STEEL CURRICULUM DEVELOPMENT GRANT

Year-End Report.....2025-2026

A final report is due on 30 June. Your final report (in year-3) will be posted to the AIST website for others to view and may be included, in whole or in part, in the AIST *Iron & Steel Technology* magazine. Along with your report, please submit the following:

- An action photo of yourself and your students while working on a project for this grant.

Project Title: Integrating Theory, Laboratory, and Simulation to Develop a Comprehensive Steel Curriculum for Workforce Development in the U.S. Steel Industry

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Team Members (include name, class and major)
1. Dr. Nilesh Kumar, MTE 491/591: Ferrous Metallurgy
2. Students in MTE491/591

Project Summary: During the 2025-2026 performance year, the Steel Curriculum Development Grant supported the implementation and continued development of the Ferrous Metallurgy curriculum at The University of Alabama. The theory component of the curriculum was fully executed through the Spring 2026 offering of MTE 491/591: Ferrous Metallurgy, with five students enrolled. The course covered key topics in steel processing, microstructure, phase transformations, heat treatment, mechanical behavior, and different classes of steels, consistent with the grant's goal of strengthening steel-related education through an integrated theory, laboratory, and simulation framework.

Although a formal laboratory component was not included in the Spring 2026 course, students received significant hands-on and experiential exposure through field trips and facility tours. These included visits to Sloss Furnace, Vulcan Park, and U.S. Steel Tubular Fairfield, Alabama, as well as tours of on-campus facilities supporting steel-related teaching and research. Students were introduced to foundry operations, pouring facilities, bladesmithing/forging resources, steel chemical composition analyzer, Gleeble thermomechanical simulation, mechanical testing equipment, gas atomization, and microstructural characterization facilities at the Alabama Materials Institute. In addition, a graduate student participated in the in-house fabrication of a Jominy end-quench setup. Plans are also underway to invest in a Charpy impact testing unit.

The simulation component was not formally implemented in Spring 2026; however, substantial preparation was completed for integration in Spring 2027. Software resources were purchased, organized, and evaluated, and training was initiated. MAGMASOFT, Thermo-Calc, ABAQUS, and COMSOL will be incorporated in future offerings to support instruction in casting, TTT/CCT behavior, forming/rolling/plastic deformation, and corrosion behavior of steels.

Overall, Year 2 successfully executed the theory component and laid the foundation for laboratory and simulation integration in the next course offering.

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Project Goals: The overall goal of this Steel Curriculum Development Grant is to develop and implement a comprehensive Ferrous Metallurgy curriculum at The University of Alabama that strengthens student understanding of steels and prepares them for careers in the steel industry. The curriculum is built around three complementary components: theory, laboratory/hands-on learning, and simulation.

During the 2025-2026 performance year, the primary goal was to execute the theory component through the Spring 2026 offering of MTE 491/591: Ferrous Metallurgy. This goal was successfully completed. The course introduced students to key topics in ferrous metallurgy, including steel processing, phases and microstructures, heat treatment, phase transformations, mechanical behavior, and strengthening mechanisms.

A second goal was to continue developing the laboratory component of the curriculum. Although a formal lab was not offered in Spring 2026, progress was made through student field trips, tours of steel-related teaching and research facilities on campus, and development of equipment needed for future hands-on experiments, including the in-house fabrication of a Jominy end-quench setup.

A third goal was to prepare the simulation component for future integration. During this performance year, effort was directed toward purchasing, organizing, evaluating, and preparing software resources such as MAGMASOFT, Thermo-Calc, ABAQUS, and COMSOL. These tools will be incorporated into the Spring 2027 course offering to expose students to modern computational approaches used in steel processing, heat treatment, deformation, casting, and corrosion analysis.

Together, these goals support the long-term objective of creating a sustainable steel curriculum that combines classroom instruction, experiential learning, and computational tools.

Project Details: The original proposal envisioned Year 2 as the first implementation year for the Ferrous Metallurgy curriculum. During the 2025-2026 performance year, the theory portion of the curriculum was fully implemented through the Spring 2026 offering of MTE 491/591: Ferrous Metallurgy. Five students enrolled in the course. The course covered the major theoretical foundations of ferrous metallurgy, including steelmaking history and primary processing, phases and structures in steels, thermo-mechanical processing, heat treatment, hardness and hardenability, tempering, physical metallurgy of Fe-C and Fe-C-X alloy systems, mechanical behavior of steels, and strengthening mechanisms.

The course also included a major term-paper assignment designed to develop students' ability to conduct literature review, synthesize technical information, and communicate metallurgical knowledge. Each student prepared and presented a review-style term paper. Some of the topics included martensitic transformation in steels, vacuum tank degassing and steel cleanliness, calcium treatment and inclusion modification in steel, and grain-size effects on stress corrosion cracking of 316L stainless steel.

Although a formal laboratory course was not offered in Spring 2026, hands-on and experiential learning activities were incorporated through field trips and facility tours. Students visited Sloss Furnace and Vulcan Park to learn about the regional history of iron and steel production. They also visited U.S. Steel Tubular Fairfield, Alabama, where they were exposed to modern steel-related manufacturing operations. On campus, students toured facilities supporting steel-related teaching and research, including the foundry, which houses metal casting and forging facility used for bladesmithing work, Hitachi OE750 steel chemical composition analyzer, Gleeble thermomechanical simulation system, mechanical testing equipment, gas atomizer, and microstructural characterization facilities at the Alabama Materials Institute.

Progress was also made toward developing the future laboratory component. A graduate student worked with the on-campus machine shop to fabricate a Jominy end-quench setup in-house. This setup will be used in future offerings to teach hardenability and heat-treatment behavior of steels. The program also plans to invest in a Charpy impact testing unit to support future laboratory instruction on toughness and microstructure-property relationships.

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The simulation component was not formally included in the Spring 2026 offering, but important preparation was completed. Software resources were purchased, organized, evaluated, and prepared for future teaching use. MAGMASOFT training capacity has been established through the Foundry Professor of Practice. Thermo-Calc will be used to teach TTT and CCT behavior of different steel grades. ABAQUS and COMSOL will be used to simulate forming, rolling, and plastic deformation in steels, and the COMSOL corrosion module will be incorporated to introduce corrosion simulation in the Spring 2027 offering.

Two guest lecture activities were also organized. One involved speakers from UA's Career Center and library, who discussed resume building, literature survey, and responsible use of AI tools. The second was delivered by Rudolf Moravec, an engineer from U.S. Steel Tubular Fairfield, Alabama, who provided students with direct industry perspective on steelmaking using Electric Arc Furnace.

Dissemination of Results: During the 2025-2026 performance year, the primary dissemination of project results occurred through the Spring 2026 offering of MTE 491/591: Ferrous Metallurgy. The course served as the main mechanism for delivering the developed steel curriculum to students and for assessing the effectiveness of the theory component. Five students enrolled in the course and received instruction on steel processing, microstructure, phase transformations, heat treatment, and mechanical behavior.

Results were also disseminated through student term-paper presentations. Each student prepared and presented a review-style technical paper on a topic related to ferrous metallurgy or materials degradation. These presentations created a forum for peer-to-peer learning and allowed students to communicate technical findings on topics such as martensitic transformation, steel cleanliness, inclusion modification, vacuum tank degassing, and stress corrosion cracking.

Additional dissemination occurred through guest lectures and field-based learning. Guest speakers from UA's Career Center, UA Libraries, and U.S. Steel Tubular Fairfield provided students with professional development, literature review guidance, responsible AI-use guidance, and industry perspectives. Field trips to Sloss Furnace, Vulcan Park, and U.S. Steel Tubular Fairfield helped connect classroom instruction with historical and modern steel-related practice.

The knowledge gained during this course offering will be used to further refine the Ferrous Metallurgy curriculum for Spring 2027, including integration of laboratory and simulation modules. Results from the continued development of the curriculum will be shared in future annual reporting to AIST, and the final curriculum outcomes will be made available as part of the final grant report.

References: Not applicable.

Project Schedule: During the 2025-2026 performance year, the major Year 2 milestone was completed: MTE 491/591: Ferrous Metallurgy was offered in Spring 2026, and the theory component of the curriculum was fully executed. The course included lectures, homework assignments, exams, student term papers, and oral presentations.

Several experiential and industry-engagement activities were also completed during the Spring 2026 semester. These included two guest lecture activities, field trips to Sloss Furnace, Vulcan Park, and U.S. Steel Tubular Fairfield, Alabama, and on-campus tours of steel-related teaching and research facilities. These activities provided students with exposure to steel history, modern steel manufacturing, and available infrastructure for steel-related education and research at UA.

Progress was also made toward future laboratory and simulation integration. During 2025-2026, the development of a Jominy end-quench setup was initiated with support from a graduate student and the on-campus machine shop. The setup is expected to be ready by August 15, 2026. Planning also continued for acquiring a Charpy impact testing unit for future laboratory instruction. In parallel, software

resources for simulation-based instruction are either in the process of being purchased or were purchased, organized, evaluated, or prepared for use.

During the 2026-2027 performance year, the curriculum will be further refined based on Year 2 experience. The next offering of Ferrous Metallurgy, planned for Spring 2027, will incorporate laboratory and simulation elements more explicitly. Planned additions include Jominy end-quench testing, expanded toughness-related instruction through Charpy impact testing capability, MAGMASOFT-based casting simulation, Thermo-Calc modules for TTT and CCT behavior of steels, ABAQUS and COMSOL simulations for forming/rolling/plastic deformation, and COMSOL corrosion simulations for ferrous alloys.

Project Cost: As of the preparation of this report, $3,057.62 of the grant funds have been spent. These expenses supported activities related to the development and implementation of the Ferrous Metallurgy curriculum, including course-related resources, preparation for hands-on instruction, field trip related expenses, and software/tool support for future curriculum integration.

This amount does not include the expenses associated with the machining and assembly of the Jominy end-quench setup. A graduate student has been involved in the in-house fabrication of this setup with support from the on-campus machine shop. The machining and assembly costs will be charged to the project once the setup is completed, which is expected by August 15, 2026.

In addition, the purchase of COMSOL modules for corrosion and electrochemical simulations is currently being discussed with the vendor. The order is expected to be placed within the next week. This purchase will support the integration of corrosion simulation into the Spring 2027 offering of Ferrous Metallurgy.

The remaining funds will be used to strengthen the laboratory component of the curriculum. Once AIST provides the remaining $5,000 for the next phase of the grant, those funds will be combined with the existing balance and used toward the purchase of a Charpy impact testing unit. This equipment will support future hands-on instruction related to toughness, heat treatment, and processing-microstructure-property relationships in steels. Additional financial support for this purchase is expected from the Department and/or College of Engineering.

Student Participation: Five students enrolled in MTE 491/591: Ferrous Metallurgy during the Spring 2026 semester. Student participation centered on classroom instruction, technical assignments, literature review, oral communication, field trips, and exposure to steel-related teaching and research facilities.

As part of the course, students completed homework assignments, exams, and a major term-paper project. Each student prepared a review-style technical paper and delivered an oral presentation. The term-paper topics included martensitic transformation in steels, calcium treatment and inclusion modification in steel, vacuum tank degassing and steel cleanliness, grain-size effects on stress corrosion cracking of 316L stainless steel, and stress corrosion cracking. These assignments helped students develop skills in literature review, technical synthesis, technical writing, and oral presentation.

Students also participated in two guest lecture activities. The first included presentations from UA's Career Center and library on resume building, literature survey, and responsible use of AI tools. The second guest lecture was delivered by Rudolf Moravec, an engineer from U.S. Steel Tubular Fairfield, Alabama, who provided an industry perspective on steel-related operations and career pathways.

Experiential learning was incorporated through field trips and facility tours. Students visited Sloss Furnace and Vulcan Park to learn about the regional history of ironmaking and steel-related industry. They also visited U.S. Steel Tubular Fairfield, Alabama, where they were exposed to modern steel-related manufacturing. On campus, students toured the foundry and facilities supporting metalcasting, bladesmithing/forging, steel chemical composition analysis, Gleeble thermomechanical processing, mechanical testing, gas atomization, and microstructural characterization.

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Overall, student participation during Year 2 provided a strong combination of theoretical learning, technical communication, industry exposure, and experiential engagement with steel-related facilities. Some photographs taken during different activities as part of the Ferrous Metallurgy course are included below.

Steel Plant Interaction: During the 2025-2026 performance year, students enrolled in MTE 491/591: Ferrous Metallurgy participated in a steel plant visit to U.S. Steel Fairfield Works and Fairfield Tubular Operations in Fairfield, Alabama. The visit provided students with direct exposure to both steelmaking and downstream tubular product manufacturing.

The tour began at Fairfield Works, located near Birmingham, Alabama. Students observed steelmaking operations associated with the facility's electric arc furnace, which has an annual capacity of approximately 1.6 million tons. The EAF supplies steel rounds to the nearby Fairfield Tubular Operations and can support both slab and rounds casting. This part of the visit helped students connect classroom discussions on steelmaking, casting, and primary processing with an operating industrial facility.

The tour then continued to Fairfield Tubular Operations, where students followed the process chain for producing seamless tubular products. This facility uses steel rounds from Fairfield Works to manufacture custom seamless steel casing and seamless standard and line pipe. Students learned that the facility produces seamless casing with outside diameters ranging from 4-1/2 in. to 9-7/8 in. and seamless standard and line pipe with outside diameters ranging from 4-1/2 in. to 8-5/8 in. The facility has an annual capacity of approximately 750,000 tons of seamless tubular products, primarily serving the energy, oil, and gas markets.

Overall, the visit allowed students to observe the connection between electric arc furnace steelmaking, casting of steel rounds, and seamless tubular product manufacturing. It provided an excellent opportunity for students to understand how steel composition, processing, thermal history, deformation, and quality control are integrated in modern steel production.

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Project Duration: This report covers the second year of the three-year Steel Curriculum Development Grant, corresponding to the 2025-2026 performance year.

How many students from this university have accepted employment in the steel industry upon graduation?

The Department of Metallurgical and Materials Engineering and other departments under the College of Engineering at The University of Alabama regularly have students accepting internships, co-ops, and full-time employment with steel and steel-related companies. However, an exact head count of students who accepted employment in the steel industry upon graduation during this reporting period is not currently available. As part of the Ferrous Metallurgy course and related steel curriculum development activities, continued effort is being made to increase student awareness of career opportunities in the steel industry through classroom instruction, guest lectures, plant tours, field trips, and exposure to steel-related research and teaching facilities. The PI also organizes Steel Day events every year at UA campus. These activities are expected to further strengthen the pipeline of students pursuing internships, co-ops, and full-time employment in the steel industry.

Future of Grant:

- ❑ I have just completed year two of the three-year grant.
- ❑ I hereby confirm that the plan contained in my original proposal will continue during the next academic year and request funding (US$5,000/Year 3) to continue the Steel Curriculum Development plan as submitted in my original proposal.

Nilesh Kumar, July 09, 2026

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Signature of Professor and Date

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