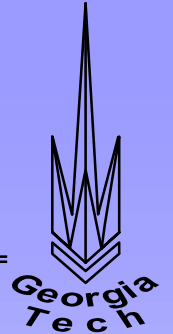


# *A General Cutting Force Model For Milling Operations*

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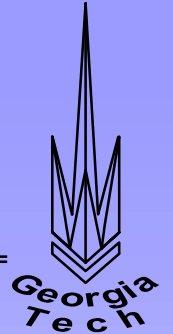


Precision Manufacturing Research Consortium  
Industrial Advisory Board  
Georgia Institute of Technology  
29 October 1997

Yawei Li  
Advisor: Dr. Steven Y. Liang

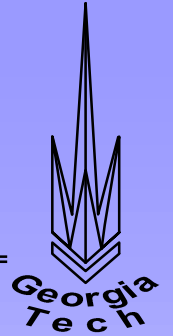
# ***Introduction***

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- ❖ Importance
  - Machinability
  - Machining Accuracy and Surface Finish
  - Chatter / Cutter Wear / Fracture
- ❖ Analytical Integration
- ❖ Convolution Method
- ❖ Explicit Expression Of Cutting Force
- ❖ Based on a General Cutting Edge
  - Cutting Edge Function
  - Cutting Condition
  - Material Properties
- ❖ Can Be Used for Any Milling Operation

# General Cutting Force Model In Angle and Frequency Domain



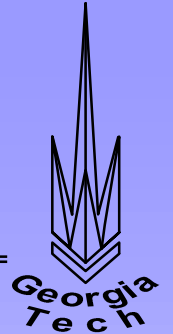
$$\vec{F}(\phi) = \begin{bmatrix} F_x(\phi) \\ F_y(\phi) \\ F_z(\phi) \end{bmatrix} = \sum_{k=-\infty}^{\infty} \vec{A}_k e^{jkN\phi} = \sum_{k=-\infty}^{\infty} \begin{bmatrix} A_{xk} \\ A_{yk} \\ A_{zk} \end{bmatrix} e^{jkN\phi}$$

where

$$\vec{A}_k = 2\pi f_0 \tilde{K} \left[ FFT \{ \bar{p}(v) w(v, T_0) \} FFT \{ h'_\beta(\tau) * Tth(\tau) \} \right. \\ \left. - \sum_{i=1}^{\infty} \left( \left( \frac{y_{\max}}{2\pi f_0} \right)^i \frac{1}{i!} FFT \{ \bar{p}(v) \delta^{(i-1)}(v - T_0) \} FFT \left\{ \left( \frac{1}{r(\tau_0)} - \frac{1}{r(\tau)} \right)^i (h'_\beta(\tau) * Tth(\tau)) \right\} \right) \right]$$

# *Case Study*

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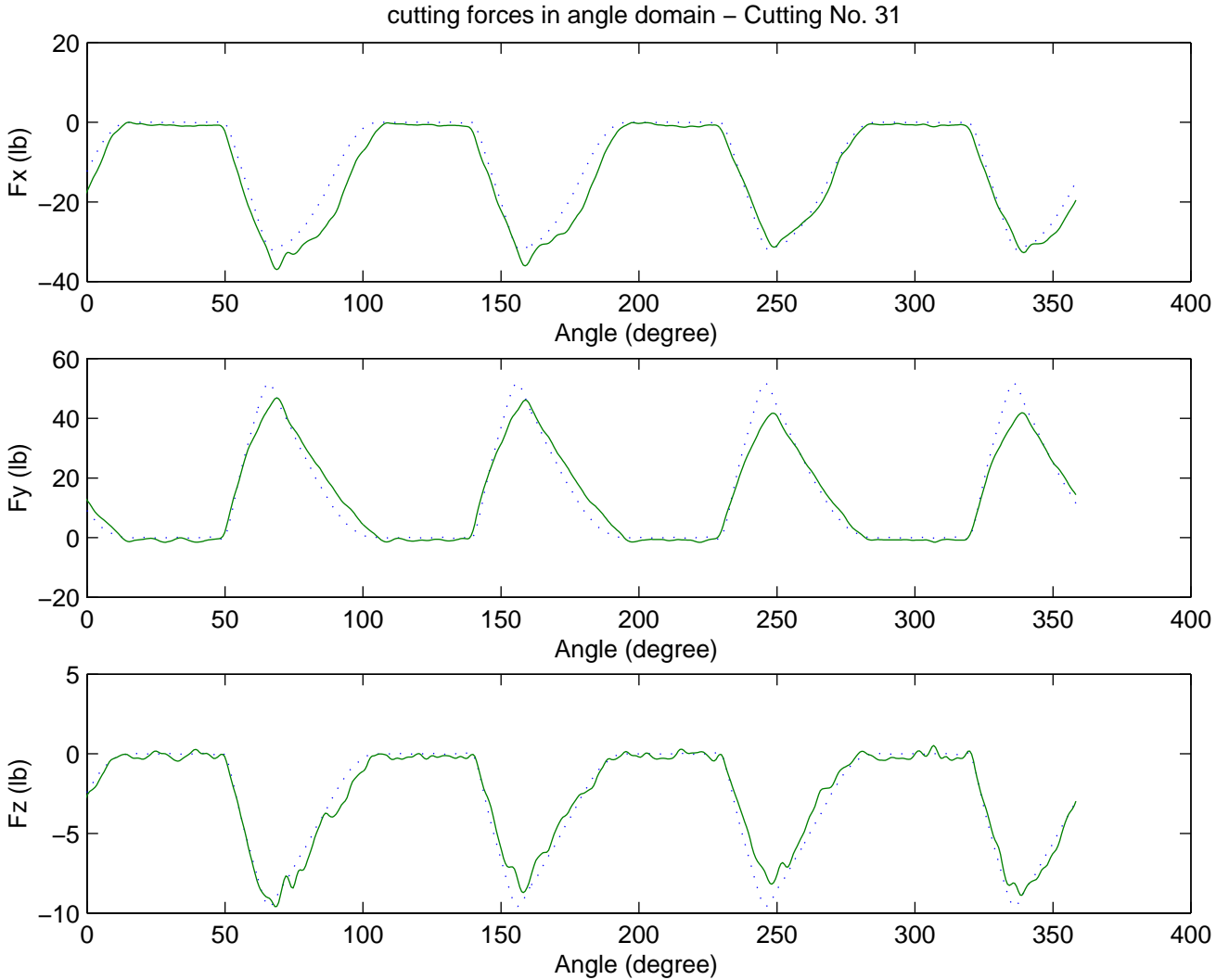
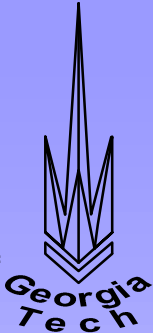
## ❖ Face Milling

- Straight Cutting Edge in 3 Dimensional Space
- Lead Angle, Radial Rake Angle, Axial Rake Angle and Diameter

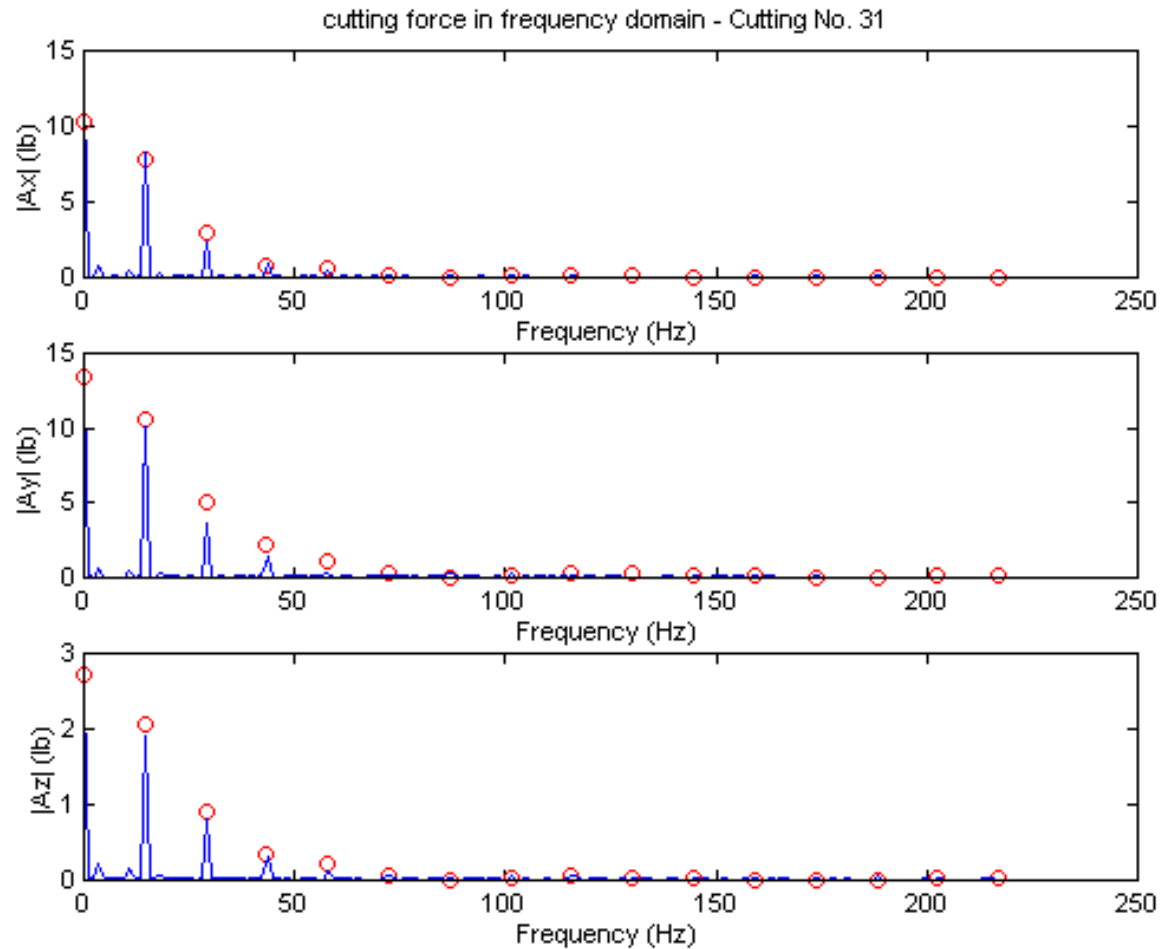
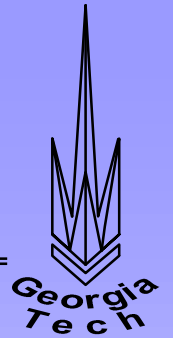
## ❖ End Milling

- Helical Cutting Edge
- Helical Angle and Diameter

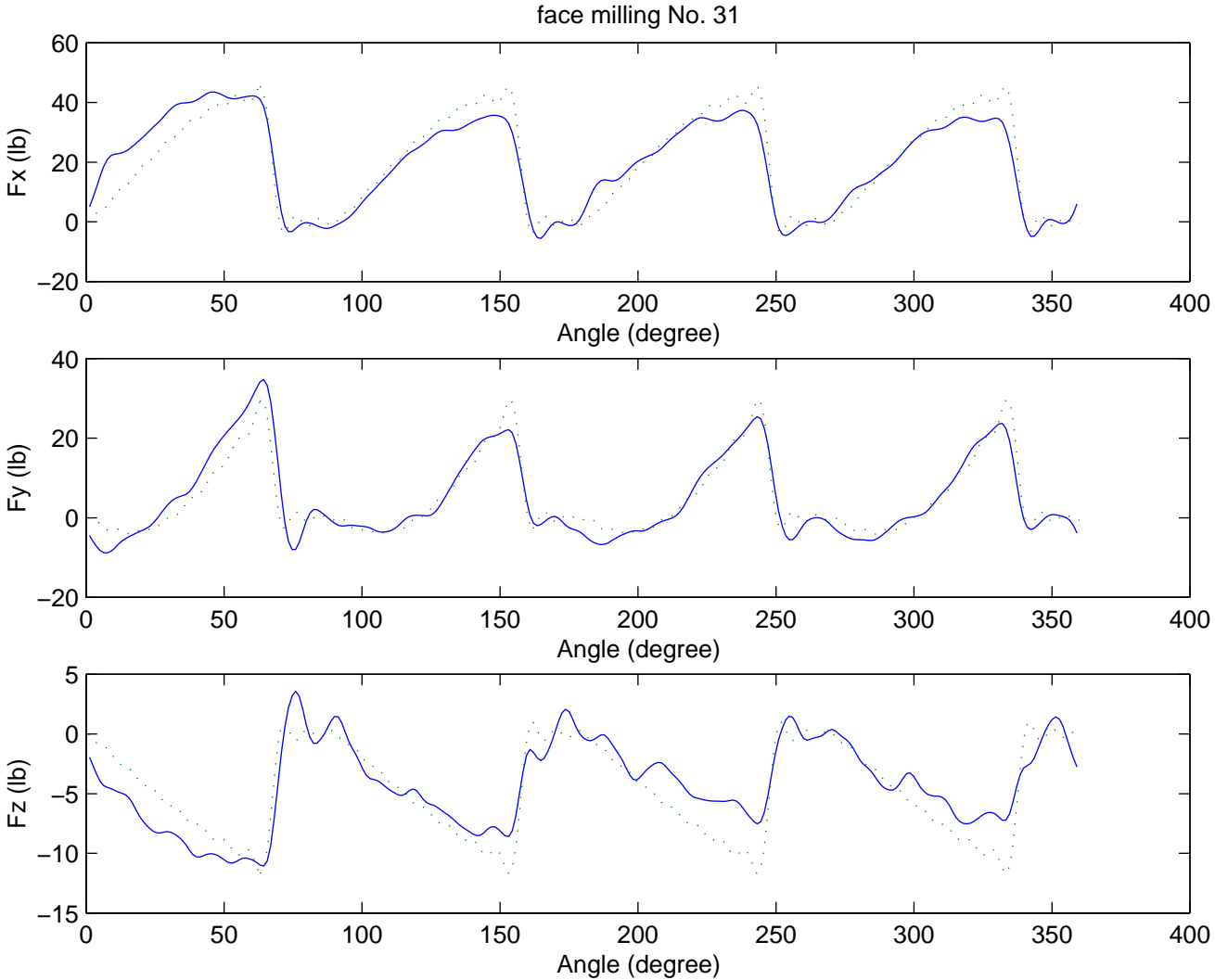
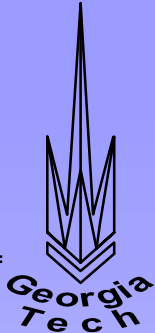
# Cutting Forces in Angle Domain - End Milling



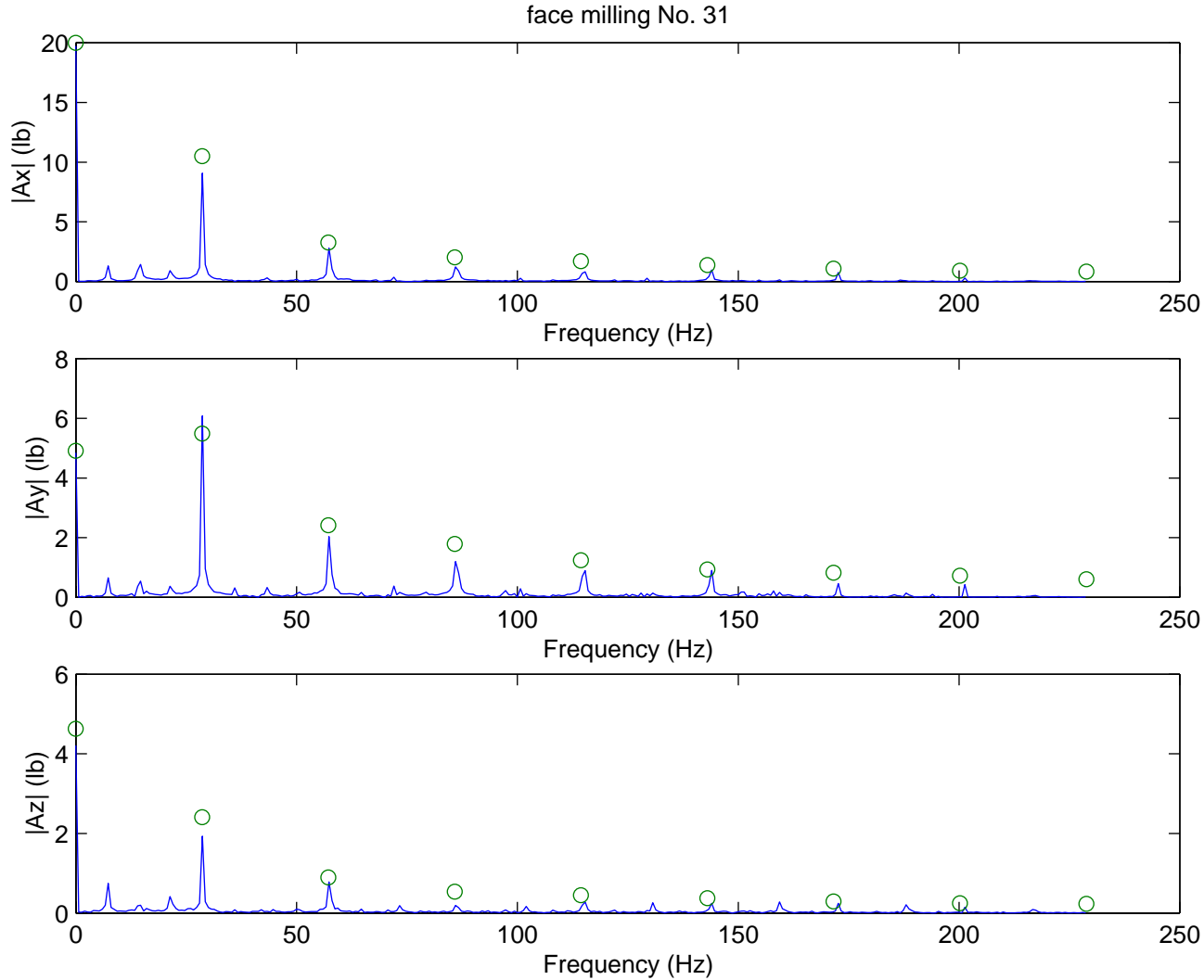
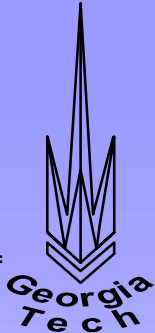
# Cutting Forces in Frequency Domain - End Milling



# Cutting Forces in Angle Domain - Face Milling



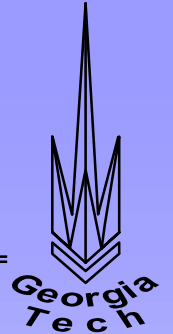
# Cutting Forces in Frequency Domain - Face Milling





# ***Conclusions***

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- ❖ General Cutting Force Model
- ❖ Explicit Expression
  - Machining Process Optimization
  - Machine Tool Design
  - On-Line Diagnostics
- ❖ Good Agreement Between Predicted and Measured Cutting Force
  - Waveform
  - Frequency Domain Components
  - Less than 15%