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Abstract— Recently, a collaborative partnership agreement between Eastern Michigan University and Engineering Technology Associates Inc., a firm specializing in structural analysis for the auto industry has been created. The partnership is envisioned to meet several goals and objectives for each partner. The main goal of this partnership is to establish a modern undergraduate and graduate computer aided and simulation facility equipped with industrial simulation software suite for teaching and research activities of faculty and students at the university. Other goals are the use of the facility as a designated training center for the local employees of other industries, utilizing the facility for attracting new students to engineering technology programs at the university, and infusing the usage of the software suite in the existing curricula of the engineering technology programs at the university so that students are well prepared for employment upon their graduation. This paper describes the current outcomes of this collaboration in utilizing the provided industrial software suite in the existing engineering technology curricula. The outcomes presented include a list of undergraduate courses in computer engineering technology, electrical engineering technology, mechanical engineering technology, and product design and development programs as well as graduate courses in computer aided engineering and renewable energy engineering programs that can benefit by using the software. Also, details of successfully developed educational modules for courses in unmanned aerial vehicle and in industrial robot engineering utilizing the software suite are presented.

Keywords— *undergraduate research experience; simulation, industrial robots; university-industry collaboration; innovation*

I. INTRODUCTION

The need for new technological approaches and accessible laboratories to provide required skills and hands-on experience for students particularly in online distance learning environment in the field of science, technology, and engineering is one of the main challenges of the higher education institutions [1]. From educational standpoint, the modeling and design of a complex product or system is an ideal activity for learning by doing.

Applying principles of sciences, mathematics, engineering and technology while the faculty assists them to develop their own ideas. The completion of such activity involves simulation of significant hardware parts that should be integrated with software to create a virtual system.

The simulation of an engineering product or system such as an unmanned vehicle or a robot can be a very beneficial project for capstone design courses or undergraduate research projects as students need to become familiar with operation and specification of different hardware such as electronic circuits, controls modules, vision systems, various instrumentations, mechanical components, motors and variety of sensors. Also, they need to get exposed to sophisticated software systems such as path planning, motion planning and obstacle avoidance systems. Implementation and simulation of such a system require creativity and innovation and the challenging nature of the activity generates excitement and motivation for students and help them gain experience working in interdisciplinary teams and learn the importance of technical communication and sharing ideas [2]-[3].

In today's engineering market, having an opportunity to work with industrial tools and software to develop a product is one of the most important experience that higher education institutions can provide to their students [4]-[5]. To create such an opportunity, various collaborative relationships between university and industry have been pursued that benefit each partner. These collaborative agreements and projects address different activities ranging from small classroom assignments to cutting-edge collaborative projects requiring technological research and development [6]-[11].

In this paper, accomplishments of a collaborative relationship between Eastern Michigan University and Engineering Technology Associates Inc. are presented. The outcomes include a list of graduate and undergraduate courses that the simulation software could be utilized to enhance students learning. Also, details of successfully developed educational modules for courses in unmanned aerial vehicle and in industrial robot engineering utilizing the software suite are presented.

II. UNIVERSITY-INDUSTRY COLLABORATION

Recently, Engineering Technology Associates Inc. (ETA), a tier-one supplier to the global automotive industry that provides engineering and development services from concept to product with expertise in metal forming, crashworthiness, occupant safety and product design, agreed to provide its cutting-edge mechanical engineering software package, the Inventium Suite [12], along with training to College of Technology at Eastern Michigan University (EMU) as part of a collaboration aimed at preparing students for real-world challenges and jobs.

Through this collaboration, each partner adds unique elements. The university provides the teaching and research facility and the instruction and development. ETA provides a suite of modern software, interface with local industries for projects, lab consulting, and design services. Students and faculty at the College of Technology have opportunities to participate in industrial projects that require innovation and creativity in dealing with real-world challenges. This experience provides more employment options for students with local industries in demanding areas.

The Inventium software suite, which is an enterprise-level CAE software provides a design tool suitable for concept to product development. It offers a high performance modeling and post-processing system and includes DYNAFORM, NISA, PreSys and VPG software.

DYNAFORM provides students with experience of creating and analyzing metal forming simulations, NISA is a robust & comprehensive finite element analysis software for engineering analysis, PreSys allows students to create advanced models that visualize where structures bend or twist, and VPG offers students hands-on experience creating simulations such as crash/safety or structural analysis.

III. APPLICATIONS OF SIMULATION IN UNDERGRADUATE AND GRADUATE CURRICULA

The first activity of this collaboration started with identifying the courses in existing undergraduate and graduate engineering technology programs that could benefit from the simulation software suite and then developing a set of laboratory exercises, homework assignments, and projects that could be infused into these courses to complement contents of the courses and enhance students learning of the subjects. The identified undergraduate and graduate courses for applications of the Inventium package are presented in Tables 1 and 2, respectively. The description of these courses can be obtained from the university course catalog [13].

The outcomes of this activity were presented in an application report [14] for use by faculty members who are teaching these courses. In addition, new courses that were not existed in the curricula and could benefit the school of engineering technology programs were proposed along with their descriptions and contents.

TABLE 1. Application of ETA Software in Undergraduate Courses

CURRICULA	COURSE CODE	COURSE NAME	ETA Software			
			PreSys	NISA	VPG	DYNAFORM
UNDERGRADUATE	CET 151	Introduction to Computing in Engineering Technology	A	A	A	A
	CET 273	Unmanned Vehicle Systems	A	A	A	-
	CET 375	Robotics Engineering	A	A	A	-
	MET 312	Applied Dynamics Principles	A	A	-	-
	MET 313	Applied Mechanics of Materials	A	A	-	-
	MET 314	Applied Thermodynamics and Heat Transfer	A	A	A	-
	MET 316	Design for Manufacturing and Tooling	A	A	-	A
	MET 319	Fluid Mechanics	A	A	-	-
	MET 411	Mechanical/Machine Design	A	A	A	A
	MET 437	Kinematics of Machines	-	A	-	-
	MET 470	Mechanical Vibrations	A	A	-	-
	MET 492	Senior Design Projects I	A	A	A	A
	MET 493	Senior Design Projects II	A	A	A	A
	PDD 435	Finite Element Analysis	A	A	A	-

TABLE 2. Application of ETA Software in Graduate Courses

CURRICULA	COURSE CODE	COURSE NAME	ETA Software			
			PreSys	NISA	VPG	DYNAFORM
GRADUATE	CAE 527	Engineering Software Development	A	A	A	A
	CAE 535	Computer-Aided Engineering	A	A	A	A
	CAE 537	Advanced Mechanics of Materials	A	A	-	-
	CAE 545	Engineering Simulation	A	A	A	A
	CAE 585	Advanced Finite Element Analysis	A	A	A	-
	CAE 565	Mechanical System Design	A	A	A	A
	CAE 575	Advanced Engineering Dynamics	A	A	-	-
	CAE 690	Development Project/Thesis	A	A	A	A
	CAE 691	Development Project/Thesis	A	A	A	A
	CAE 692	Development Project/Thesis	A	A	A	A
	CAE 586	Computational Flow Simulation	A	A	-	-
	REE 553	Thermal Systems Design	A	A	-	-
	REE 555	Wind Turbine Design, Construction and Testing	A	A	A	-
	REE 563	Advanced Wind Turbine Design and Analysis	A	A	A	-

IV. EXAMPLE OF DEVELOPED SIMULATION MODULES

The second developmental activity of this collaboration was to design and implement a set of complementary educational modules utilizing ETA software and when possible integrate it with other industrial software to provide students with greater and more comprehensive experience in integration and application of simulation software. Currently, two modules that provide students with a step-by-step process for simulation of real engineering products are developed. These modules are used by students to complement their engineering design and development experience in different engineering technology programs.

The first module is developed to provide undergraduate students with experience of simulating a complex engineering system namely a quadcopter. This module is used in a sophomore-level course entitled Unmanned Vehicle Systems. The second module provides students with the process of simulating and testing an industrial robotic arm, which is another complex engineering system. This module is used in a junior-level course entitled Robotics Engineering.

A. Unmanned Aerial Systems Module

The unmanned vehicle systems is a 3-credit course, which covers topics related to vehicles without a human pilot, navigator, or driver onboard. These systems are either controlled autonomously by on-board computers or by a driver/navigator/pilot on the ground using remote control. This course provides hands-on opportunity for the students to assemble/design their own UVS systems. Students work in teams to practically learn how to collaborate and work with each other to create and build their own UVS with both autonomous and remote control navigation, telemetry, imaging, weather logging, and autopilot mission.

This module is designed for simulation of unmanned aerial vehicle (UAV) or commonly known as drone. The module provides application of ETA package for:

1. Projects on Structural design and analysis of an unmanned aerial vehicle such as Rudder, Elevator, Wings, Cockpit, Fuselage, Aircraft Interiors, etc., which consist of exercises for:
 - Model creation for Geometry.
 - Finite element modelling of the structure.
 - Creation of loads and boundary conditions for structure.
 - Creating the material properties.
 - Performing Normal mode and static stress analysis.
 - Checking for G loads and Aerodynamic loads.
 - Generating Results and optimization of structure.
 - Report Generation.
2. Projects on aerodynamic simulation of structures through fluid-structure interaction analysis (CFD), which consist of exercises for:
 - Creating the model for Geometry.

- Finite element modelling based on CFD criteria.
- Fluid flow loads and boundary conditions for structure.
- Creation of material properties.
- Supersonic flow Analysis of UAV flying body with cavity at Fuselage section.
- Report Generation.

The unmanned aerial system are classified as rotorcraft or fixed-wing aircraft. The structure consist of landing stands, propellers, beams, central mounting unit, camera, batteries and motors. In this module, model/eigenvalue analysis of an actual quadcopter using Presys and NISA software is presented. The quadcopter was developed by a team of four undergraduate students as their design project for unmanned vehicle systems course in summer of 2015 as shown in Fig. 1.



Fig. 1: A Quadcopter Designed by Students

The model geometry is created in the Catia V5 software [15] and is saved in .IGES and .STP file extensions for importing into Presys as presented in Fig. 2.

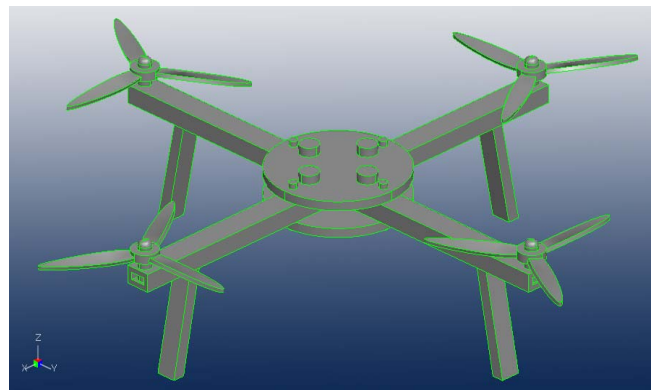


Fig. 2: Quadcopter Geometry created in the Catia V5 software

Linear static analysis is performed to study the behavior of structures under external applied loads such as Thermal loads and forces. The model is meshed by using triangular mesh

shell elements on the outer surface. Then, the shell mesh is converted into Tetrahedron 3D mesh as shown in Fig. 3.

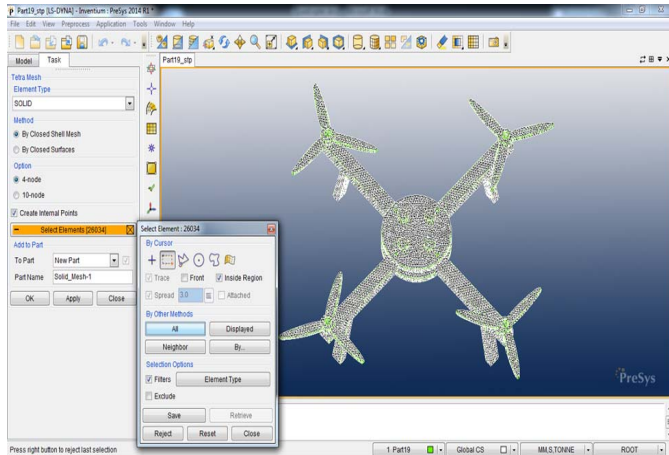


Fig. 3: Finite element modeling using shell elements on outer surfaces

For this analysis, ABS plastic material was chosen from the material library and all six degrees of freedom were arrested by assigning SPC at the base of stands for fixed condition to the ground. Then, loads were assigned by using Preprocessor tab-BCS-Create-BCS-Force and the required force values for X, Y and Z directions were entered. Preprocessor tab-BCS-Create-BCS-Node Temperature was used for applying temperature loads.

The static analysis is performed to determine static stresses and displacements. The model is saved and exported to .nis file format to be used in NISA software. The NISA software generates 26 .dat file, which is imported to Presys for post processing. Then, the thermal stresses, principal and Von Mises stresses and also displacements are obtained in order to optimize the structure as shown in Fig. 4.

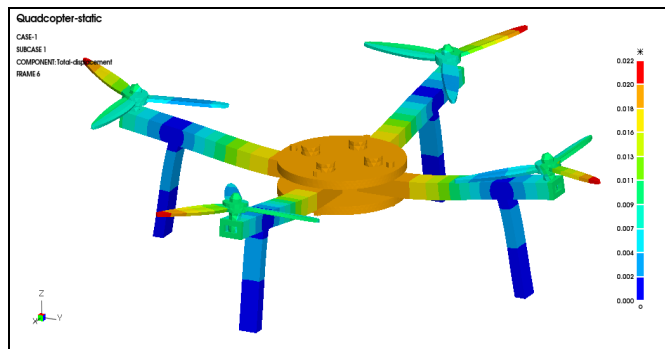


Fig. 4: Typical result with corresponding displacement

B. Robotic Engineering Module

The robotics engineering is a 3-credit course, which addresses topics related to fundamental of electronics and mechanics of robots; robot motion and speed control systems; robot dynamics and kinematics; robot programming; construction, mechanics, and electrical control of robots; sensing and vision systems for robots, obstacle avoidance systems for robots; robot communications and interfacing; different structures of mobile robots including four wheel and

differential drives. This course provides hands-on opportunity for students to assemble/design their own robot. Students work in teams to practically learn how to collaborate and work with each other to create and build an autonomous robot.

This module is designed for simulation of industrial robots. The module provides application of ETA package for:

- Structural design and analysis of robots such as weight bearing member, joints, axles bending, loaded robotic arm analysis.
- Thermal analysis for thermal expansion, compression of structures and joints in high and low temperature operating zones.
- Kinematic analysis and motion simulation of robot links.

In this module, a six degree-of-freedom industrial robot as shown in Fig. 5 is analyzed for static analysis in order to simulate the behavior of the structure against the external applied loads and temperature using Presys and NISA software.

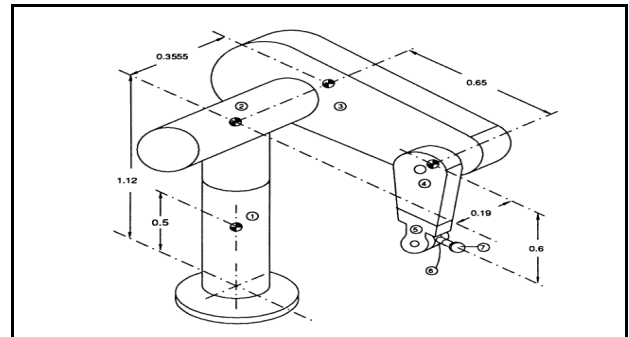


Fig. 5: A six degree-of-freedom industrial Robotic Arm

Catia V5 software is used to create the geometry and is saved in .IGES and .STP file extensions for importing into Presys. The finite element analysis of the CAD model is performed in Presys environment by using triangular mesh shell elements on the outer surface as shown in Fig. 6. Then, the shell mesh is converted into Tetrahedron 3D mesh.

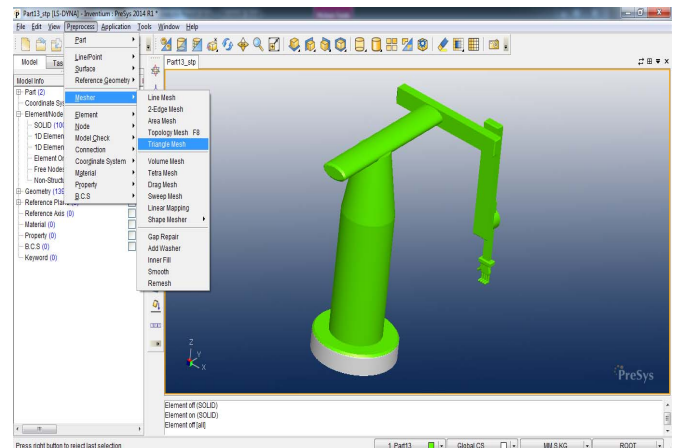


Fig. 6: Finite Element Modeling

For this analysis, aluminum material was chosen from the material library and all six degrees of freedom were arrested by assigning SPC at the base of stands for fixed condition to the ground. The force load was applied to the robotics joint that picks up the object and the thermal loads were applied to the structure.

Linear static analysis is performed to study the behavior of structures under external applied thermal loads and forces. The Static analysis provides static stresses and displacements, which are saved and exported into .nis file format to be processed in NISA software. Once this is processed, NISA generates 26 .dat file, which is used for post processing by Presys software as shown in Fig. 7.

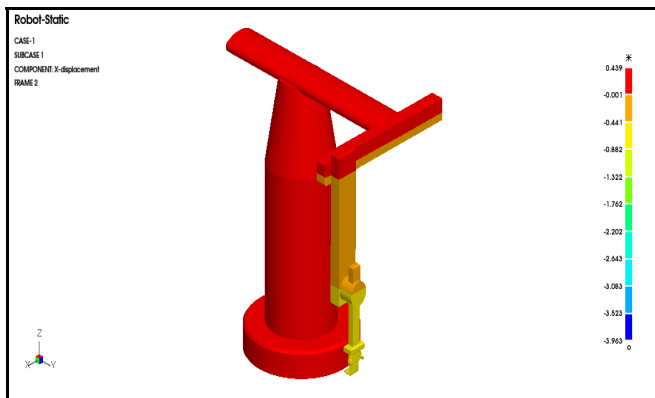


Fig. 7: Typical result with corresponding displacement

V. CONCLUSION

One of the main benefits of this partnership was establishment of a modern undergraduate and graduate software facility for teaching and research purposes at university and the opportunity to use the facility as a designated training facility for the local employees of other industries. Another benefit of this collaboration was empowerment of university to attract new students into engineering and technology programs by providing a software facility that gives students access to the state-of-the-art technology that would enhance their preparation for employment. Also, the university benefits from this collaboration by providing an opportunity for local industries to come to university to receive training. Similar experience is provided to students by enabling them to utilize the advanced software tools in completing their assignments and in implementing their projects.

The collaboration resulted in infusion of the industrial simulation software in a number of undergraduate and graduate courses and in development of a set of educational modules with laboratory exercises, projects, and homework problems that are used to involve students in various engineering technology programs with software integration and simulation experience using state-of-the-art industrial software at their sophomore, junior, and senior years at the university. The

experience that students gain through these simulation activities enhances their understanding of complex engineering systems that are subjects of their various courses.

Although, the main goal of this collaboration was to develop a number of educational modules utilizing industrial simulation software for undergraduate engineering and technology courses, the success of this collaboration resulted in other activities be initiated between university and ETA. These activities include internship and cooperative educational opportunities for the students at ETA and a number of ideas for joint research projects with ETA.

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