The University Senate of Michigan Technological University

Proposal 8-22

Establishment of a Master of Science in Manufacturing Engineering

Submitted by: Manufacturing and Mechanical Engineering Technology (MMET) Department

I. Background:

The Manufacturing and Mechanical Engineering Technology (MMET) department was formed as a new department in the College of Engineering in fall of 2019 as part of the university restructuring. The MMET department administers the BS Mechanical Engineering Technology (MET) program and the Minor in Manufacturing Systems. There are approximately 170 undergraduate MET program students and eight faculty members associated with the department. The MMET department manages the MMET Machine Shop located in the M&M building. The MMET Machine Shop is used for several manufacturing courses, enterprise course fabrication, and for developing undergraduate, graduate, and faculty research projects.

The MET BS degree has a focus area of Manufacturing that offers three technical elective courses to provide students with an understanding of "how things are made and work." In addition, there are manufacturing core MET courses with other manufacturing related courses in other focus areas. All students graduating with a MET degree are exposed to fundamentals of machining, manufacturing processes, and quality control methods, among others. With this manufacturing emphasis in the degree many employers hire MET students as Manufacturing Engineers, Process Engineers, Production Engineers, and Quality Engineers.

The MMET department supports the interdisciplinary MS in Mechatronics degree. MMET currently has five graduate courses that are taught by MMET faculty. MMET tenure-track and tenured faculty as well as some lecturers advise graduate students from other departments on campus inside and/or outside of the College of Engineering, but the lack of a graduate program in the department makes progress on a research agenda difficult. The faculty in MMET have manufacturing industry experience, and most teach courses and conduct research in manufacturing areas.

This degree is designed to be a flexible degree program, attracting people who work in industry, and who may come from a wide range of undergraduate backgrounds (e.g. manufacturing engineering, mechanical engineering, electrical or computer engineering, materials science and engineering, manufacturing engineering technology, mechanical engineering technology, etc.)

II. Proposal

1. **Proposal date:** February, 2021.
2. **Proposer primary contact:** John L. Irwin, Professor/Chair, MMET department

   MMET Manufacturing Degree Taskforce Members:
   Scott Wagner, Associate Professor, MMET
   David Labyak, Assistant Professor, MMET
   David Wanless, Senior Lecturer, MMET

Nicholas Hendrickson, Adjunct Instructor, MMET

3. General description and characteristics of program, including learning goals:

a. **Description:** This MS degree encompasses the building blocks of advanced manufacturing such as; smart manufacturing, modeling, simulation, sustainability, additive manufacturing, and advanced materials (Figure 1). This 30-credit degree is designed for the traditional student or working professional to align course projects to applications in their place of work. Courses will be offered in a variety of formats to suit the learner. The courses can be satisfied online or in person, and application projects will be performed on campus or at an employee's workplace. For instance, while studying the topic of Geometric Dimensioning and Tolerances a course project may involve analyzing the list of operations for producing a product to determine the manufacturing processes necessary to satisfy the tolerances applied in the design. This task would be applicable for a person that is working in industry in an engineering position. Therefore, the task described will satisfy both their course requirements, and possibly standard job duties. For traditional students enrolled in the program, the MMET Machine Shop will take the place of the industrial setting.

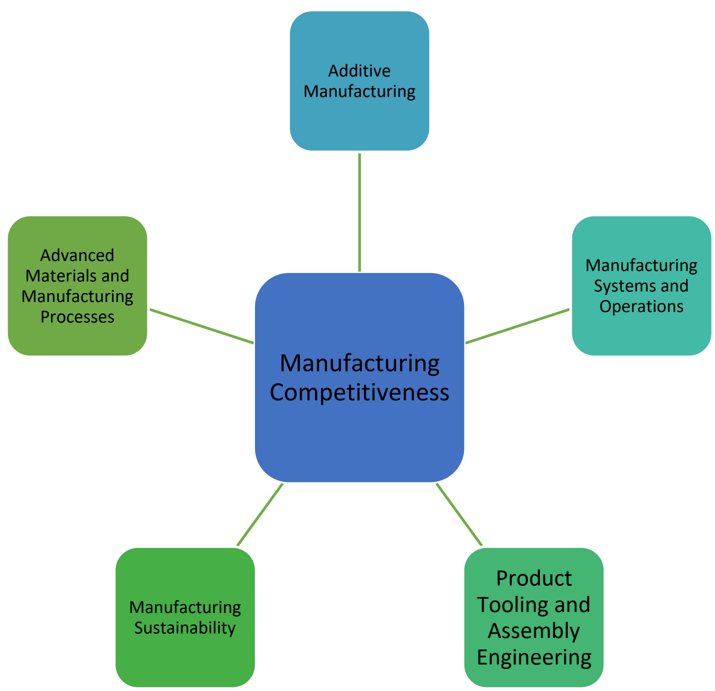


Figure 1. MS Manufacturing Engineering Building Blocks

b. **Characteristics:** The Four Pillars of Manufacturing Engineering were developed by the Society of Manufacturing Engineers (SME) through its Center for Education. The four pillars model builds on the topics in the SME body of knowledge for the certification of manufacturing engineers. The four pillars model defines topics in the categories of: 1) Materials, and manufacturing processes; 2) Product, tooling, and assembly engineering; 3) Manufacturing systems, and operations; and 4) Manufacturing competitiveness. The four pillars model is the structure that has been used to inspire the curriculum developed for this proposed MS in Manufacturing Engineering. The graphic representation of the four pillars is depicted as a structure including foundation, and the supporting pillars (Figure 2). The degree has 16 required credits, with most courses in the Manufacturing Competitiveness category. Additional credits in the emphasis areas align with the other categories described in the four pillars model, with the option to conduct research in any emphasis area.

Figure 2. SME Four Pillars

c. **Graduate Learning Goals:**

Upon graduation students will be able to:

- Estimate manufacturing competitiveness in terms of quality, continuous improvement, and manufacturing management.

• Contribute to the advanced manufacturing body of knowledge (Thesis option), investigate advanced manufacturing methods (Report option), or recognize advanced manufacturing methods (Coursework option).
• Demonstrate effective communication skills in written, graphic, and oral formats.
• Select responsible, legal, and ethical modes of conduct to sustain the manufacturing engineering profession.

4. **Rationale.**
The need for manufacturing engineers and engineering managers is evident from recent studies regionally, from Wisconsin and Michigan, as well as nationwide. The NEW (Northeast Wisconsin) Manufacturing Alliance Needs, Skills, & Talent Survey was conducted in 2019 tallying responses from over 100 manufacturers. One primary outcome from this report is that curriculum and training programs that develop **process engineers** and data analysts are in high demand. The report also indicates that IT, **Engineering**, **Production**, and Research & Development functions/departments will be most heavily impacted by the integration of **Industry 4.0**.

Automation Alley is Michigan's Industry 4.0 knowledge center. Their mission is to help manufacturers of all sizes understand the rapid technological changes associated with digitalization, so that Michigan and the nation remain globally competitive. In the Automation Alley 2019 Industry 4.0: From Vision to Implementation report, a positive rate of change in the areas of **additive manufacturing** and **advanced materials** is shown in the following four technology markets: 1) Automotive, 2) Medical 3) Retail, and 4) Energy. Additive manufacturing (3D printing) is a process that creates three dimensional objects by depositing layers of materials, which is an integral part of Industry 4.0 technologies. Given the growth of additive manufacturing, it has been included as an emphasis area in this proposal.

Nationwide interest in manufacturing fields of study according to a 2016 Survey conducted by Opinion Research Corporation, indicates that 37 percent of millennials perceive manufacturing as a high technology career choice, notably higher than both Generation X (27 percent) and Baby Boomers (23 percent). The study also reveals that more millennials (49 percent) believe **engineering is a needed skill in manufacturing,** and forty percent of millennials also recognize that manufacturing careers are high paying. These findings are a good indication for the ability to recruit young people into manufacturing engineering careers.

National Science and Technology Council, 2018 report "Strategy for American Leadership in Advanced Manufacturing," identifies the developing and transitioning of new manufacturing technologies, including **smart manufacturing,** as a core component. To achieve this, small and medium manufacturers must have the knowledge to upgrade their operations. An example of the smart manufacturing technologies referred to in this study includes **additive manufacturing**.

5. **Related programs**.
There are numerous accredited manufacturing degree programs at the undergraduate level, including (26) ABET EAC Manufacturing Engineering degrees and (27) ABET ETAC Manufacturing Engineering Technology degrees. In addition, there are two ABET ETAC Manufacturing and

Mechanical Engineering Technology degrees. Institutions in Michigan offering EAC or ETAC Manufacturing degrees are; University of Michigan, Western Michigan, Lake Superior State, and Lawrence Tech.

There are a number of universities in Michigan offering master's programs in Manufacturing Engineering. These include Western Michigan University, Wayne State University, and the University of Michigan. In addition, the University of Michigan offers a dual-degree program of Master of Engineering in Manufacturing and Master of Business Administration.

Regionally, programs are offered at the University of Wisconsin-Stout, Illinois institute of Technology, and the University of Wisconsin-Madison. Other programs of note are Arizona State, and Clemson. Typically, these degree options are offered as on-campus, or online options.

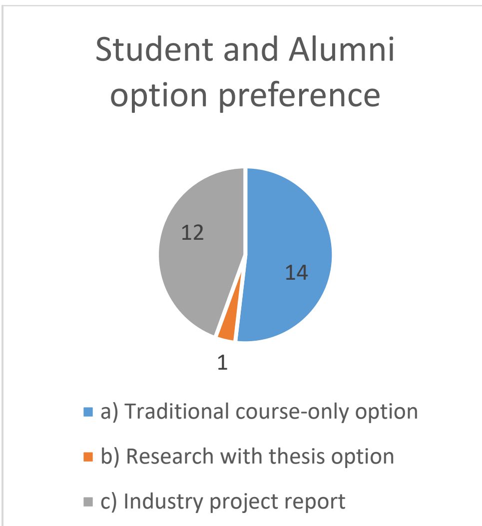
Most often, however, a graduate degree in manufacturing engineering is achieved through a master's in Mechanical Engineering, with a focus in manufacturing. This degree path is more commonly found in universities throughout the United States. Universities that offer graduate programs in engineering, offer a Master of Science in Mechanical Engineering, with an educational focus in Manufacturing. Michigan Tech also offers this graduate degree option. The obvious advantage to this proposed degree is the name recognition having manufacturing in the degree title. Moreover, a wider range of elective courses in various disciplines are available in this proposed degree. The Manufacturing Engineering degree will attract a wider audience of degree majors that otherwise would not necessarily pursue a degree in Mechanical Engineering, with a manufacturing focus. Students with degrees other than mechanical or manufacturing such as biomedical, electrical, chemical, robotics or material science may desire some basic knowledge and skills in print reading, CAD modeling software, and manufacturing processes. Graduates with the master's in Manufacturing Engineering will be prepared to earn SME Certifications.

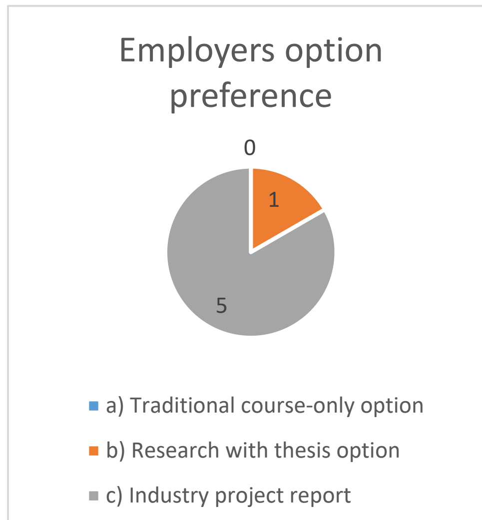
Within all the graduate degrees that fall under the manufacturing engineering discipline, the prerequisites are fairly common. The programs are primarily intended for individuals who possess a baccalaureate degree, with a major in a technical field such as engineering or technology, possess a grade point average of 3.0 or higher, have completed undergraduate courses, or have work experience in Computer Aided Design, Computer Aided Manufacturing, quality control, statics, and strength of materials. The Graduate Record Exam (GRE) is not required in all instances. The majority of universities offer these graduate programs by accommodating the work requirements of full-time professionals with courses offered in the evenings and weekends, or by distance learning means.

6. **Projected Enrollment**.
A survey was conducted by the MMET department, to assess the interest in the MS in Manufacturing Engineering degree by employers, as well as current MET students and alumni. Additional questions in the survey were to assess the most popular methods of delivery for the program. The survey was distributed by email to two groups; employers using the 10 individuals

on the MMET department Industrial Advisory Board, current students, and alumni using the MMET student email group list and emails from 2019-20 MET graduates. The responses yielded a typical 20-30% return for the student and alumni, n=27. For the employer survey there is representation from companies such as Pettibone, Cummins, Greenheck, and Honda Manufacturing, n=6.

The response to the first question, “Would you consider the opportunity to obtain a MS in Manufacturing Engineering requiring 30 credits after completing your MET degree?” was 23 (85%) yes. For employers, the same question was answered 6 (100%) yes. Students and alumni were approximately evenly split between preferring the course only option, and industry project report option, and employers were 5 out of 6 (83%) interested in the industry-based project report option as shown in Figure 3 & 4.





Figures 3 & 4. MS Degree option preference – Student and Alumni & Employers

The survey indicates that there is interest in all the emphasis areas that are in this proposal, as shown in Figure 5. The current students were mostly interested in Manufacturing Systems and Operations, where the employers were evenly split between Advanced Materials and Manufacturing Processes and Additive Manufacturing.

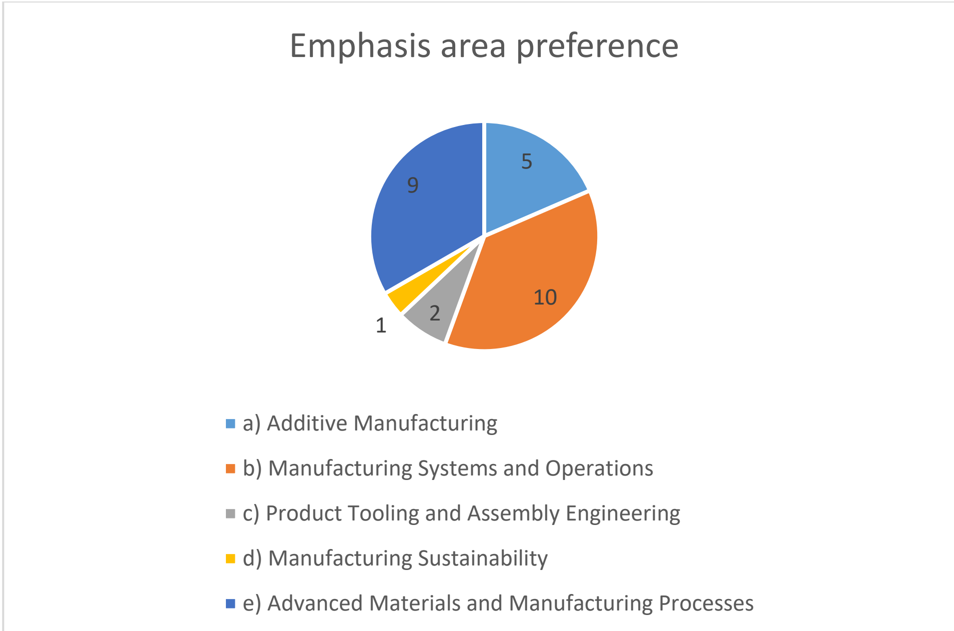


Figure 5. Emphasis area preference – Current Students

The marketing plan for the MS in Manufacturing Engineering is to use social media to target current Michigan Tech students, and early career alumni, to consider pursuing the degree. For students interested in this degree, it will be advised to take advantage of the Accelerated Master's program. The Graduate School will also be encouraged to actively market this degree with international students, with an interest in manufacturing over traditional product design research and development. MET alumni are the most likely group to target, since they are familiar with the faculty and the facilities. The ability to complete projects as part of the degree requirements is favored by MET Alumni. The vast majority 25 (93%) of the students answered "yes" to the question "Would you be interested in course lab assignments being satisfied by completing in-plant projects in the workplace?" and 100% of the employees also answered "yes".

The need for the degree is reinforced by the 6 (100%) response by employers that "yes" to the question "Would you consider hiring an applicant with this MS in Manufacturing Engineering?" This is also reinforced with the Bureau of Labor Statistics (BLS) data, indicating that Occupational Employment and Wages, May 2018 for 11-3051 "Industrial Production Managers". This role is defined by the BLS as "Plan, direct, or coordinate the work activities and resources necessary for manufacturing products in accordance with cost, quality, and quantity specifications." Michigan has the highest concentration of jobs with this title shown in Table 1. The Location Quotient (LQ) compares the concentration of an industry within a specific area, to the concentration of that industry nationwide. An LQ greater than 1 indicates an industry with a greater share of the local area employment than is the case nationwide, which Michigan is the highest of the top 5 states. The employment estimate and mean wage estimates for this occupation, are shown in Table 2. The Relative Standard Error (RSE) of the employment estimate is a measure of the reliability or precision of the employment estimate. The relative standard error is defined as the ratio of the standard error to the survey estimate. The reported annual wage for Industrial Production

Managers of $113,370 is higher than the mean annual salary for MET majors of $99,310 as reported by National Occupational Employment and Wage Estimates, United States Department of Labor. This increased salary is an incentive for MET alumni to pursue this certificate and further their education.

Table 1. Top five States with the highest concentration of jobs and location quotients for Industrial Production Managers

State	Employment	Employment per thousand jobs	Location quotient	Hourly mean wage	Annual mean wage
Michigan	13,110	3.04	2.42	$57.10	$118,760
Wisconsin	6,580	2.31	1.84	$53.01	$110,250
Iowa	3,490	2.27	1.81	$47.14	$98,040
Ohio	11,380	2.10	1.68	$52.50	$109,190
Kentucky	3,800	2.01	1.60	$46.80	$97,340

Table 2. Nationwide employment estimate and mean wage estimates for Industrial Production Managers

Employment	Employment RSE	Mean hourly wage	Mean annual wage	Wage RSE
181,310	0.7 %	$54.51	$113,370	0.3 %

7. **Scheduling plans**.
Courses will be offered in the regular fashion during the fall and spring semesters, with all required MFGE courses available through remote instruction, whether synchronous or asynchronous (MET 5400 – Key Factors of Holistic Safety (1), MFGE 5000 - Organizational Leadership (3), MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3), MFGE 5200 - Industry 4.0 Concepts (3)). Depending upon the courses selected by the student to complete their degree, most (if not all) of the degree may be earned through remote instruction, whether synchronous or asynchronous.

Students surveyed were rather split in how they would prefer to have courses offered, but the majority 21 (78%) preferred a traditional 14-week semester, requiring three contact hours per week, as compared to weekends, or two-week intensives in the summer. The preferred mode of delivery for students was approximately split between the options of on-campus in person labs, and labs offered on weekends or summer, as shown in Figure 6. Employers preferred 4 out of 6 (67%) the option "c" offering in person labs on weekends, or in the summer. Given these responses, it was decided to not include courses with labs for the online certificate, although the courses will include application-based learning activities to be performed at the workplace. Group projects will accommodate students that are not currently in roles that accommodate a workplace project.

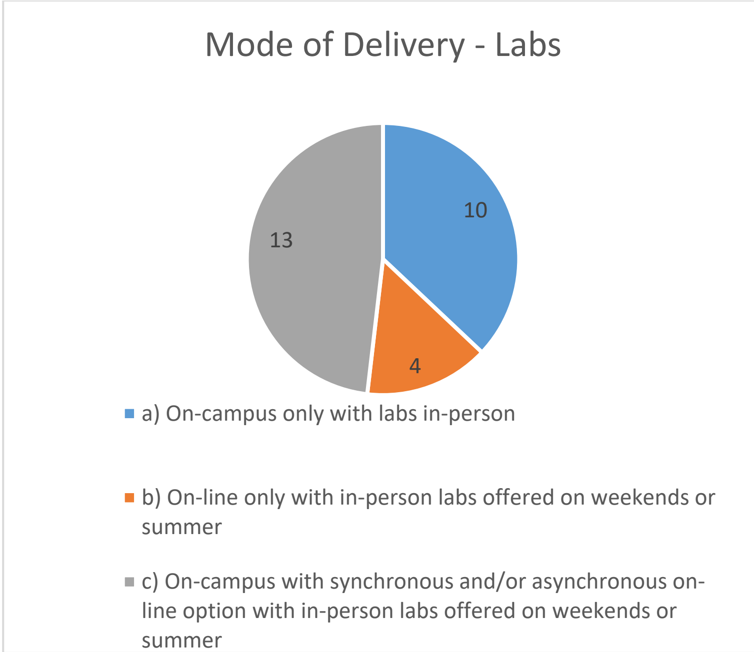


Figure 6. MET current student survey results - course mode options

8. **Curriculum design**.

Options:

Thesis: 20 course credits plus 10 research credits

Report: 24 course credits plus 6 research credits

Coursework: 30 course credits

Required Courses: Take the (16) credits from this list.

MA 5701 - Statistical Methods (3)

MET 5400 – Key Factors of Holistic Safety (1)

MFGE 5000 - Organizational Leadership (3)

MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)

MFGE 5200 - Industry 4.0 Concepts (3)

MEEM 5010 – Professional Engineering Communication (3)

Or

MEEM 6010 –Engineering Research Communication (3)

Manufacturing Emphasis Area Electives: The remaining courses are subject to advisor approval, with the limitation of a maximum of 12 credits at the 3000-4000 level. Example courses are shown below; other courses/areas may be suitable as well.

- **Additive Manufacturing**
- **Manufacturing Systems and Operations**
- **Product Tooling and Assembly Engineering**
- **Quality Engineering**
- **Manufacturing Sustainability**
- **Advanced Materials and Manufacturing Processes**
- **Cyberphysical Systems**

Additive Manufacturing
MFGE 5300 - Design for Additive Manufacturing (3)
MFGE 5400 - Additive Manufacturing Lab (3)
MEEM 5695 – Additive Manufacturing (3)

Manufacturing Systems and Operations
MEEM 5656 - Advanced Production Planning (3)
BA 5610 - Operations Management (3)
MET 4355 - Industrial Systems Simulation (3)
MET 4510 - Lean Manufacturing and Production Planning (3)
MET 4585 - Facilities Layout and Safety Design (3)
EET 5373 - Advanced Programmable Controllers (4)
SAT 4343 - Network Engineering (3)

Product Tooling and Assembly Engineering
MET 4550 – Computer Aided Manufacturing (3)
Or
MEEM 4430 - Advanced Computer Aided Design and Manufacturing Methods (3)
MEEM 5670/ENG5670 - Experimental Design in Engineering (3)

Quality Engineering
MEEM 5650 - Advanced Quality Engineering (3)
MEEM 5655 – Introduction to Lean Manufacturing (3)
MEEM 5670 – Experimental Design in Manufacturing (3)

Manufacturing Sustainability
ENG 5510 - Sustainable Futures I (3)
ENG 5520 - Sustainable Futures II (3)
ENG 5540 - Sustainable Forest-Based Biofuel Pathways (3)

Advanced Materials and Manufacturing Processes
MET 4780 - Advanced Manufacturing (3)
MET 4377 - Applied Fluid Power (3)
MET 4378 - Advanced Hydraulics: Electro-hydraulic Components & Systems (3)
MSE 5100 - Introduction to Materials Science and Engineering with Advanced Topics (3)
MSE 5400 - Statistical Quality Control in Materials Manufacturing (3)

EET 5144 - Real-Time Robotics Systems (4)
EET 5147 - Industrial Robotic Vision System and Advanced Teach Pendant (4)

9. **New course descriptions**.
MFGE 5400 - Additive Manufacturing Lab (3)
A hands-on approach is used to investigate Additive Manufacturing technologies. Key concepts are demonstrated by implementing the generic eight-step AM process. Students will design and print parts using various AM machines.

10. **Model schedule**.
Required Courses:
MA 5701 - Statistical Methods
Introduction to design, conduct, and analysis of statistical studies, with an introduction to statistical computing and preparation of statistical reports. Topics include design, descriptive, and graphical methods, probability models, parameter estimation, and hypothesis testing.
Credits: 3.0
Lec-Rec-Lab: (0-3-0)
Semesters Offered: Fall, Spring, Summer
Restrictions: Must be enrolled in one of the following Level(s): Graduate
MFGE 5000 - Organizational Leadership
Team building, ethical decision making, enhanced communication skills, critical thinking, and people skills are discussed. Students learn the practice of leadership, as it relates to organizational effectiveness.
Credits: 3.0
Lec-Rec-Lab: (3-0-0)
Semesters Offered: Fall
Restrictions: Must be enrolled in one of the following Level(s): Graduate
MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing
GD&T is the universal manufacturing language. This course will focus on the ASME Y14.5-2018 standard, and cover the concepts of GD&T needed to communicate effectively in the manufacturing sector. Includes: assembly tolerance stack-up, applying and interpreting geometric symbols, datum reference frames, and calculating position and profile tolerance.
Credits: 3.0
Lec-Rec-Lab: (0-3-0)
Semesters Offered: Fall Online
Restrictions: Must be enrolled in one of the following Level(s):
MFGE 5200 - Industry 4.0 Concepts
An examination of Industry 4.0 as it relates to manufacturing. Topics include smart factories, cyber physical systems, proactive maintenance, computer simulation, horizontal and vertical integration, and barriers to implementation.
Credits: 3.0
Lec-Rec-Lab: (0-3-0)
Semesters Offered: Spring Online
Restrictions: Must be enrolled in one of the following Level(s): Graduate

MEEM 5010 - Professional Engineering Communication

Course introduces graduate students to conventions of professional engineering communication, such as composing technical documents, and working effectively in teams. Students will practice creating effective visuals for reports and slides, and develop and deliver presentations.

Credits: 3.0
Lec-Rec-Lab: (0-3-0)
Semesters Offered: Fall, Spring, Summer
Restrictions: Must be enrolled in one of the following College(s): College of Engineering, College of Computing
Pre-Requisite(s): MEEM 4901(C) or ENT 4950(C) or Graduate Status >= 1

MEEM 6010 - Engineering Research Communications

Guides students through the process of preparing proposals, publishing research, and presenting at conferences and other venues, with a focus on practical application of rhetorical concepts. Students will prepare proposals, papers, and presentations related to their own research.

Credits: 3.0
Lec-Rec-Lab: (0-3-0)
Semesters Offered: Spring
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering, College of Computing.

MET 5400 - Key Factors of Holistic Safety

Students learn industry best safety practices with respect to; risk management, lockout/energy isolation, fluid power and electrical symbols, basic circuit design and machine design, and sequence of operation involved with automation controls and mechanical motion.

Credits: 1.0
Lec-Rec-Lab: (1-0-1)
Semesters Offered: Spring
Restrictions: Must be enrolled in one of the following Level(s): Graduate;

Table 3. Course Only Option

Year 1- Fall semester: 9 credits	**Year 1- Spring semester: 9 credits**
MFGE 5000 - Organizational Leadership (3)	Emphasis Area Course (3)
MA 5701 - Statistical Methods (3)	MFGE 5200 - Industry 4.0 Concepts (3)
MEEM 5010 - Professional Engineering Communication (3)	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
Year 2- Fall semester: 9 credits	**Year 2- Spring semester: 4 credits**
Emphasis Area Course (3)	Emphasis Area Course (3)
Emphasis Area Course (3)	MET 5400 – Key Factors of Holistic Safety (1)
Emphasis Area Course (3)	

Table 4. Report Option

Year 1- Fall semester: 9 credits	**Year 1- Spring semester: 9 credits**

MFGE 5000 - Organizational Leadership (3)	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
MA 5701 - Statistical Methods (3)	MFGE 5200 - Industry 4.0 Concepts (3)
Emphasis Area Course (3)	MEEM 6010 - Engineering Research Communication (3)
Year 2- Fall semester: 9 credits	**Year 2- Spring semester: 4 credits**
Emphasis Area Course (3)	MFGE 5999 - Graduate Research in MfgE (3)
Emphasis Area Course (3)	MET 5400 – Key Factors of Holistic Safety (1)
MFGE 5999 - Graduate Research in MfgE (3)	

Table 5. Thesis Option

Year 1- Fall semester: 9 credits	**Year 1- Spring semester: 9 credits**
MFGE 5000 - Organizational Leadership (3)	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing (3)
MA 5701 - Statistical Methods (3)	MFGE 5200 - Industry 4.0 Concepts (3)
Emphasis Area Course (3)	MEEM 6010 - Engineering Research Communication (3)
Year 2- Fall semester: 9 credits	**Year 2- Spring semester: 5 credits**
Emphasis Area Course (3)	MFGE 5999 - Graduate Research in MfgE (4)
MFGE 5999 - Graduate Research in MfgE (6)	MET 5400 – Key Factors of Holistic Safety (1)

11. **Library and other learning resources**.

    Students will have access to all Library resources, Michigan Tech subscription to digital databases, interlibrary loans, and degree specific subscription-based journals and conference proceedings.

    Since this degree builds on the foundation of undergraduate degrees in MET, ME-EM, and MSE, no additional library and learning resources are required.

12. **Faculty resumes**.

The MMET Manufacturing Degree Taskforce Members are the faculty that will teach the graduate courses. Each has five plus years of experience in the manufacturing industry in areas of: operations/facilities management, process engineering, quality management, plant engineering/maintenance supervision, and manufacturing engineering. Faculty have education in leadership studies, organizational leadership and quality, manufacturing operations, mechanical engineering technology, and mechanical engineering.

Table 6. MET Faculty

Faculty Teaching	**Link to Webpage**	**Course(s)**
Scott Wagner	Link	MET 5400 - Key Factors of Holistic Safety
David Wanless	Link	MFGE 5000 - Organizational Leadership, MET 4780 - Advanced Manufacturing

David Wanless and Nicholas Hendrickson	Link	MFGE 5100 – Tolerance Analysis with Geometric Dimensioning & Tolerancing, MET 4550 – Computer Aided Manufacturing
John Irwin or TBD	Link	MFGE 5300 - Design for Additive Manufacturing, MFGE 5400 - Additive Manufacturing Lab
David Labyak or TBD	Link	MFGE 5200 - Industry 4.0 Concepts

13. **Available/needed equipment**.

The MMET Machine Shop is fully equipped with:

Five mills
Five lathes
Two drill presses
Three band saws
Three sanders, including one combination sander
Two grinders
Five different types of welders
A hydraulic press
A hydraulic press brake
A notcher and a bender for working with piping/tubing
A hydraulic metal shear
A plasma cutter
A CNC plasma table
FARO Edge arm for scanning and measuring
Stratasys Fortus 400mc 3D prototyping machine

14. **Program costs**.

PROGRAM REVENUE	Year 1	Year 2	Year 3	Years 4-n
Enrollment (MS students)	8	12	16	20
Tuition revenue (MS students-15 credits/year at $1,285/credit)	$154,200	$231,300	$308,400	$385,500
PROGRAM EXPENSES				
Program Director (8,000/yr stipend, CoE	$8,000	$8,000	$8,000	$8,000
Part Time faculty, CoE ($24,000 per year, CoE)	$24,000	$24,000	$24,000	$24,000
Total annual expenses	$30,000	$30,000	$30,000	$30,000
REVENUE – EXPENSES	**$124,200**	**$201,300**	**$278,400**	**$355,500**

Marketing One Time Cost: $ 10,000 (CoE, College of Engineering budget).

Enrollment is expected to reach steady state by year four. Non-degree seeking students, seeking only one or two graduate certificates, may add to the revenues. Upon the growth in enrollment, additional laboratory equipment will be acquired to support larger classes. The first priority for the laboratory expansion will be given to the additive manufacturing capabilities

15. **Space**.
    There are no additional space needs.

16. **Policies, regulations and rules**.
    No special regulations and rules

17. **Accreditation requirements**.

    The proposed degree will not seek accreditation from ABET or other professional society.

18. **Implementation Date**.

    Fall 2022.