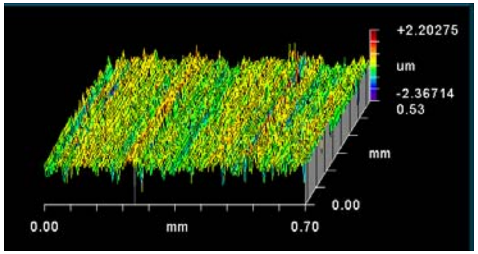
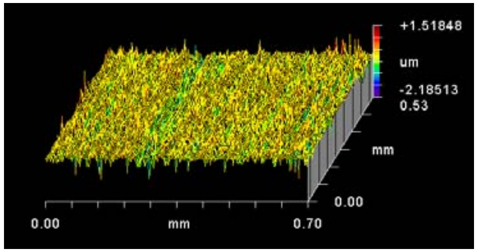
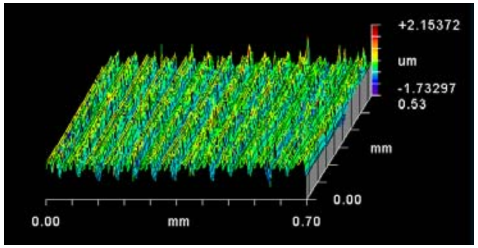
Evaluation of Functional Characteristics of Precision Finished Surfaces



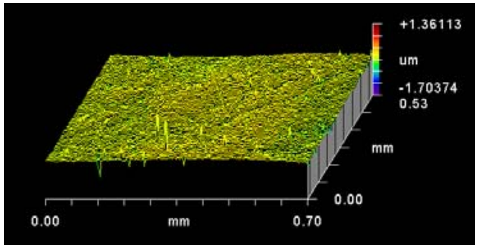
(a)



(b)



(c)



(d)

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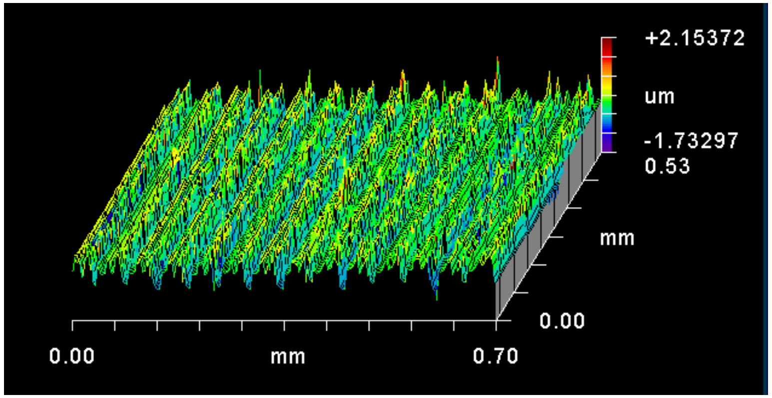
Overview

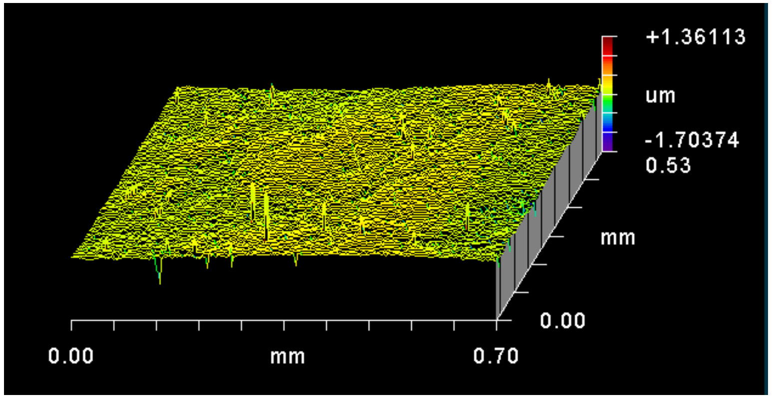
- Introduction
- Sliding Friction Experiments
- Surface Analysis
- Rolling/Sliding Friction Tester
- Modeling
- Ongoing/Future Work
- Acknowledgements

Introduction

- Objective
  - To study the relationship between surface textures produced by different finishing processes and their frictional response under rolling and/or sliding contact conditions.



Turned Surface



Isotropic Surface

Frictional Response of Precision Finished Surfaces under Lubricated Sliding Conditions

- Experimental Work
  - Experiment 1: Frictional response of precision finished surface

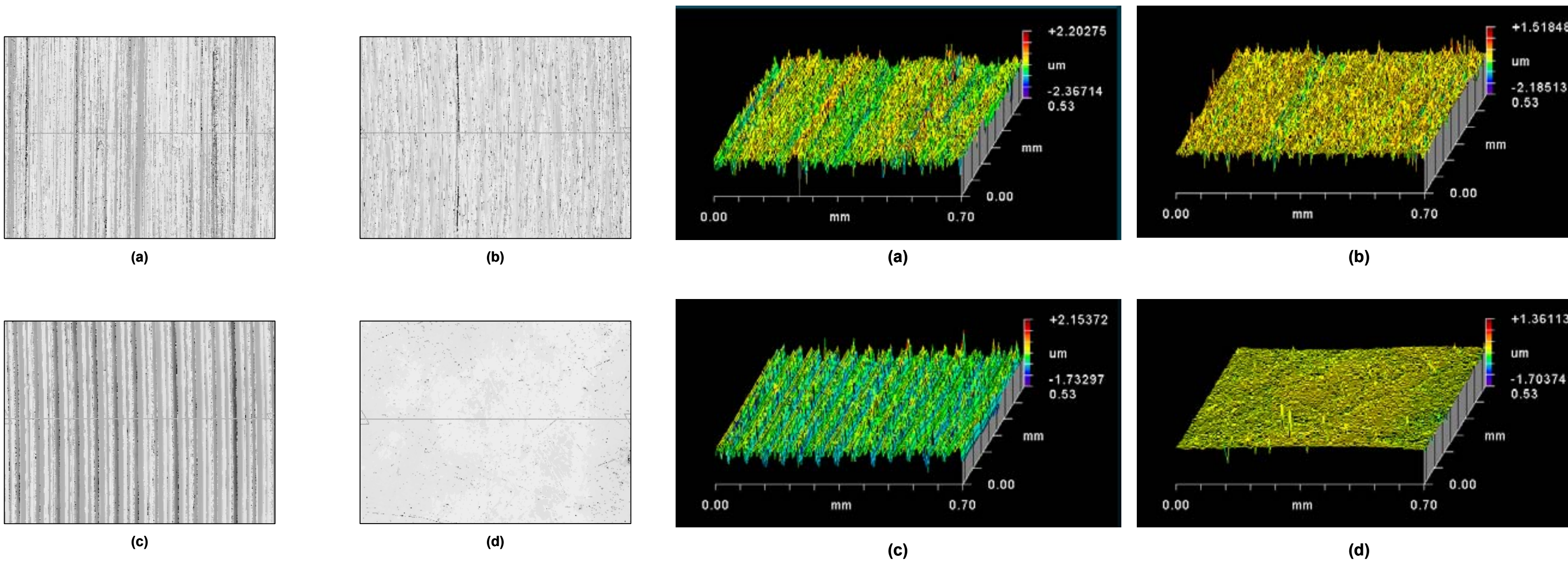
Type of Surface	Normal Load	Sliding Speed
Ground (GD) Honed (HN) Hard Turned (HT) Isotropic Finished (IF)	Low: 200 N High: 600 N	Slow: 1 mm/s Fast: 3 mm/s

  - Experiment 2: Effect of ground texture direction

Texture direction	Normal Load	Sliding Speed
Along lay Across lay	Low: 200 N High: 600 N	Slow: 1 mm/s Fast: 3 mm/s

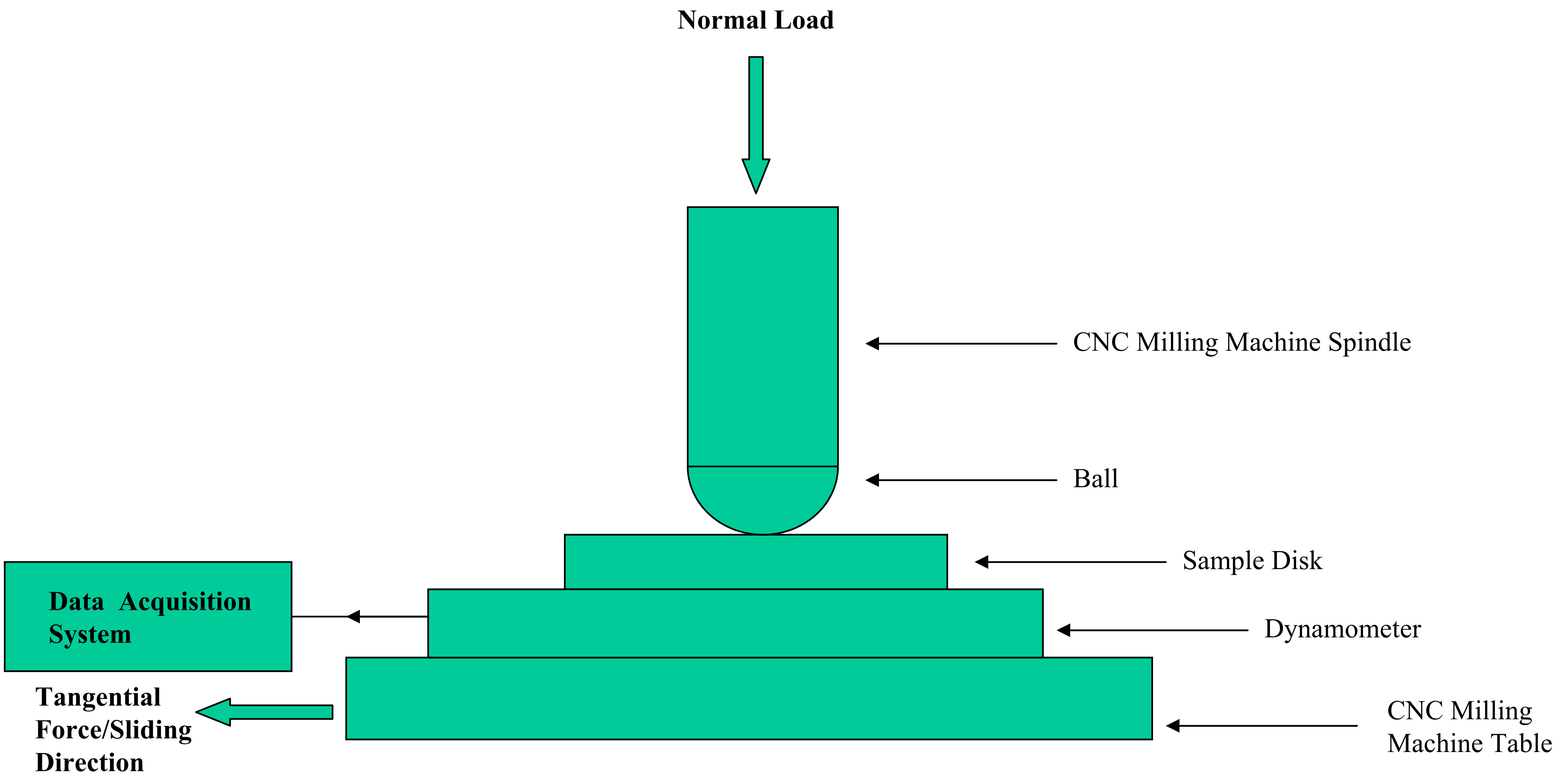
Surfaces Analyzed

- Surface data acquired from Zygo white light interferometer

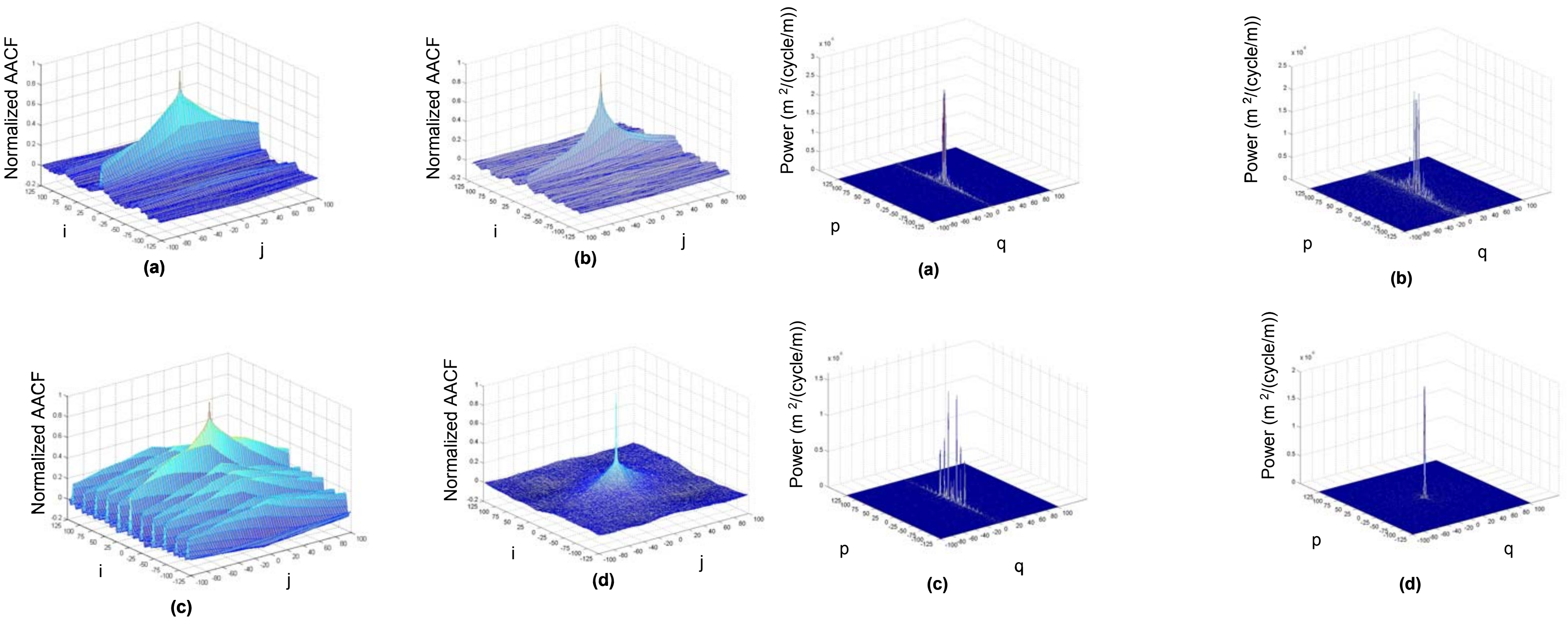


Gray scale images (left) and 3-D surface maps (right) for:
(a) GD, (b) HN, (c) HT and (d) IF surfaces

Experimental Setup



AACF and APSD Analysis



AACF (left) /APSD (right) plots for: (a) GD, (b) HN, (c) HT and (d) IF surfaces.

AACF: Areal Autocorrelation Function, APSD: Areal Power Spectral Density

3-D Surface Topographic Parameters

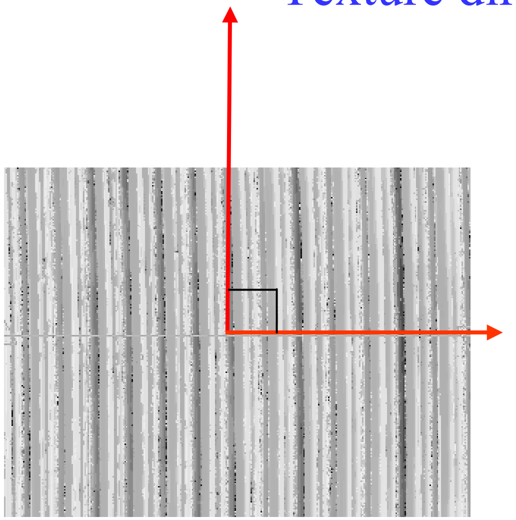
- Amplitude parameter
  - The 3-D root mean square roughness height (S_q)

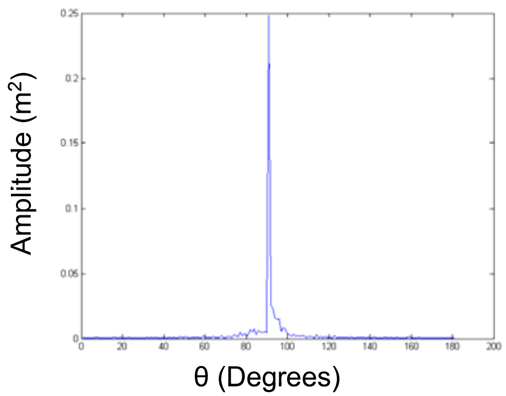
- AACF is used for computation of:
  - Fastest autocorrelation decay length (S_{al}) for computation of density of summits (S_{ds})

Surface	S_q (µm)	S_{al} (µ)	S_{ds} (/mm^2)
GD	0.424	5.5	5806.97
HN	0.196	6.59	3009.71
HT	0.331	48.51	61.11
IF	0.083	20	422.53

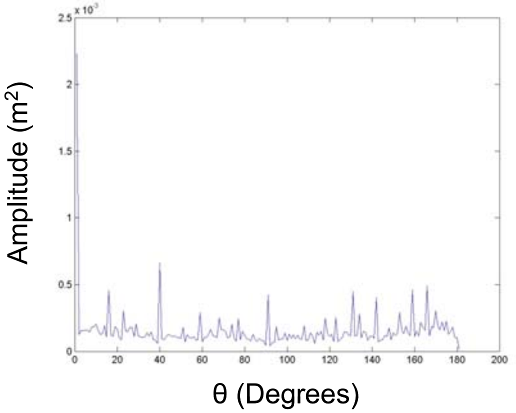
3-D Parameters

- APSD is used for computation of :
  - Texture direction (S_{td})





(a)



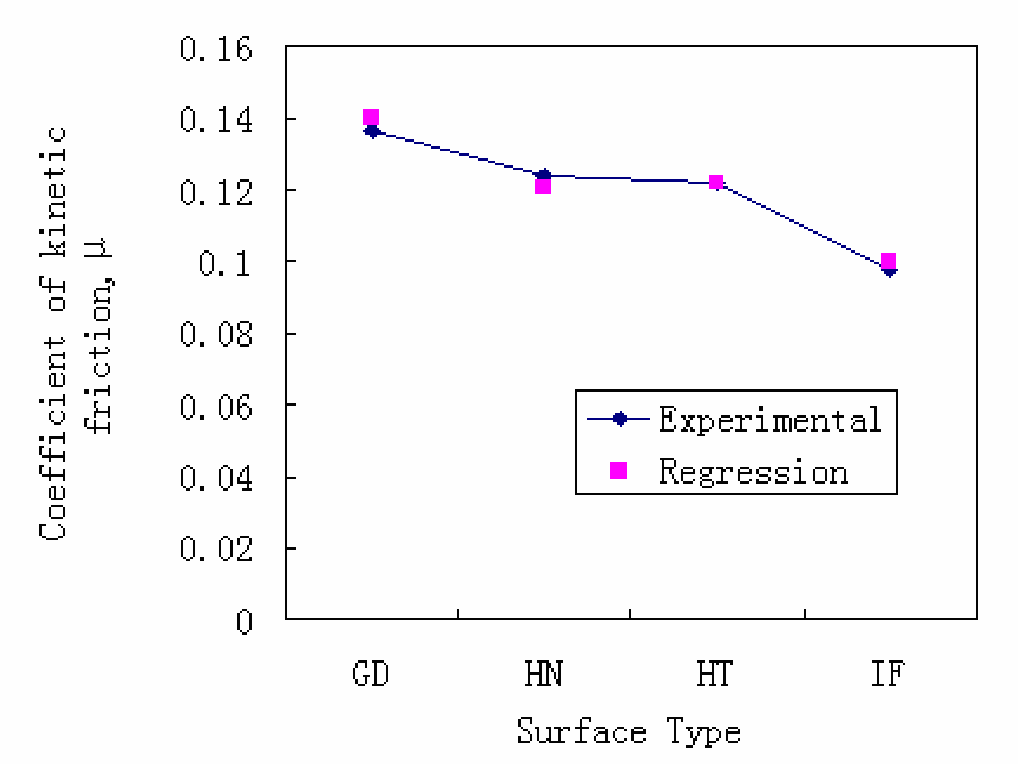
(b)

Angular spectrum plots for:
(a) surfaces with unidirectional lay e.g. hard turned surface and, (b) isotropic surface.

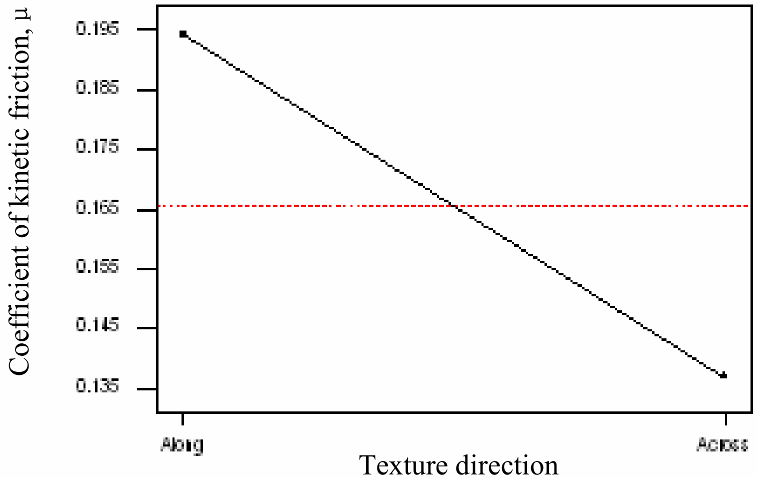
Results and Discussion

- Regression Model for sliding friction

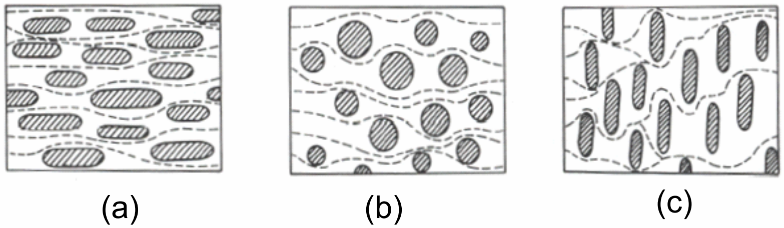
$$\mu = 0.136 S_q^{0.175} S_{ds}^{0.0207}$$



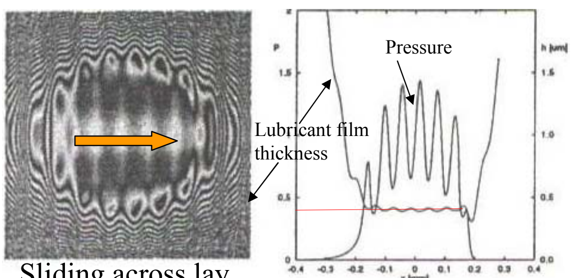
Effect of Ground Texture Direction



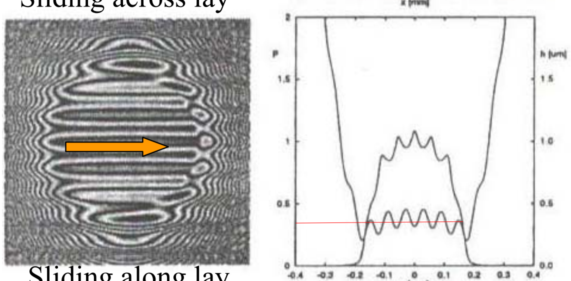
Effect of Texture Direction



Schematic of lubricant flow in surfaces with: (a) longitudinal, (b) isotropic and (c) transverse texture.



Sliding across lay



Sliding along lay

Simulation results from Venner et al.

Modeling Frictional Response of Precision Finished Surfaces

- Two basic approaches can be taken for modeling
  - Using a rough surface elastic / elasto-plastic contact model (like Greenwood-Williamson / CEB model) for asperity-to-asperity contact in unlubricated regime and Patir & Cheng model for partial EHL . (***Limitation: use of statistical models for asperity distribution***)
  - Digitizing the precision finished surface and solving EHL numerically, and at h=0 the Reynolds equation will reduce to dry contact (Hu et. al). The mixed EHL is governed by just one equation.

    (Limitation: computationally intensive)
- Second modeling approach currently under development.

Conclusions from Sliding Friction Experiments

- The 3-D root mean square roughness height, S_q, and the density of summits, S_{ds}, can be used to quantify the influence of surface texture on the coefficient of sliding friction for precision finished surfaces.
- For the conditions investigated, the IF surface yields the lowest coefficient of sliding friction while the GD surface yields the highest.
- Effect of lay on the frictional response of the ground surface is significant and accounts for up to 45% variation in the mean coefficient of kinetic friction between the two extreme cases of sliding direction (along and across the lay).
- The effect of GD surface lay direction on the friction coefficient may be explained by the effect of the lay on lubricant flow/pressure and the resulting surface interaction.

Experimental Setup for Rolling and/or Sliding Contact Friction

- Identical samples are prepared by a finishing process
- Samples are secured to parallel rotating shafts and placed in contact under a normal load
- Load data and shaft torque data are taken simultaneously
- Using the known radius of the samples as a moment arm length, torque data is converted into force of friction at the point of contact
- These force data are then divided by the corresponding normal load data to yield the Coefficient of Friction, μ.

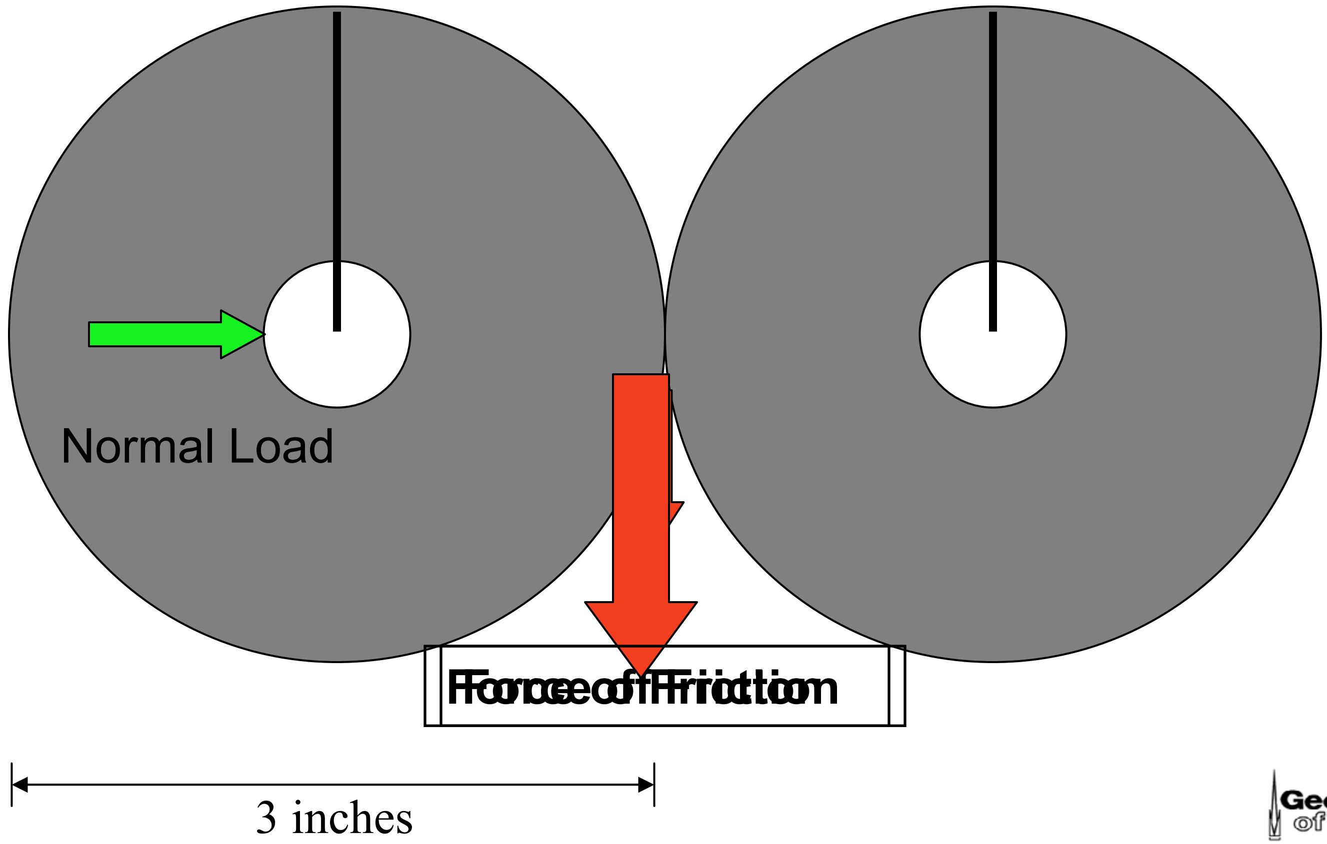
Rolling and Rolling/Sliding Friction

•Two identical samples are turned together in contact under a normal load, n(t).

•Torque, T(t), is measure and the resulting friction force, f(t), is calculated.

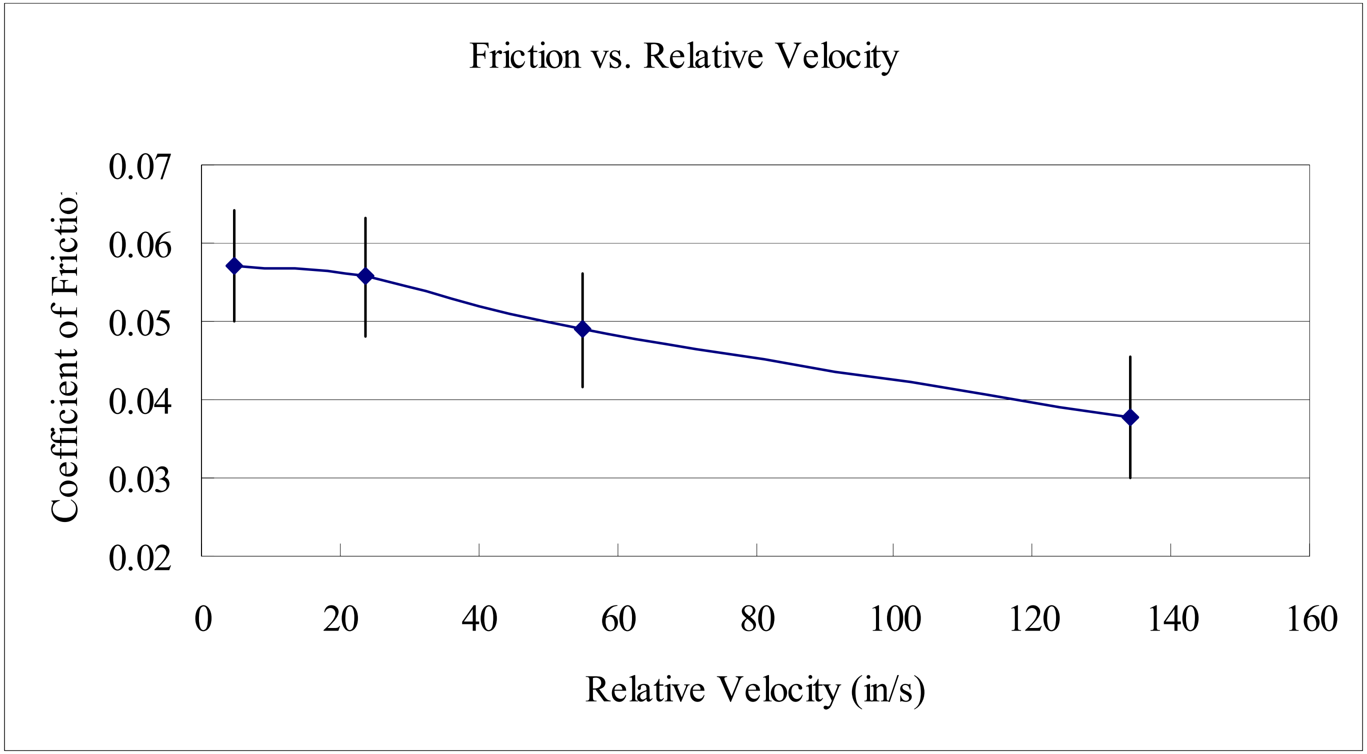
•Dividing f(t) by n(t) gives the desired result of rolling coefficient of friction.

•If a relative velocity is present between the two surfaces, f(t) changes accordingly.



Picture of the Setup

Sample Data for Turned Surface



Ongoing and Future work

- Ongoing
  - Friction tester has been fully fabricated and is functional
  - Friction data is being acquired for turned and ground samples
- Future
  - Design of experiments for rolling/sliding friction to capture the effect of texture on friction
  - Modeling the frictional response using Hu et al. approach for solving EHL for a digitized surface and then correlating the friction data with 3-D texture parameters.

Acknowledgement

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- Mr. Steven Sheffield, MARC

Questions?