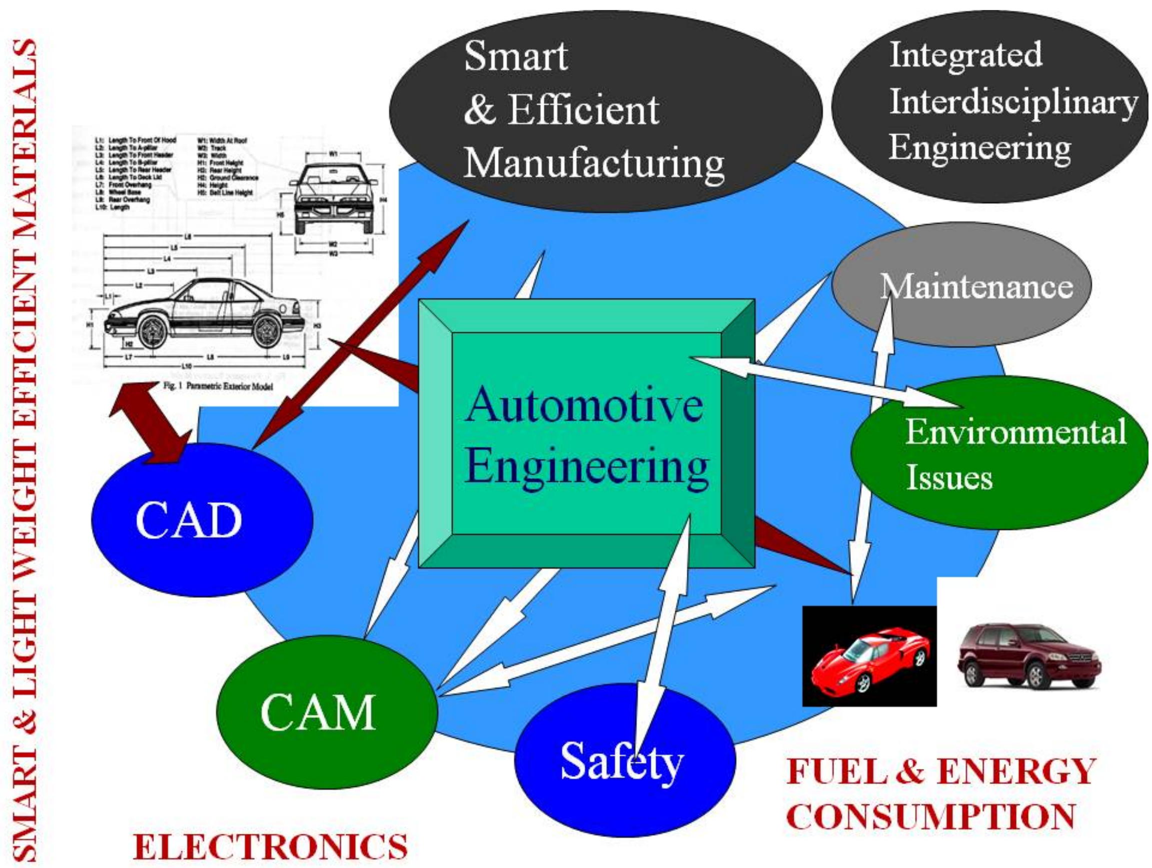
Mechanical Engineering (M.S.M.E.) with

Automotive Engineering Emphasis

University of Alabama at Birmingham (UAB)

&

Automotive Research Association of India (ARAI)



VISION: To be recognized as an internationally renowned practical applications plus research-oriented automotive engineering master's degree program – a first choice of the automotive industry with a global orientation.

MISSION: Development of high quality engineering talent and technology to meet the current and future needs of sustainability and the growth of the automotive industry in India.

Our Educational Goal

Applying a three pronged approach integrating Research, Education & Outreach in Collaboration with Global Automotive Industry and academia to Produce High Quality Automotive Engineering Graduates

- Knowledgeable & Skilled in the State-of-the-art & State-of-the-practice of design, manufacturing, environmental issues, safety, maintenance, and thermal, energy, and fuel systems of automotives with strong foundation of Mathematical Thinking and Information Technology
- Familiarity with integrated computational simulation and experimental engineering approach, tools & technology as well as the relationships among processes, process equipment, integrated design, performance and maintenance and life-cycle.
- Excellent Work Ethics, Responsibility to Engineering Profession & Society with a life-long learning culture With Spirit of generosity and entrepreneurship *thinking out-of-the-box*
- Excellent Communication and Presentation Skills with high motivation to effectively function in multi-disciplinary teams in Global Environment

Productive & Contributing the day They Enter the Work Force

UAB Faculty

Douglas M. Boylan, Research Professor (Mechanical Engineering); Power Generation, Energy Sources and Environments.

Krishan K. Chawla , Professor (Materials Engineering); Metal, Ceramic, and Polymer Matrix Composite Materials; Fibers, Interfacial Phenomena.

Gary Cheng, Associate Professor (Mechanical Engineering); Computational Fluid Dynamics, Multi-phase Combustion, Computational Acoustics

Alan Eberhardt, Associate Professor, (Biomedical Engineering); Solid Mechanics, Analytical and Numerical Methods in Biomechanics.

Yasushi Ito, Research Assistant Professor (Mechanical Engineering): Mesh Generation & Adaptation, Computational Fluid Dynamics.

Jong-Eun Kim, Research Associate Professor (Mechanical Engineering); Computational Structural Mechanics, Fluid-Structure Interactions, Multidisciplinary Optimization.

Roy P. Koomullil., Associate Professor (Mechanical Engineering); Computational Fluid Dynamics, Turbulence and Flow Modeling Using Generalized Grids.

David L. Littlefield, Professor (Mechanical Engineering); Computational Structural Mechanics, High Impact and Blast analysis, Computational Methods

Sally Anne McInerny, Professor, (Mechanical Engineering); Mechanical Systems, Vibrations, Acoustics

Robert Meakin, Professor, (Mechanical Engineering); Computational Fluid Dynamics, Moving Body and Complex Applications, Aerodynamics.

Robert H. Nichols, Research Associate Professor (Mechanical Engineering); Computational Fluid Dynamics, Turbulence Modeling, Grid Generation Software

Tina Oliver, Assistant Professor (Mechanical Engineering); Mechanical Systems and Vehicle Dynamics and Design.

Selvum Pillay, Assistant Professor (Materials Engineering); Manufacturing Processes, Composite Material Characteristics

Douglas Ross, Assistant Professor (Mechanical Engineering); Mechanical Systems, CAD, Computer Aided Geometry Design, Numerical Methods

Alan Shih, Research Associate Professor (Mechanical Engineering); Computational Fluid Dynamics, Mesh Generation, Visualization Systems and Software

Bharat Soni, Chair and Professor, (Mechanical Engineering); Computational Structures and Fluid Dynamics, Mesh Generation and adaptation, CAGD, and Design Optimization.

Uday Vaidya, Professor (Materials Engineering): Composite Material Characteristics, testing, and manufacturing processes

Peter Walsh, Research Professor (Mechanical Engineering); Combustion and Gasification for Industrial process Heat and Power Generation.

ARAI Faculty

N V Marathe, Sr. Dy. Director & Head, Powertrain Engineeering: Powertrain, Engines, Transmission, Fuels, Emission Control

A B Komawar, Sr. Dy. Director & Head, Automotive Electronics Lab: Automotive Electronics, Embedded Systems, Instrumentation, Controls, EMI, EMC, OBD, Electric & Hybrid Vehicles

K C Vora, Dy, Director & Head, ARAI Academy: Engine Design & Development, Emission Formation & Controls, After-treatment Devices, CO2 Emission, Automotive Passion & Ethics, Leadership, Teamwork, Presentation Skills, Product Development, Benchmarking, QFD & FMEA

R H Urdhwareshe, Dy. Director & Head, Homologation Management & Regulation Department: Automotive Certification & Homologation, Globalization of Norms, Calibration

S S Sandhu, Dy. Director & Head, Vehicle Evaluation Lab: Vehicle Testing, Evaluation, Durability trials, Test Tracks, Safety Checks, Certification

N V Karanth, Dy. Director & Head, Noise, Vibration & Harshness Lab: Acoustics, Noise & Vibration Measurement, Anechoic Chamber & Reverberation Rooms, Noise Source Identification, Modal Testing Theory and Application, Analysis and Design of Automotive Exhaust and Intake Systems, Passby, Incab & Tail Pipe Noise Control, Acoustic Material Characterization, Mount Design, Ride Comfort of Vehicles

M R Saraf, Dy. Director & Head, Structural Dynamics Lab: Stress, strain, and strength with reference to engineering design and analysis, Analytical & experimental determination of stresses in relationship to the fatigue strength. Structural Dynamics, deflection, post-yield behavior, residual stresses, temperature & corrosion effects, Vehicle Dynamics, Four Poster Simulation, Multi body Dynamics

A V Mannikar, Dy. Director & Head, Passive Safety Lab: Active and passive safety, Crashworthiness, Pedestrian Safety and Ergonomics, Anthropometry, Mechanics of Human Movement, Warning Devices

A R Arankalle, Dy Director, Forging Industry Division, Automotive Materials, Manufacturing Processes, Test & analysis of Oil, Fuel, Coolants & Lubricants, Wet Emission Analysis, Failure Analysis

S S Thipse, Sr. Asst. Director & Head, Alternate Fuels Lab: Automotive Engineering Basics, Alternate Fuels & Alternate Energy, Hydrogen Storage, Fuel Cells

V K Jadhav, Asst. Director & Head, Quality Management Department: Quality & Environmental Management Systems, Quality Assurance, Design for Manufacturing, Six Sigma Approach, NABL, Audits.

B V Shamsundara, Asst**.** Director & Head, Automotive Lighting Lab: Photometry, Fundamentals of light, vision and color, spectral measurements and Colorimetry, Automotive Lamps and Light Signaling Devices

H A Nakhawa, Asst. Director, Emission Certification Lab: Emission Analyzers and Measurements, Chassis Dynamometer, CVS, Driving Cycles, Nano Particle Measurement,

S Juttu, Sr Project Engineer, Powertrain Engineering: Introduction to Turbulence, Combustion and Flame Propagation, Combustion Modeling, CFD, HCCI Combustion, High Speed Combustion Photography

Adjunct Faculty (To be Discussed)

- Engineering Mathematics for Problem Solving
- Body Engineering
- Robotics
- Electronics & Micro-Eleconics

Program Requirements

Core courses + one of the specialization tracks

Tracks:

- **Product Development & Design**
- **Manufacturing & Materials**
- **Automotive Engineering Tools & Technologies**
- **Automotive Enabling Technologies & Simulations**

Course Listings with Description

Unless otherwise noted, all courses are for 3 semester hours of credit. The courses listed below should be considered at this point as a starting point for discussion with the Advisory council. It may turn out that we may need one more Track and in some special cases the academic advisors may allow combining courses from different tracks for a specific student based on his / her aptitude and industry needs.

Core Courses

1. Engineering Mathematics for Problem Solving

Formulating problems in mathematical language for a variety of automotive related applications. Algebraic equations, differential equations, statistics. Some exposure to solving the problems but heavy immersion in defining the problems.

2. Applied Physics & other sciences for multidisciplinary problem solving (UAB)
Multidisciplinary perspective that includes Applied physics, engineering, art, psychology, marketing, and economics. Using a decision-making framework, emphasis placed on quantitative methods. Building mathematical models and accounting for interdisciplinary interactions.

3. **Computational Modeling & Simulations (UAB)**
Modeling and computational simulation techniques for solving realistic automotive engineering problems of practical interest – fluid mechanics, structures, heat transfer, acoustics, vibration, optics, safety, etc.. Introduction to mesh generation, CAD, and stability, convergence, and accuracy of numerical methods.

4. **Automotive Engineering Systems Analysis (ARAI)**
Approximate techniques for the analysis of problems in Automotive Engineering including body engineering, power train, safety, embedded systems, emissions, sustainability, etc. This course will provide emphasize a systems approach to automotive design. A semester team based design project would be required. This course is intended to give an overview of the entire car as a complete unit and to look at the interactions between systems with first order analysis.

5. **Noise & Vibrations (ARAI)**
Fundamentals of Vibration & Noise, Vibration and Noise Measurement, Automotive NVH, Noise Specifications and Standards, Anechoic Chamber & Reverberation Rooms, Noise Source Identification, Modal Testing Theory and Application, Analysis and Design of Automotive Exhaust and Intake Systems, Passby, Incab & Tail Pipe Noise Control, Acoustic Material Characterization, Mount Design, Ride Comfort

6. **Automotive Laboratories (ARAI)**
Powertrain, Emissions, Structural Dynamics, Safety, EMI/EMC and hands on understanding of Automotive Technologies, R&D as well Vehicle Testing. Emphasis on laboratory report writing, oral presentations, team-building skills and the design of experiments.

Elective Courses

Materials & Manufacturing

Following topics relating to materials engineering to be consolidated into two or three elective courses.

7. **Advanced Materials.** Composites – non metallic and metallic. Other specialty materials used in Automotive design and manufacturing. Role of Nano technology in Automotive systems.

8. **Mechanics of Polymers.** Constitutive equation for linear small strain viscoelastic response; constant rate and sinusoidal responses; time and frequency dependent material properties; energy dissipation; structural applications including axial loading, bending, torsion; three dimensional response, thermo-viscoelasticity, correspondence principle, Laplace transform and numerical solution methods.

9. **Composite Materials: Mechanics, Manufacturing and Design.** Composite materials, including naturally occurring substances such as wood and bone, and engineered materials from concrete to carbon-fiber reinforced epoxies. Development of micromechanical models for a variety of constitutive laws. Link between processing and as-manufactured properties through coupled fluid and structural analyses.

10. **Smart Materials and Structures.** Theoretical aspects of smart materials, sensors and actuator technologies. It will also cover design, modeling and manufacturing issues involved in integrating smart materials and components with control capabilities to engineering smart structures.

11. **Materials in Manufacturing and Design.** Material selection on the basis of cost, strength, formability and machinability. Advanced strength analysis of heat-treated and cold-formed parts including axial, bending, shear and cyclic deformation. Correlations of functional specifications and process capabilities. Problems in redesign for productibility and reliability.

12. **Global Manufacturing and supply chain management.** Globalization and manufacturing paradigms. Product-process-business integration. Product invention strategy. Customized, personalized and reconfigurable products. Mass production and lean production. Mathematical analysis of mass customization. Traditional manufacturing systems. Reconfigurable manufacturing systems. Reconfigurable machines. System configuration analysis. Responsive business models. Enterprise globalization strategies. The global integrated enterprise.

13. **Time Series Modeling, Analysis, Forecasting.** Time series modeling, analysis, forecasting, and control, identifying parametric time series, autovariance, spectra, Green's function, trend and seasonality. Examples from manufacturing, quality control, ergonomics, inventory, and management.

14. **Laser Materials Processing.** Application of lasers in materials processing and manufacturing. Laser principles and optics. Fundamental concepts of laser/material interaction. Laser welding, cutting, surface modification, forming, and rapid prototyping. Modeling of processes, microstructure and mechanical properties of processed materials. Transport phenomena. Process monitoring.

15. **Assembly Modeling for Design and Manufacturing.** Assembly on product and process. Assembly representation. Assembly sequence. Datum flow chain. Geometric Dimensioning and Tolerancing. Tolerance analysis. Tolerance

synthesis. Robust design. Fixturing. Joint design and joining methods. Stream of variation. Auto body assembly case studies.

Automotive Design:

16. **Quality Assurance and Design for Manufacturing.** Design for quality. Process behavior over time. Concept of statistical process control (SPC). Process capability study. Tolerance. Measurement system analysis. Implication of customer satisfaction and profitability. Including Applications of probability and statistics in design reliability and quality control.

17. **Global Product Development.** A project-based course in which each (global) student team comprising students from different universities will be responsible for development of a product for the global market. Teams will use collaboration technology tools extensively. Several case studies on global product development will be presented and follow-up lectures will focus on the issues highlighted. QFD, FMEA, DVP&R would be included.

18. **Design Synthesis**. Integration of ideas, concepts, and fundamentals of science and engineering into preliminary design; synthesis of technical, human, and economic actors. Mathematical modeling and design optimization.

19. **Fatigue in Mechanical Design.** A broad treatment of stress, strain, and strength with reference to engineering design and analysis. Major emphasis is placed on the analytical and experimental determination of stresses in relationship to the fatigue strength properties of machine and structural components. Also considered are deflection, post-yield behavior, residual stresses, temperature and corrosion effects.

20. **Automotive Body Structures.** Emphasis is on body concept for design using first order modeling of thin walled structural elements. Practical application of solid/structural mechanics is considered to design automotive bodies for global bending, torsion, vibration, crashworthiness, topology, material selection, packaging, and manufacturing constraints.

21. **Mechanics of Human Movement.** Dynamics of muscle and tendon, models of muscle contraction. Kinematics and dynamics of the human body, methods for generating equations of motion. Mechanics of proprioceptors and other sensors. Analysis of human movement, including gait, running, and balance. Computer simulations and discussion of experimental measurement techniques.

22. **Experimental Design and Uncertainty Analysis**. Introductory statistics, general and detailed uncertainty analysis, design of experiments, instrumentation, data acquisition, correlation and evaluation of results.

23. Embedded systems and EMC

24. **Mechatronic Systems Design and Microelectromechanical Systems.** Mechatronics is the synergistic integration of mechanical disciplines, controls, electronics and computers in the design of high-performance systems. Case studies, hands-on lab exercises and hardware design projects cover the practical aspects of machine design, multi-domain systems modeling, sensors, actuators, drives circuits, simulation tools, DAQ, and controls implementation using microprocessors. Basic integrated circuit (IC) manufacturing processes; electronics devices fundamentals; microelectromechanical systems fabrications including surface micromachining, bulk micromachining, LIGA and others. Introduction to micro-actuators and microsensors such as micromotors, grippers, accelerometers and pressure sensors. Mechanical and electrical issues in micromachining. IC CAD tools to design microelectromechanical structures using MCNC

ENERGY:

25. **Powertrain Engineering.** Overview of Powerterain. Engine Characteristics. Engine Breathing and Advanced Valve Train. Engine Combustion. Pollutant Formation. Pollutant Control and Engine Management. Alternative Powertrain Technologies. Engine Mechanics Fundamentals. Transmission and Clutch. Powertrain Noise and Vibration. Powertrain Design Case Studies.

26. **Combustion**. Theory and applications of combustion: thermochemistry, mass transfer, chemical kinetics, analysis of reacting systems, conservation equations, premixed flames, diffusion flames, droplet combustion, solid fuel combustion, pollutant emissions and detonations.

27. **Automotive Fuels & Emission:** Conventional Fuels, Alternate Fuels like Biodiesel, Alcohol, LPG, CNG, HCNG, Hydrogen, Emission Cause & Effects, Emission from SI Engines & Controls, Emission from CI Engines & Controls, After-treatmentment Devices, Emission Measurement & Analysis.

28. **Heating, Ventilating and Air Conditioning**. Applied to automotive design

29. **Thermal Systems Design**. Comprehensive design problems requiring engineering decisions and code/standard compliance. Emphasis on energy system components: piping networks, pumps, heat exchangers. Includes fluid transients and system modeling.

30. **Classical Thermodynamics**. Macroscopic thermodynamics, first- and second-law formulation, entropy generation and energy, general relations for single-phase and multi-phase systems. Thermodynamic and heat transfer details of interfacial phenomena and phase transitions. Boiling and condensation near immersed bodies. Internal flow convective boiling and condensation.

31. **Heat Transfer**. Conduction, convection, radiation and multimode. Boiling and Condensation Heat Transfer. Thermodynamic and heat transfer details of interfacial phenomena and phase transitions. Boiling and condensation near immersed bodies. Internal flow convective boiling and condensation.

Automotive Dynamics

32. **Vehicle Dynamics**. Class topics include the tire influence, the design of suspension, and the design of the chassis. Design projects which incorporate the selection of the tire and wheel and the design of a suspension for a given application are assigned. Chassis design is currently a theoretical topic without a design project. Dynamics of the motor vehicle. Static and dynamic properties of the pneumatic tire. Mechanical models of single and double-track vehicles enabling prediction of their response to control forces/moments and external disturbances. Directional response and stability in small disturbance maneuvers. The closed-loop driving process. Behavior of the motor vehicle in large perturbation maneuvers. Ride phenomena treated as a random process.

33. **Advanced Engineering Acoustics.** Derivation of the acoustic wave equation and development of solution techniques. Transmission and reflection from solids, plates and impedance boundaries. Radiation and scattering from non-simple geometries. Green's functions; boundary element and finite element methods. Sound in ducts and enclosures. Introduction to structural-acoustic coupling. Automotive and other applications considered.

34. **Vehicle Control Systems.** Design and analysis of vehicle control systems such as cruise control, traction control, active suspensions and advanced vehicle control systems for Intelligent Vehicle-Highway Systems (IVHS). Human factor considerations such as driver interfaces. This course may be used as part of the IVHS certification program.

35. **Control of Advanced Powertrain Systems.** Will cover essential aspects of electronic engine control for spark ignition (gasoline) and compression ignition (diesel) engines followed by recent control developments for direct injection, camless actuation, active boosting technologies, hybrid-electric, and fuel cell power generation. Will review system identification, averaging, feedforward, feedback, multivariable (multiple SISO and MIMO), estimation, dynamic programming, and optimal control techniques.

Automotive Enabling Technologies & Simulations

36. **Introduction to Finite-Element Method**. Concepts and applications of the finite element method. Development and applications of basic elements used in

engineering mechanics. Use of finite-element analysis software. Application of finite-element concept to several areas of mechanics.

37. **Computer Methods in Mechanical Engineering**. Applications of digital computers to solutions of problems in mechanical engineering, matrices, roots of equations, solution of simultaneous equations, curve fitting by least squares, differential and integration, differential and partial differential equations.

38. **Introduction to Computational Fluid Dynamics**. Review of governing equations of fluid dynamics, mathematical behavior of partial differential equations, basic aspects of discretization, basic CFD techniques, basic grid generations, coordinate transformations, advanced numerical schemes, future CFD methodology.

39. **Advanced Computational Fluid Dynamics**. Finite volume scheme, Eigenvalues and Eigenvectors, Method of Characteristics, Upwind Schemes, Flux Vector Splitting, Flux Difference Splitting, Explicit and Implicit Schemes, Flux Jacobians, Newton Methods, Boundary Conditions, Weak Solutions, TVD, PISO Methods.

40. **Introduction to Turbulent Flows**. Characteristics of turbulence, length and time scales, energy cascade, vorticity stretching, Reynolds averaging technique, Closure problem, Boussinesq hypothesis, Eddy viscosity concepts, introduction to zero-, one- and two-equation models, Reynolds stress model.

41. **Computational Structural Mechanics I**. Modeling and simulation of three-dimensional solid bodies using computational methods. Fundamental principles in structural mechanics and basic concepts of numerical methods. Practice of static, vibration, and high-speed impact simulation using finite element codes.

42. **Numerical Mesh Generation**. Mesh generation strategies, error analysis, and their role in field simulation systems and engineering applications. Structured and unstructured meshing algorithms including algebraic, elliptic, parabolic, hyperbolic, advancing front and Delaunay triangulation methods, computer aided geometry techniques and surface generation schemes.

43. **Computer Aided Geometry Design**. Bezier curves, polynomial interpolation, splines, NURBS, tensor product Bezier surfaces, composite surfaces, Differential Geometry, Parametric curves and surfaces, decimation and refinement algorithms.

44. **Computer Visualization Techniques in Engineering**. Introduction to the importance of scientific visualization in engineering, algorithms in data visualization, computer graphics, and visualization software.

45. **Advanced Visualization and Virtual Reality**. Advanced scientific visualization in engineering, algorithms in data visualization, computer graphics, and visualization software.

46. **Design Optimization Techniques**. Methods of numerical optimization techniques applied to engineering design. Methods for optimization of both single and multiple variable functions, constrained, and unconstrained. Real-world problems as examples and student projects.

47. **Multi-Disciplinary Design Optimization**. Methods of numerical optimization techniques applied to engineering design. Statistical design optimization methodologies utilizing design of experiments and meta-modeling techniques. Multi-criteria formulations and multidisciplinary design optimization (MDG) frameworks. Real-world problems as examples and student projects.

48. **Fluid Structure Interactions**. Modeling and simulation of fluid-structure interaction (FSI) phenomena using computational methods. The Arbitrary Lagrangian Eulerian (ALE) formulation, a variety of interpolation methods, mesh movement and time mapping algorithms, Solution of FSI problems using the interface codes.

49. **Enabling Technology Tools for Scientists**. Computational methods and tools for simulations and modeling of mechanical and biomedical applications. Numerical geometry, numerical mesh generation, and scientific visualization tools will be introduced and applied.

50. **Parallel Computational Simulations**. Parallel algorithms for high fidelity simulations will be covered using domain decomposition strategies. Performance evaluation and metrics will be developed. MPI, OpenMP, PVM, and other parallel message passing languages will be described. Shared and distributed memory machines will be considered.

51. **Special Topics in (Area)**. 1-4 hours.

52. **Individual Study in (Area)**. 1-4 hours.

53. **Seminars in Automotive Engineering**. 1 hour.

54. **Non-Thesis Research**. 1-12 hours.

55. **Master's Degree Thesis**. Prerequisite: Admission to candidacy. 1-12 hours.