

# ME 5990

## Machining Dynamics

### Course Schedule

### Fall 2004

| Day (#)      | Topic   | Description  | # Lec.                   | Assignments   |
|--------------|---|--|--------------------------|---|
| W 09/01A (1) | Course Information<br>1.1 Mechanics versus Dynamics<br>1.2 Review of the Ideal Chip Formation Model | Format, grading, policies, honor code, goals<br>Their difference and the link between them<br>Orthogonal process geometry and velocities   | 1/5<br>2/5<br>2/5        | Assign Paper Set 0 Reading<br>(Chapters 2 and 8.4 of ME 5610 Notes) |
| W 09/01B (2) | Arrange paper presentations<br>1.2 Review of the Ideal Chip Formation Model, cont'd                 | Orthogonal force-geometry relations<br>Strain and energy<br>Ideal vs. reality — concepts and assumptions   | 1/5<br>2/5<br>1/5<br>1/5 |   |
| W 09/08A (3) | 1.2 Review of the Ideal Chip Formation Model, cont'd<br>1.3 Nonlinearities in Machining             | Ideal vs. reality — experimental images<br>Size effect   | 2/5<br>3/5               | Assign HW1<br>Assign Paper Set 1 Reading                            |
| W 09/08B (4) | 1.3 Nonlinearities in Machining, cont'd<br>1.4 Review of Steady-State Dynamic Analysis              | Process damping<br>The chatter condition<br>Frequency-response<br>Linear stability analysis  | 1/5<br>1/5<br>2/5<br>1/5 |   |
| W 09/15A (5) | Quiz 1<br>Paper Presentation 1a<br>Paper Presentation 1b  | Historic Graphical Techniques for Machining Stability Analysis   | 1/5<br>2/5<br>2/5        |   |
| W 09/15B (6) | 1.5 Machining Dynamics Problems   | Stability-limit diagrams — general characteristics<br>Stability-limit diagrams — speed measured<br>Vibration-level diagrams — unstable/chatter<br>Vibration-level diagrams — stable/forced | 1/5<br>2/5<br>1/5<br>1/5 | <i>HW1 Due</i>  |
| W 09/22A (7) | 1.5 Machining Dynamics Problems, cont'd   | High-speed machining (HSM)<br>Variable-speed machining (VSM)   | 3/5<br>2/5               | Assign Paper Set 2 Reading  |
| W 09/22B (8) | 2.1 A Single-Tooth, 1-D, LTI Model  | The physical model<br>Time-domain representation   | 2/5<br>3/5               |   |
| W 09/29 (9)  | Quiz 2<br>Paper Presentation 2a<br>Paper Presentation 2b  | Analytical Stability Solutions for 1-D, Linear, Time-Invariant Machining Processes   | 1/5<br>2/5<br>2/5        | Assign HW2  |
| W 09/29 (10) | 2.1 A Single-Tooth, 1-D, LTI Model, cont'd<br>2.2 Process Orientations                              | Frequency-domain representation<br>C-axis rotation   | 2/5<br>3/5               |   |
| W 10/06 (11) | 2.2 Process Orientations, cont'd  | L-axis rotation<br>Why break down the model into so many pieces?   | 3/5<br>2/5               |   |

## Course Schedule

| Day     | (#)  | Topic   | Description   | # Lec.                   | Assignments                                      |
|---------|------|---|---|--------------------------|--|
| W 10/06 | (12) | 2.3 Feedback Mechanisms and Phases Shifts   | Block diagram representation<br>Phases and frequencies  | 3/5<br>2/5               |  |
| W 10/13 | (13) | 2.4 Stability and Energy Considerations   | Review of definitions of stability<br>Energy interpretations  | 3/5<br>2/5               | Assign Paper Set 3 Reading                       |
| W 10/13 | (14) | 3.1 Traditional Frequency-Domain Approach   | Vibration growth approach<br>Nyquist approach with arbitrary overlap factor   | 2/5<br>3/5               | <i>HW2 Due</i>                                   |
| W 10/20 | (15) | Quiz 3<br>Paper Presentation 3a<br>Paper Presentation 3b  | Nonlinearities — Structural Dynamics, Size Effect and Process Geometry  | 1/5<br>2/5<br>2/5        | Assign HW3                                       |
| W 10/20 | (16) | 3.1 Traditional Frequency-Domain Approach, cont'd<br>3.2 Eigenvalue Problem Approach<br>3.3 Energy-Based Approach | Solution for unity overlap factor<br>Basic algebra for 1-D case<br>A quantitative time-domain approach  | 1/5<br>2/5<br>2/5        |  |
| W 10/27 | (17) | 3.3 Energy-Based Approach, cont'd<br>3.4 Evaluating the LTI Assumption  | Structural energy / process energy<br>Total energy and stability limit<br>Comparison to Tlustý's frequency-domain solution<br>Where the 'L' and 'TI' are lost — intermittency and/or kinematics | 2/5<br>1/5<br>1/5<br>1/5 | Assign Paper Set 4 Reading                       |
| W 10/27 | (18) | 4.1 Accounting for Size-Effect Nonlinearity<br>4.2 Effects of Corner Radius – Turning                             | Basic linearization of process force<br>The orthogonal equivalent for corner-radiused tooling<br>Corner radius background   | 2/5<br>2/5<br>1/5        | Assign Final Project                             |
| W 11/03 | (19) | Quiz 4<br>Paper Presentation 4a<br>Paper Presentation 4b  | Periodic Time Variation — Intermittency and Kinematics  | 1/5<br>2/5<br>2/5        | <i>HW3 Due</i>                                   |
| W 11/03 | (20) | 4.2 Effects of Corner Radius – Turning, cont'd  | Effect of displacements on chip area<br>An analytical chip area formulation   | 1/5<br>4/5               | <i>Draft Final Project Proposals Due</i>         |
| W 11/10 | (21) | 4.2 Effects of Corner Radius – Turning, cont'd  | Linearization of chip area nonlinearity<br>Stability solution   | 2/5<br>3/5               | Assign Paper Set 5 Reading                       |
| W 11/10 | (22) | 4.3 Accounting for Periodic Time Variation  | Basic intermittent orthogonal process<br>Traditional time-averaging approach<br>Traditional time-averaging approach, cont'd<br>Added stability lobes  | 1/5<br>1/5<br>1/5<br>2/5 | <i>Final Project Proposals Due</i><br>Assign HW4 |
| W 11/17 |      | Cancelled for ASME IMECE  |   |                          |  |
| W 11/17 |      | Cancelled for ASME IMECE  |   |                          |  |
| W 11/25 |      | Thanksgiving  | Relax and Enjoy!!   |                          |  |
| W 11/25 |      | Thanksgiving  | Relax and Enjoy!!   |                          |  |

### Course Schedule

| Day     | (#)  | Topic   | Description  | # Lec.                       | Assignments                           |
|---------|------|---|--|------------------------------|---------------------------------------|
| W 12/01 | (23) | Quiz 5<br>Paper Presentation 5a<br>Paper Presentation 5b                                      | Milling Stability  | 1/5<br>2/5<br>2/5            |                                       |
| W 12/01 | (24) | 4.3 Accounting for Periodic Time Variation, cont'd<br>4.4 Multiple Teeth and Multi-D Dynamics | Effects of key parameters<br><br>Problem classification<br>Multi-tooth cancellation of dynamic force time variation<br>Multiple-solutions for multi-D – the eigenvalue problem | 2/5<br><br>1/5<br>1/5<br>1/5 |                                       |
| W 12/08 | (25) | 4.5 Real Multi-Tooth, Time Varying Processes – Boring and Milling                             | 3-D equation of motion for boring process<br>Boring solution<br>Milling geometry   | 2/5<br>2/5<br>1/5            | Assign Paper Set 6 Reading            |
| W 12/08 | (26) | 4.5 Real Multi-Tooth, Time Varying Processes – Boring and Milling, cont'd                     | Milling geometry, cont'd<br>Kinematic equations for forcing function<br>Time varying directional gains   | 2/5<br>1/5<br>2/5            | <i>HW4 Due</i>                        |
| M 12/13 |      | All Done!   |  |                              | <i>Final Project Due by 9:00 a.m.</i> |