Multidisciplinary Senior Design
Project Readiness Package

Project Title:	Development of a strain gauge based rotating dynamometer
Project Number: (assigned by MSD)	P176xx
Primary Customer: (provide name, phone number, and email)	Rui Liu, Tel: 585-475-6819, Email: rleme@rit.edu
Sponsor(s): (provide name, phone number, email, and amount of support)	Rui Liu, Tel: 585-475-6819, Email: rleme@rit.edu Amount of support: $2,000
Preferred Start Term:	Fall 2016
Faculty Champion: (provide name and email)	Rui Liu
Other Support:	As applicable
Project Guide: (assigned by MSD)	

Rui Liu — 07-05-2016
Prepared By — Date

Received By — Date

Items marked with a * are required, and items marked with a † are preferred if available, but we can work with the proposer on these.

Project Information

*** Overview:**

The cutting force is one of the most important machining process variables related to the cutting performance. It is also used as an important indicator in designing a machine tool, and for cutting process optimization, investigation of the fundamental study of cutting/machine tools performance, prediction of surface roughness, tool wear monitoring, prediction of chattering and other applications Therefore, the cutting force measurement using dynamometers is considered as an essential requirement in machining studies during turning, milling, drilling, and grinding.

To realize this requirement, cutting forces can be measured by a strain gauge based dynamometer. For this type of dynamometer, the cutting forces are measured by the deformations which can be detected by strain gauges mounted at the special structure between the cutting tool/workpiece and the machine tool table and are converted to proportional electric signals. To make cutting force signals readable, the electrical signals need to be captured, transmitted, amplified, conditioned, converted to digital signals and read by a microprocessor.

The goal of this senior design project is to develop a strain gauge based rotating dynamometer which is used to measure the cutting forces with respect to the rotating cutting tool during milling and drilling operations. Students will learn how to operate the structure design and finite element analysis, signal processing, data acquisition, and wireless transmission from this project. The developed dynamometer will be capable of mounting to the milling machine and the drilling machine in our machine shop to measure cutting forces in three directions. And the following project will seek to accommodate this dynamometer to a standard 400 size Gleason hobbing machine.

*** Preliminary Customer Requirements (CR):**

- Rating of Customer Requirements
    1- High Importance
    2- Medium Importance
    3- Low Importance

Table of Customer Requirements

CR#	Customer Requirement	Rating
CR01	This dynamometer can measure cutting forces in three dimensions accurately	1
CR02	This dynamometer is designed to measure cutting forces up to 500 N and 2000 rpm	1
CR03	The dynamic range of the dynamometer is suitable for cutting force measurements	2
CR04	The rigidity of the dynamometer is suitable for cutting force measurements	2
CR05	Make sure the temperature fluctuations will not affect cutting force measurements	2
CR06	This dynamometer can be mounted to the milling machine	1
CR07	This dynamometer can be mounted to the drilling machine	2
CR08	Create instructions for other customers to use	1

*** Preliminary Engineering Requirements (ER)**:
The device will satisfy the following requirements, these requirements have been gathered though the use of customer interviews, and benchmarking of products with similar functions.

ER#	Requirement	Associates CRs
ER01	Design the structure of dynamometer to measure cutting forces in three dimensions	CR01
ER02	Design the structure of dynamometer to measure cutting forces up to 500 N	CR02
ER03	Design the structure of dynamometer to have the suitable rigidity	CR04
ER04	Design the structure of dynamometer to measure cutting forces up to 2000 rpm	CR02, CR03
ER05	Design the strain gauge arrangement to measure cutting forces in three dimensions	CR01
ER06	Design the acquisition module	CR01
ER07	Design the wireless transmission	CR01
ER08	Data visualization and processing via Matlab/C/Labview	CR01
ER09	Figure out the sensitivity of dynamometer	CR01
ER10	Figure out the cross sensitivities	CR01
ER11	Design the connections to join the dynamometer to the shaft of the tool holder spindle on a milling machine and a drilling machine	CR06, CR07
ER12	Static calibration test	CR01, CR02
ER13	Dynamic calibration test	CR02, CR03
ER14	Thermal effects test	CR05
ER15	Cutting test	CR01, CR02
ER16	Create instructions	CR08

*** Constraints:**

- Expense cannot exceed $2,500
- Dynamometer must be able to fit into milling and drilling machines in ME machine shop
- Designed to be durable and robust

*** Project Deliverables:**
Minimum requirements:

- All design documents (e.g., concepts, analysis, detailed drawings/schematics, BOM, test results)
- Working prototype (including circuit and program)
- Written instructions
- Poster
- All teams finishing during the spring term are expected to participate in ImagineRIT

[†] Budget Information:
Budget is estimated in the range of $2,000.

[*] Intellectual Property:
The project is intended to be open source for use by students and science enthusiasts and intellectual property does not have to be protected.

Project Resources

† Required Resources (besides student staffing):
Describe the resources necessary for successful project completion. When the resource is secured, the responsible person should initial and date to acknowledge that they have agreed to provide this support. We assume that all teams with ME/ISE students will have access to the ME Machine Shop and all teams with EE students will have access to the EE Senior Design Lab, so it is not necessary to list these. Limit this list to specialized expertise, space, equipment, and materials.

Faculty list individuals and their area of expertise (people who can provide specialized knowledge unique to your project, e.g., faculty you will need to consult for more than a basic technical question during office hours)	**Initial/ date**
John Wellin, Jason Kolodziej	
Environment (e.g., a specific lab with specialized equipment/facilities, space for very large or oily/greasy projects, space for projects that generate airborne debris or hazardous gases, specific electrical requirements such as 3-phase power)	**Initial/ date**
Materials Science Lab	
Equipment (specific computing, test, measurement, or construction equipment that the team will need to borrow, e.g., CMM, SEM,)	**Initial/ date**
Materials (materials that will be consumed during the course of the project, e.g., test samples from customer, specialized raw material for construction, chemicals that must be purchased and stored)	**Initial/ date**
Steel, Electronic devices	
Other	**Initial/ date**

† Anticipated Staffing By Discipline:

Dept.	**# Req.**	**Expected Activities**
BME		
CE		
EE	2	signal processing, data acquisition
ISE		
ME	3	structure design, finite element analysis
Other		

*** Skills Checklist:**
Indicate the sills or knowledge that will be needed by students working on this project. Please use the following scale of importance:
1 = must have
2 = helpful, but not essential

3 = either a very small part of the project, or relates to a “bonus” feature
blank = not applicable to this project

Biomedical Engineering

	BME Core Knowledge		BME Elective Knowledge
	Matlab		Medical image processing
	Aseptic lab techniques		COMSOL software modeling
	Gel electrophoresis		Medical visualization software
	Linear signal analysis and processing		Biomaterial testing/evaluation
	Fluid mechanics		Tissue culture
	Biomaterials		Advanced microscopy
	Labview		Microfluidic device fabrication and measurement
	Simulation (Simulink)		Other (specify)
	System physiology		
	Biosystems process analysis (mass, energy balance)		
	Cell culture		
	Computer-based data acquisition		
	Probability & statistics		
	Numerical & statistical analysis		
	Biomechanics		
	Design of biomedical devices		

Computer Engineering

	CE Core Knowledge		CE Elective Knowledge
	Digital design (including HDL and FPGA)		Networking & network protocols
	Software for microcontrollers (including Linux and Windows)		Wireless networks
	Device programming (Assembly, C)		Robotics (guidance, navigation, vision, machine learning, control)
	Programming: Python, Java, C++		Concurrent and embedded software
	Basic analog design		Embedded and real-time systems
	Scientific computing (including C and Matlab)		Digital image processing
	Signal processing		Computer vision
	Interfacing transducers and actuators to microcontrollers		Network security
			Other (specify)

Electrical Engineering

	EE Core Knowledge		EE Elective Knowledge
1	Circuit Design (AC/DC converters, regulators, amplifies, analog filter design, FPGA logic design, sensor bias/support circuitry)	2	Digital filter design and implementation
	Power systems: selection, analysis, power budget	1	Digital signal processing
	System analysis: frequency analysis (Fourier, Laplace), stability, PID controllers, modulation schemes, VCO’s & mixers, ADC selection		Microcontroller selection/application
1	Circuit build, test, debug (scope, DMM, function generator	2	Wireless: communication protocol, component selection
1	Board layout		Antenna selection (simple design)
1	Matlab		Communication system front end design
	PSpice		Algorithm design/simulation

	EE Core Knowledge		EE Elective Knowledge
1	Programming: C, Assembly		Embedded software design/implementation
	Electromagnetics: shielding, interference		Other (specify)

Industrial & Systems Engineering

	ISE Core Knowledge		ISE Elective Knowledge
	Statistical analysis of data: regression		Design of Experiment
	Materials science		Systems design – product/process design
	Materials processing, machining lab		Data analysis, data mining
	Facilities planning: layout, mat'l handling		Manufacturing engineering
	Production systems design: cycle time, throughput, assembly line design, manufacturing process design		DFx: manufacturing, assembly, environment, sustainability
	Ergonomics: interface of people and equipment (procedures, training, maintenance)		Rapid prototyping
	Math modeling: OR (linear programming, simulation)		Safety engineering
	Project management		Other (specify)
	Engineering economy: Return on Investment		
	Quality tools: SPC		
	Production control: scheduling		
	Shop floor IE: methods, time studies		
	Computer tools: Excel, Access, AutoCAD		
	Programming (C++)		

Mechanical Engineering

	ME Core Knowledge		ME Elective Knowledge
1	3D CAD	1	Finite element analysis
2	Matlab programming		Heat transfer
1	Basic machining		Modeling of electromechanical & fluid systems
1	2D stress analysis		Fatigue and static failure criteria
1	2D static/dynamic analysis		Machine elements
	Thermodynamics		Aerodynamics
	Fluid dynamics (CV)		Computational fluid dynamics
2	LabView		Biomaterials
	Statistics	3	Vibrations
1	Materials selection		IC Engines
			GD&T
			Linear Controls
			Composites
			Robotics
			Other (specify)