

Institutional Effectiveness Report 2019-20

Program: Mechanical Engineering MS

College and Department: College of Engineering – Mechanical Engineering

Contact: Mohan Rao

Mission: The Mechanical Engineering (ME) Department, within a regional and global context, will prepare its students for productive career in a competitive, dynamic, technologically-based society; will advance the knowledge of mechanical engineering principles and applications; and will serve the public.

The Mechanical Engineering M.S. program at Tennessee Tech provides students advanced engineering skills and state-of-the-art knowledge in selected areas for positions in industry or pursuing a PhD. Students focus their programs on specific interests among several areas:

- Acoustics and Vibrations
- Design / Mechanical Systems
- Energy Harvesting / Smart Materials
- Energy Storage / Fuel Cells / Battery
- Smart Materials / Sensors
- Material Characterization and Modeling
- Robotics / Mechatronics / Controls
- Thermal Science / Fluid Mechanics

The program is research oriented and includes both thesis and non-thesis options for M.S. students. Graduate faculty work with students in advanced and in-depth studies on topics of mutual interest; provide guidance in fundamental and applied research; help develop powers of analysis, synthesis and critical thinking; and prepare students to follow academic and research careers through doctoral-level studies. The master's degree program consists of 30 hours for a thesis option and 33 hours for a non-thesis option.

The graduate program in Mechanical Engineering contributes directly to the missions of the Department, College, and University by preparing advanced level graduates consistent with the following mission statements:

COLLEGE OF ENGINEERING MISSION: To graduate innovative engineers who solve technological challenges to meet societal needs.

VISION: The Mechanical Engineering Department at Tennessee Tech aspires to be recognized globally for outstanding education and research, leading to well-qualified engineers who are adaptive professionals, inquisitive, entrepreneurial and successful in engineering practice, research, and public service.

Program Goal:

1. Recruit and mentor very talented, research active faculty who will excel in teaching, research and scholarly activities and enhance the reputation of the Department of Mechanical Engineering at both regional and national levels.
2. Increase the number and quality of MS and PhD graduates until they are about 10% of the undergraduate population. The goal is to have a thriving graduate program with quality students.
3. Increase externally funded research activation, proposals and journals submitted, and conference publications of the Department of Mechanical Engineering faculty per year.

Student Learning Outcome:

1. Improve communication skills of Mechanical Engineering graduate students through mastery in both verbal and written communication skills.
2. Demonstrate the ability to conduct basic theoretical and/or applied research (MSME Thesis Option) or Independent study (MSME Non-thesis Option).
3. Students will give professional presentations or write scholarly manuscripts worthy of publication in conferences and/or peer reviewed journals.

A departmentally developed curriculum map can be found in Appendix 1 that shows the connections between courses and student learning outcomes.

Assessment Methods:

1. *Graduate Student Exit Interviews:* Written survey and oral discussion with students are targeted toward determining the quality of the program, attainment of selected learning outcomes, and the adequacy of resources and facilities to achieve these. See Graduate Student Exit Interview Form for the survey questions included. The survey results will be updated in the upcoming year since data are analyzed once every two years.
2. *Percentage of MSME Students Employed or Attending Graduate School in another university:* The ME Department, along with the Centers of Excellence, perform exit interviews with graduating students and collect data on their next placement, feedback to the program, and level of their success. The data is collected, compiled and analyzed by the Centers and departments as a tool to improve the quality and environment of the graduate program. Percentage of MSME students who are employed upon graduation or who have been admitted to PhD programs is a good indicator of the quality of our graduate program. The results will be updated in the upcoming year since data are analyzed once every two years.
3. *Co-Op Employer Surveys:* Administered by the Office of Career Services to employers of students participating in the Co-Op program. Employers provide feedback regarding (1) individual student performance, and (2) more general assessment-related questions regarding performance of the M.E. program. Results from this tool are included if and when available.

4. *Alumni Surveys:* One way of evaluating the effectiveness of the graduate program is to track the placement and performance of MS graduates either in their places of employment or doctoral programs in which they are enrolled. Results of such surveys help identify any weaknesses in the program for appropriate remedial measures to be crafted and implemented. They also help determine the strengths of the program. The surveys are conducted once every two years and results presented accordingly.
5. *ME External Advisory Board Feedback:* Feedback from the ME External Advisory Board is an important source of program improvement, guidance, and supporting evidence regarding the performance of students who are graduates of the MSME program. The Advisory Board contains representatives of several key constituency groups of the program, i.e., employers, alumni, and the professional community at large.
6. *IDEA Teaching Evaluations:* IDEA evaluations are a university required tool for assessment of teaching of graduate faculty. The average IDEA ratings on Progress on Relevant Course Learning Objectives, Teaching Effectiveness, and Usefulness of the Course are used. The IDEA survey instrument makes provision for students to provide comments on each course. Some students use this as a vehicle to provide feedback on course topics and course requirements.
7. *Average Number of Funded Research Projects:* A summary of external funds generated by the M.E. department using data provided by the Office of Research (per year per ME Faculty Member) is an indicator of the growth of external research provided by the faculty. Data are compiled for proposals and activations by the College of Engineering. The results will be updated in the upcoming year since data are analyzed once every two years.
8. *Average Journal and Conference Publications per faculty per Year:* All faculty members engage in regular professional development that enhances their teaching, scholarship and practice. These include but are not limited to the participation in workshops, training courses, and conferences, technical paper and proposal reviews, journal and conference publications, conference and symposium organization, and professional society activities. Support for faculty development is provided for faculty to attend workshops, training courses, and conferences. If the activity is primarily instruction-related, the department's Student Course Fees fund can be used. For more research-related activities, such as conferences, Center funds, indirect cost returns, and/or project funds are typically used. Additional opportunity for development is provided through the hosting of seminars on a frequent basis by a variety of sources including CoE departments, CMR, CESR, WR, CITL, student groups, and individual faculty.

Results:

Program Goal 1: Recruitment and Retention of Faculty

The ME Department at TTU has 17 full-time, tenure-track and tenured faculty positions, three lecturers, and one adjunct faculty. This includes the Dean, Associate Dean for Research and Innovation, Director of CMR, Interim Chair of MET, Department Chair and Associate Chair positions. Of the tenure and tenure-track ranks, 10 faculty members hold the rank of full professor; three are associate professors and four are assistant professors. Given the breadth of the mechanical engineering field and the technical background required to contribute to the advancement of the state-of-the-art, the ME faculty body is diverse in academic background and research. Departmental faculty members are all expected to contribute to the instructional, research, advising, and service activities of the department.

During the 2019-20 AY, the ME department was successful in recruiting two outstanding faculty -- Dr. Rory Roberts was hired as tenured Associate Professor and Dr. Arman Sargholzaei as tenure track Assistant Professor.

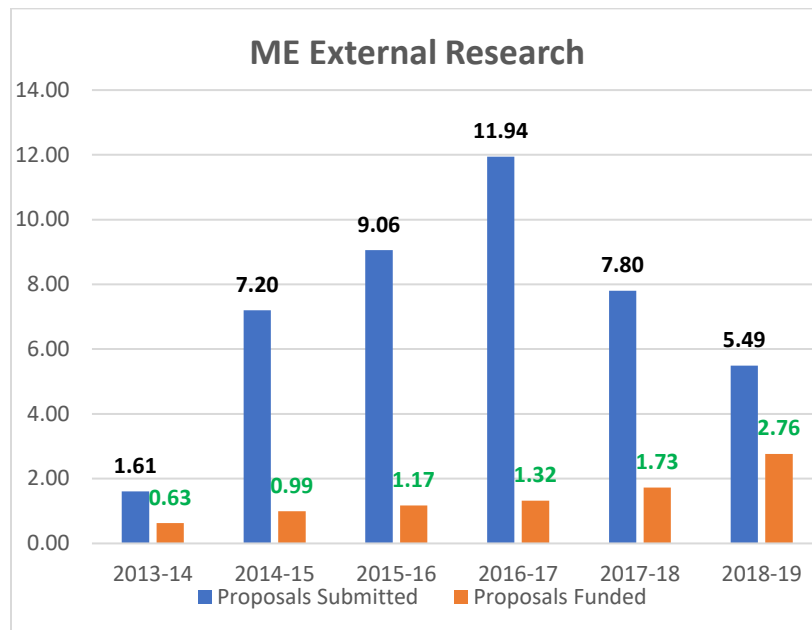
Program Goal 2: Increase Number of MS Students per Year

Over the period from 2012-2017, a total of 715 complete student applications to the MSME program were received. Two hundred and eighty-four applications (40%) were granted admission (including provisional standing). A total of 165 actually enrolled during this time. Sixty-one MS degrees have been awarded during this period. These data reflect the high standards related to retention and quality control of MS graduates that is implicit in the MSME program. These data are updated every five years during the THEC MS Program review.

We have had some decrease in both applications and student enrollment of MS students during AY 2019-20, particularly from international students due to COVID-19 concerns. We are not sure if this trend will continue into the next year or not at this point. The good news is that we have had a number of our own domestic UG students apply and join our program. In addition, we have also had over a dozen of our own UG students sign up to our fast-track MS program.

Program Goal 3: Increase Research and Scholarship Activities

The ME department faculty engage in externally funded research projects/grants from agencies such as the National Science Foundation, Department of Defense, Department of Energy, Office of Naval Research, NASA, Air Force Office of Scientific Research, ASHRAE, MIT Lincoln Labs, State of TN, and industries such as Cummins and Bristol Compressors, among others. Sponsored projects facilitate research and scholarship, which consequently help build intellectual capital for the MS and Ph.D. programs through student-involved research activity and the possible creation of knowledge in the process. Funds generated from externally sponsored projects and proposals submitted by the ME faculty during the past five years have increased from about \$600k to \$2.7 million as shown below.



All faculty members engage in regular professional development that enhances their teaching, scholarship, and practice. These include, but are not limited to, the participation in workshops, training courses, and conferences, technical paper and proposal reviews, journal and conference publications, conference and symposium organization, and professional society activities. More than 18 journal papers and 20 conference proceedings were published by the ME graduate faculty during 2019-2020, translating into an average number of scholarly articles published in journals by the collective ME faculty of approximately 1.7 journal papers per year. Several of the published papers were lead-authored or co-authored by MS students.

Student Outcome 1: Communication in Area of Specialization

Graduate students are required to make oral presentations of their thesis. Evaluation feedback for these oral presentations is provided to the students, which helps them to improve their technical communication skills. Many of the core courses also require oral presentations that are evaluated as part of the course grades. Evidence of achievement in technical writing is provided through the accomplishment of written theses that are reviewed and approved by the student’s advisory committee. The results of the oral and thesis assessment for 2019-20 are shown below. It can be seen that all the data presented are above the threshold of 3.0 set by the program.

Oral Defense and Thesis Assessment Results

Evaluation of Oral Presentation	Results on a scale of 1-4
Visual Aids	3.66
Presenter	3.5
Presentation mechanics	3.33
Quality of English	3
Technical Content	3
Technical Writing	3

Student Outcome 2: Demonstration of Research or Independent Study

Graduate students are encouraged to participate in the annual Research and Creative Inquiry Day held during the month of April to present posters on their research. During the current year, five ME students participated in the competition.

The MS alumni survey conducted previously in year 2017-18 indicate that 97% of graduates felt the M.S. program provided them with the technical knowledge required to be successful in their field. The same number of the respondents indicated that the program gave them the ability to undertake technical work independently. The surveys also indicated that 97% of the respondents felt technically competent to pursue life-long learning as a result of the M.S. program; therefore, a survey of graduate student

alumni is an indicator of the success of our graduate students in their professional careers. The survey results will be updated in the upcoming year since data are analyzed once every two years.

Student Outcome 3: Give professional presentations or write scholarly manuscripts

Advisors and graduate committees provide guidance and training to students in research methods. Successful completion of the thesis requirement provides evidence of the ability for further study. Each student's advisory committee has an opportunity to evaluate and approve the student's thesis or project report. After the completion of his or her research work, each MS candidate undergoes a thesis defense, in which the results of the candidate's research are presented to the advisory committee. During this examination and thesis defense, the committee may ask any questions in regards to the thesis research and/or the candidate's academic coursework and preparation.

Oral Defense and Thesis Assessment data below to support this outcome indicate that the student outcome is at or above the threshold of 3.0 set by the program.

	Results on a scale of 1-4
Evaluation of Oral Presentation	
Content	3
Responses to Questions and comments	3.66

In addition, the Graduate Student Exit Interview Survey asks students "Have you attended any professional meeting/conference during your graduate program?". Six of the eight students (75%) indicated having attended a professional meeting/conference. Students are also asked "Have you authored or co-authored a paper during your graduate program?". Five of eight students (62.5%) indicated having authored or co-authored a paper.

Modifications for Improvement:

Student Outcome 2: Demonstration of Research or Independent Study

In Fall 2019, the faculty of Mechanical Engineering changed the ME 6990- Research and Thesis credit requirements for students in Mechanical Engineering from 6 credits to 8 credits. This proposed change will expedite the MS student's involvement in their research earlier (due to 2 fewer credit hours of coursework) and enable more in-depth investigation into the research (due to 2 additional research credit hours). The requirements for non-thesis MS students will remain the same as 33 credits of course work including one 3 credit independent study. A new course will be offered in Fall 2020. ME 6910 Research Methods was created to provide opportunities for MS students to learn professional elements of conducting research and prepare them for their MS research. It is mandatory for all ME-MS students pursuing a thesis option.

Appendices

1. Curriculum Map

Appendix 1: Curriculum Map

Curriculum Map of MS Program in Mechanical Engineering			
	Student Learning Outcomes		
Courses & Degree Requirements ↓	Demonstrate an enhanced expertise in their area of specialization in Mechanical Engineering.	Conduct basic, applied and/or empirical research and/or design.	Give professional presentations or write scholarly manuscripts worthy of publication in conferences and or peer reviewed journals.
Graduate Level Coursework. * (Minimum 21 credit hours for thesis Option; 30 credit hours for non-thesis). A maximum of 9 credit hours can be at the 5000 level.	X		
ME 6990- Research and Thesis (6 to 8 credit hours for thesis option).	X	X	X
ME 6960- Independent Project Course (3 credit hours for non-thesis option).	X	X	X
ME 6910-1 credit. Introduction to Graduate Research		X	X

* Graduate-level courses in the Mechanical Engineering Department have been grouped into four broad categories; refer to Table 1 below. To ensure that students are exposed to a breadth of fundamental engineering principles, it is proposed that students will be required to register for at least two courses listed in each category, courses deemed to be acceptable for potential inclusion in the program of study are listed in bold red font in Table 1. The content and format of the independent project course, including the comprehensive examination, for non-thesis will be entirely at the discretion of the faculty member teaching the class. Typically, this course will be taken in the final semester listed on the program of study. The approved program of study can list no more than two three-credit hour, 6000-level courses in either advanced mathematics or science.

Suggested Categories of Graduate-Level Courses
Currently Offered in the Mechanical Engineering Department

Energy, Fluids, and Thermal Systems

ME 5210 Refrigeration and Air Conditioning

ME 5220 Air Conditioning Design

ME 5260 Energy Conversion and Conservation¹

ME 5310 Gas Dynamics

ME 5510 Aerodynamics

ME 5610 Steam Power Plants

ME 5620 Turbomachinery

ME 5630 Internal Combustion Engines

ME 5720 Thermal Design

ME 5730 Numerical Heat Transfer

ME 6010 Conduction Heat Transfer

ME 6030 Radiation Heat Transfer

ME 6040 Intermediate Fluid Mechanics

ME 6050 Convection Heat Transfer

ME 6210 Advanced Thermodynamics

ME 7040 Mass Transfer

ME 7070 Fluid Mechanics of Suspensions

ME 7080 Advanced Viscous Flow

ME 7090 Computational Fluid Dynamics

ME 7100 Turbulence

Mechanics, Materials Science, and Experimental Methods

ME 5160 Experimental Stress Analysis

ME 5190 Advanced Mechanics of Materials

ME 5380 Introduction to Data Acquisition and Signal Processing

ME 5460 Mechanical Properties of Materials

ME 5470 Interdisciplinary Studies in Ceramic Materials Processing

ME 5480 Microstructural Analysis

ME 5490 Properties and Selection of Engineering Materials

ME 6350/CEE 6350 Finite Element Analysis

ME 6360 Introduction to Continuum Mechanics

ME 6760 Smart Materials and Structures

ME 6810 Advanced Materials Science I

ME 6930/CEE 6930 Theory of Elasticity

ME 7600/CEE 7510 Theory of Plates and Shells

ME 7620/CEE 7620 Advanced Finite Element Analysis

ME 7640/CEE 7640 Theory of Inelastic Material Behavior

¹ Courses in red are offered every year.

ME 7650/CEE 7650 Continuum Theories of Materials
ME 7660/CEE 7710 Fracture Mechanics
ME 7670/CEE 7720 Fiber-Reinforced Composite Materials
ME 7680/CEE 7820 Theory of Elastic Stability
ME 7810 Advanced Materials Science II

Acoustics, Vibrations, Dynamics, and Controls

ME 5060 Machine Vibrations

ME 5120 Intermediate Dynamics
ME 5640 Dynamics of Machinery II

ME 5810 Automatic Controls

ME 5930 Noise Control

ME 6370/CEE 6370 Vibrations of Continuous Media
ME 6430 Fundamentals of Acoustics

ME 6440 Applied Acoustics

ME 6510 Motion Programming of Planar Mechanisms

ME 6710 Advanced Dynamics of Machinery

ME 6730 Modal Vibration Analysis
ME 7510 Space Mechanisms
ME 7710 Dynamics of Machinery
ME 7720 Transfer Function Synthesis of Dynamic Systems

Design, Manufacturing, Mechatronics, and Robotics

ME 5020 Applied Machine Design
ME 5140 Introduction to Robotics and Intelligent Machines Engineering
ME 5180 Finite Element Methods in Mechanical Design

ME 5370 Mechatronics and Intelligent Machines Engineering

ME 5450 Design for Manufacturability

ME 6610 Fatigue and Wear in Mechanical Design
ME 6620 Plasticity and Creep in Mechanical Design

ME 6640 Advanced Robotics

ME 6830 Advanced Computer-Aided Design and Manufacturing