Workholding Optimization for Turning of Ring Shaped Parts

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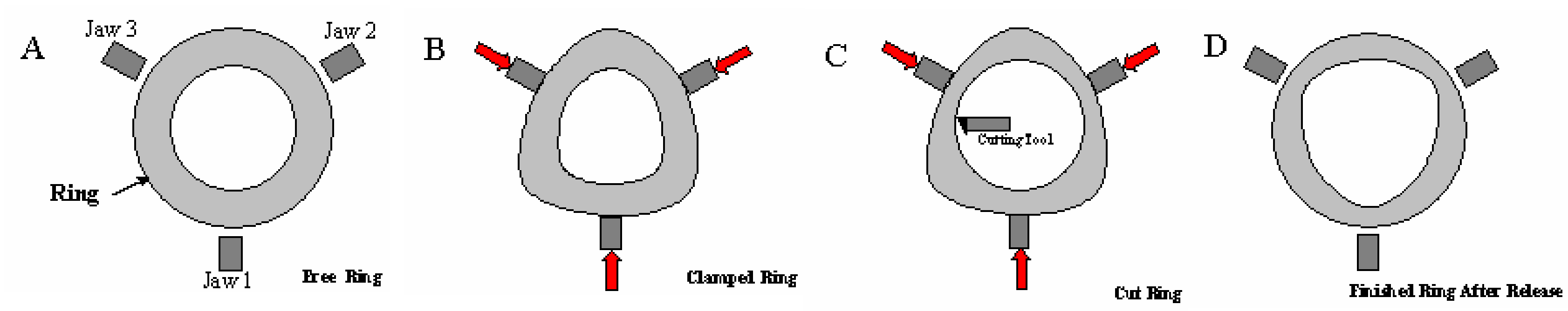
Conventional Chuck - Introduction



- Four steps used to cut the bore of a thin walled ring in a conventional three jaw chuck
  - A. The ring is ready to be rotated and machined
  - B. The ring is clamped in a chuck and it becomes elastically deformed
  - C. As the ring is bored, the shape of initial surface becomes close to an ideal circle
  - D. Upon releasing the chucking force, the ring, due to its elastic nature, tends to spring back to its initial shape
- Therefore, permanent roundness error remains in the bored ring

Research Objectives

- To predict finished cut profile of a complete ring subjected to clamping and machining forces

- To predict the minimum clamping force that prevents the ring from slipping

- To experimentally verify the theoretical models for wide range of cutting forces

- To develop an optimization model that determines the associated clamping forces and number of jaws to achieve a desired ring tolerance

Ring Deformation Modeling

Input : Ring Geometry, Material Properties, Clamping and Cutting Forces

Determine bending moment at angular cross section datum

Determine bending moment at all cross section

Strain Energy Equation For Curved Beam

$$\frac{\partial U}{\partial T_i} = 0$$

Castigliano Theorem

Output : Reaction Forces

$$\delta = \frac{\partial U}{\partial P}$$

Castigliano Theorem

Output : Deformation

Assumptions:

- Thickness Ratio of 1
- In Plane Point Loading
- Deformations are Small, Elastic
- Material is Homogeneous, Isotropic

where:

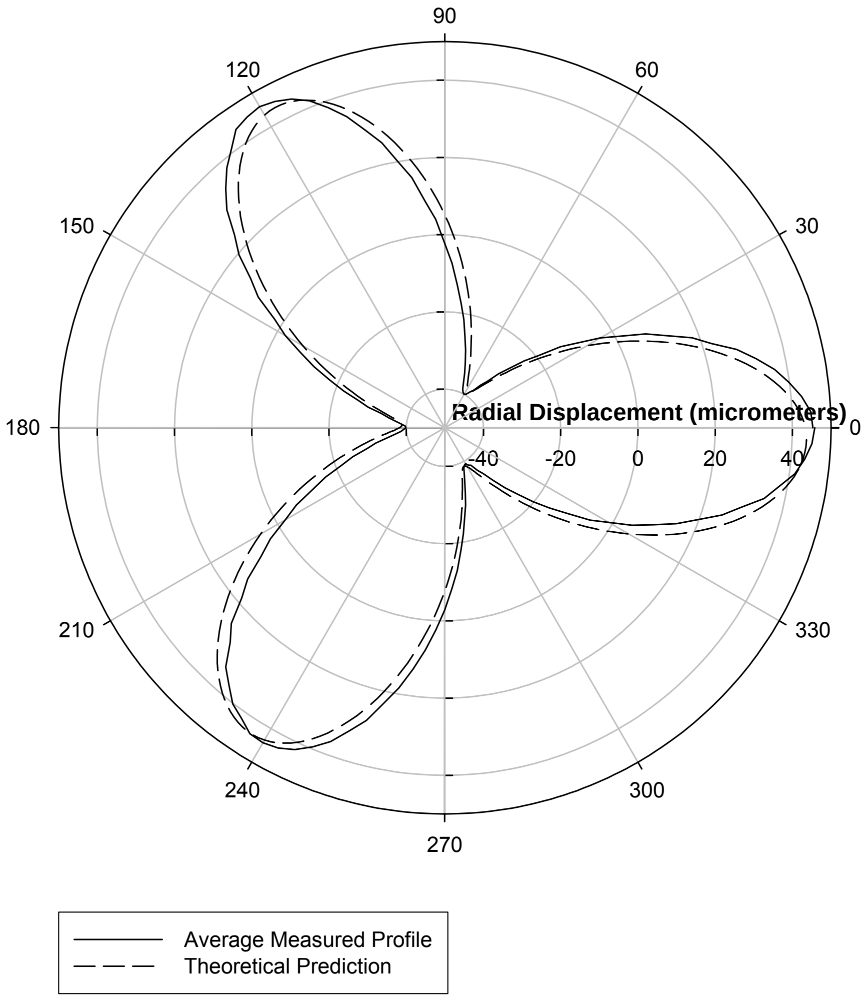
δ : deformation

U : Strain Energy

T_i : reaction forces

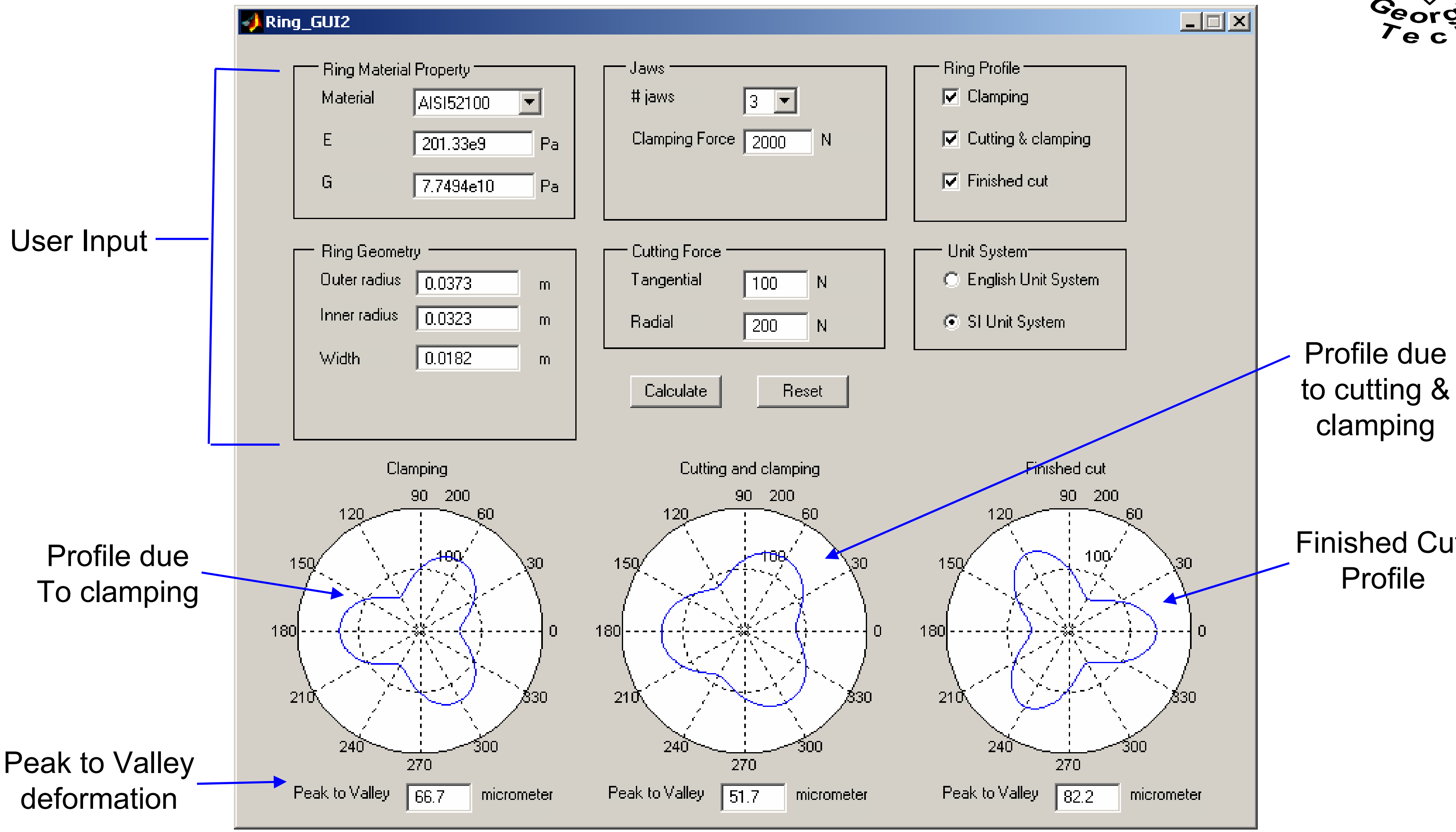
P : virtual normal force

Finished Cut Experimental Validation

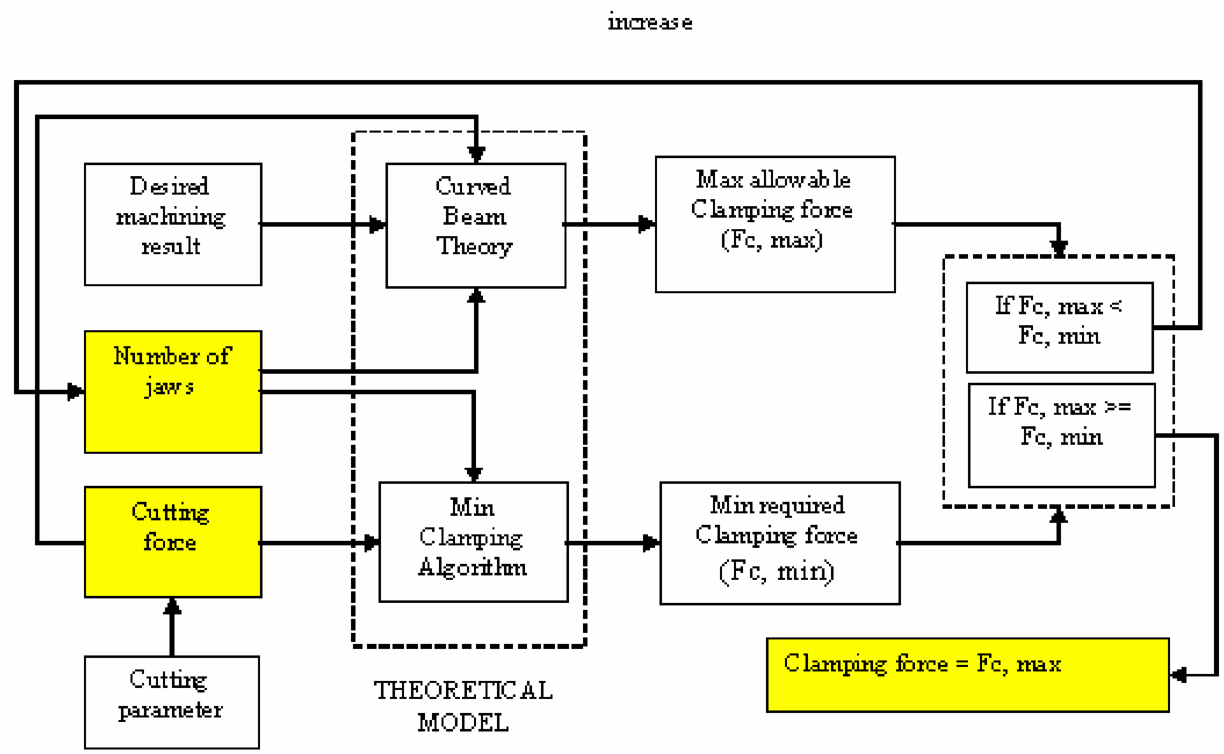


- An average clamping force of 2.56 KN
- Cutting condition: Cutting speed of 42.6 m/min, feed of 0.76 mm/rev and depth of cut of 0.406 mm (tangential cutting force of 345 N and radial cutting force of 281 N)
- The prediction was in good agreement with experimental results (average error of 4%).

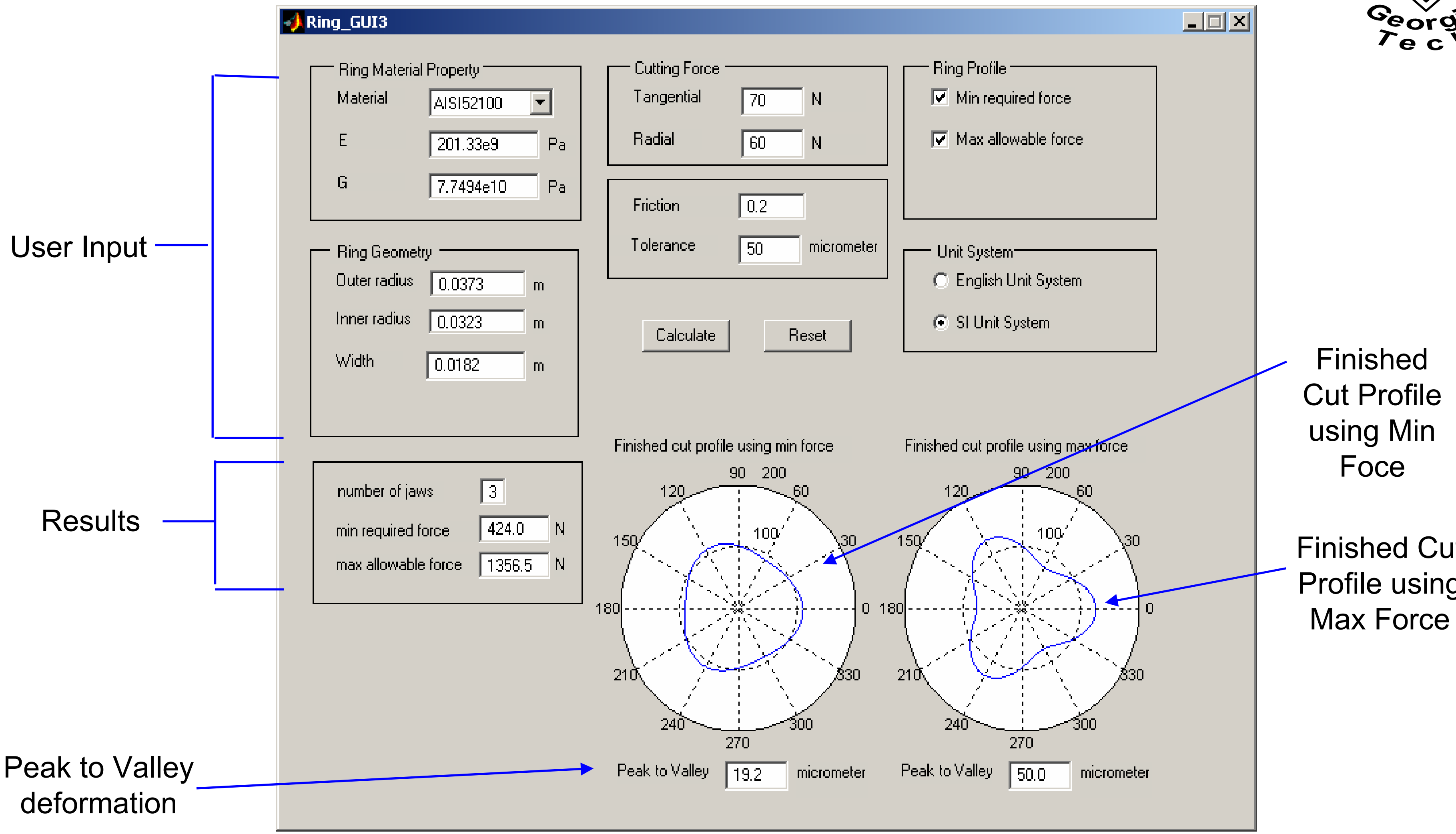
Simulation of Finished Cut Profile



Optimization Approach

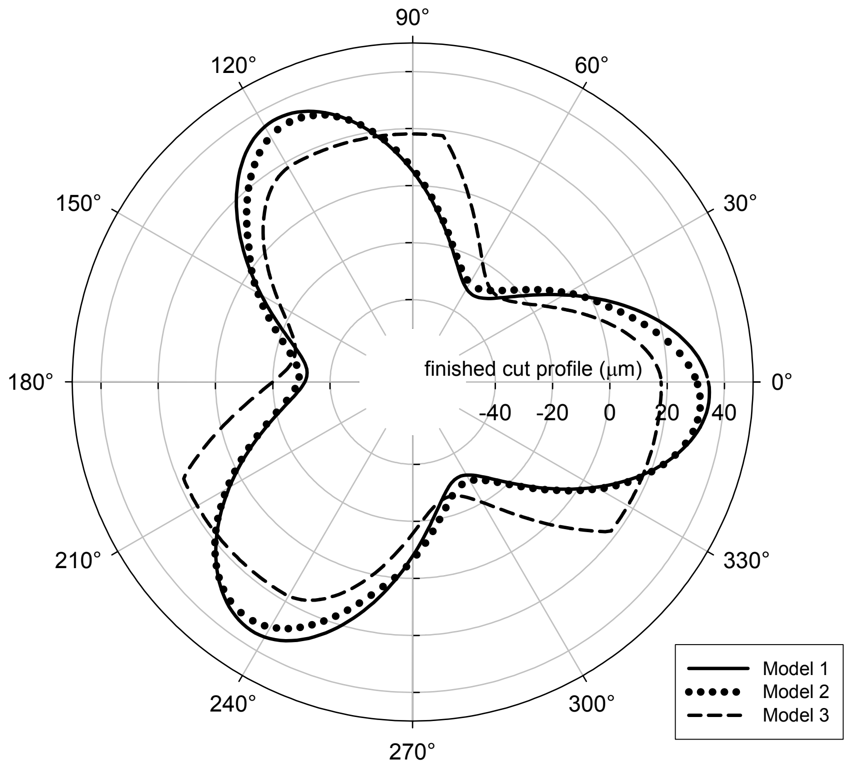


Simulation of Optimized Clamping Force



Novel Concept of Dynamic Chucking

- Simulation shows that a chuck with independently and adaptively controlled jaw forces can yield superior part roundness



Model 3 simulates the performance of the dynamic chuck

Summary

- Analytical model (and software) developed for simulation of ring deformation due to chucking and cutting forces
- Model accounts for the effects of clamping, cutting and unclamping
- Chucking optimization model (and software) developed for determining number of jaws and minimum chucking force based on ring roundness tolerance
- Dynamic chucking concept proposed

Ongoing & Future Work

- Experimental verification of ring deformation model over wider range of cutting conditions
- Experimental verification of chucking optimization model
- Evaluation of high friction materials for chucking applications