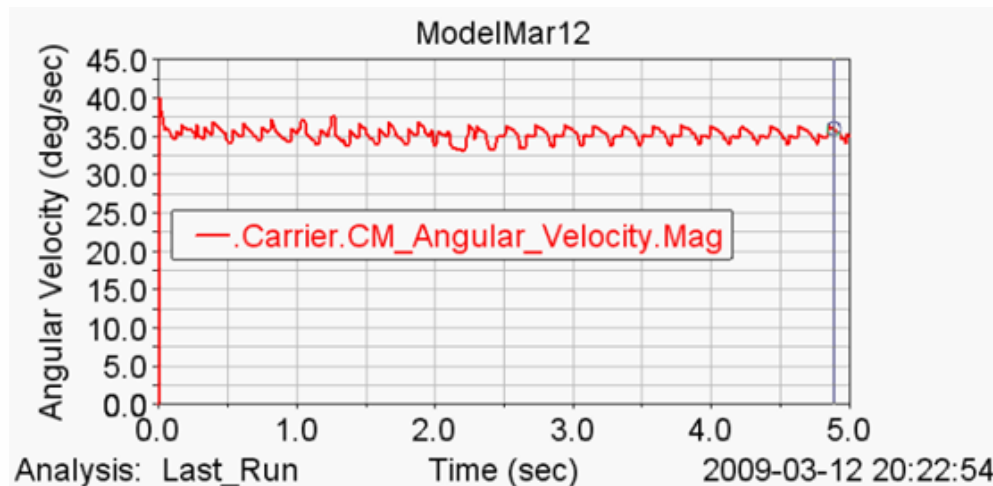
Case II. Sun gear a operates at 120°/sec; Gear 1 operates at 60°/sec; The motors run in opposite direction.

Theoretical carrier output is

$$n_x = \frac{n_a}{i_{ax}^b} + \frac{1}{i_{bx}^a} \frac{n_2}{i_1}$$

$$= \frac{120}{5.7} + \frac{60}{1.213 * 3.5} = 35.18^\circ/\text{sec}$$

ADAMS carrier output:  
35.16°/sec

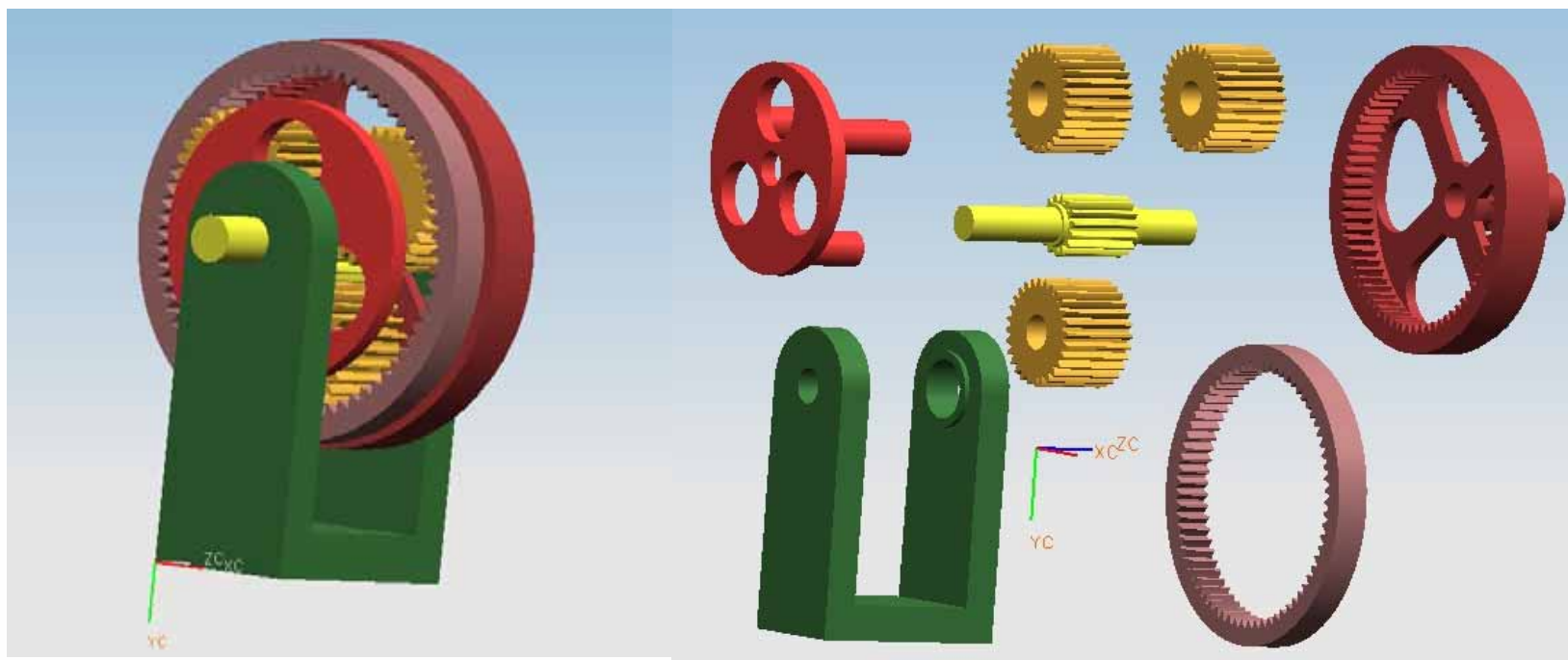


# Planetary Gear Transmission II

Non-standard gear train design:

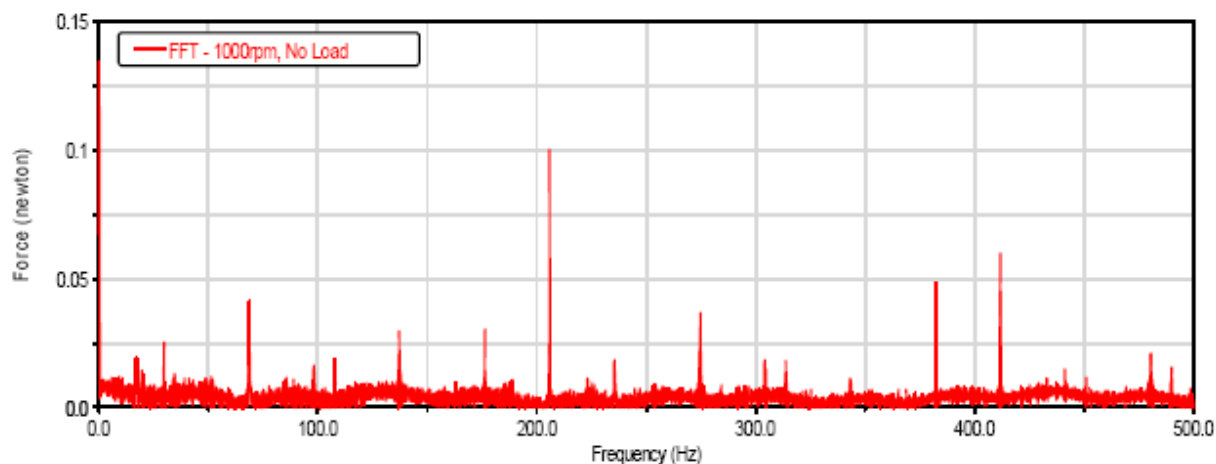
Design parameters:  $P_1=22\text{kW}$ ;  $n_1=1500\text{ rpm}$ ; Gear ratio:  $i=134$

Number of sun gear teeth: 15; Number of planet gears: 3



# ADAMS Simulation Results

<i>Known Frequencies</i>	<i>Hz</i>
<i>GMF</i>	205.9
<i>Input Shaft</i>	16.71
<i>Carrier</i>	2.974
<i>Planets</i>	4.370
<i>Output Shaft</i>	0.1244



The FFT of the force on the input shaft joint yielded many peaks when the gearbox was very lightly loaded. Note:  $29.4838 \text{ Hz} = \text{GMF}/7$ ;  $274.5552 \text{ Hz} = 4\text{GMF}/3$ ;  $411.8118 \text{ Hz} = 2\text{GMF}$ , etc...

# Conclusions and Acknowledgement



- ADAMS software can be used effectively to facilitate mechanical design with a short learning curve.
- ADAMS is being used to help our program meet ABET accreditation requirements for student skills.
- The introduction of ADAMS into the course allowed students to experience a culminating design experience that combined previous coursework.
- ADAMS can predict the fault patterns of a gear train and may obviate some costs of field testing.
- The authors have found the ADAMS software to be a useful teaching and research tool.
- The authors gratefully acknowledge the contributions from ME518 students.





## Contact Details :

- For further information please contact

Xi Wu

Department of Mechanical Engineering

California Polytechnic State University

San Luis Obispo, CA93407-0358

Telephone Number: (805) 756-5214

Email Address: [xwu@calpoly.edu](mailto:xwu@calpoly.edu)