

Development of Mechanical Engineers Skills for an Emerging Electric Vehicles Industry

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Abstract— The last ten years have seen a steady stream of inventive and beneficial advances in the field of electric vehicles (EVs), which may help society in a variety of ways, from improved quality of life to economic and environmental benefits. The field of engineering is expanding in the world of electric vehicles. Engineers that can collaborate across many disciplines are far more in demand by businesses. The study of job duties and technical competencies based on market demands for mechanical engineering is presented in the current article. This study is based on job descriptions and job postings from EVs firms. Following the investigation, job roles, technical abilities, and engineering tools needed to build a career for mechanical engineering graduates in the field of EVs and Electric Mobility are categorized. A list of topics that are crucial for knowledge and comprehension in the field of electric vehicles is revealed by the analysis. Additionally, integrating new engineering software tools for systems design and analysis into the designed curriculum is imperative for mechanical engineering graduates. The present analysis is helpful for creating new programs, adding courses, or upgrading existing ones in the area of electric vehicles.

Keywords— *Engineering Education, Electric Vehicles, Technical Skills, Job Market, Mechanical Engineering*

I. INTRODUCTION

The last ten years have seen a steady stream of inventive and beneficial advances in the field of electric vehicles (EVs), which may help society in a variety of ways, from improved quality of life to economic and environmental benefits. The market for plug-in electric vehicles for passengers is growing significantly. In 2021, a total of 6.75 million electric vehicles were sold. In 2021, more EVs were sold in a single week than were sold in the entire year of 2012. In the first half of 2022, a total of 4.3 million new EVs were delivered, an increase of +62% over the first half of 2021 [1]. In the following years, it is expected that this tendency will continue. The governments of KSA and the UAE are making significant investments in the Gulf area to achieve a 30% EV penetration rate by 2030 [2]. By putting money into EVs and renewable energy sources, KSA and the UAE have demonstrated a progressive approach to the adoption of EVs.

The ecosystem of smart electric transportation includes more than just electric vehicles. New electric mobility technologies will undoubtedly alter the demands of the labor market in cities. A wider and more adaptable set of skills are necessary for highly qualified professionals [3]. In order to keep up with trends in the business and in the field of research, academic programs must incorporate new technologies. The authors of [4] focused on challenges related to electric mobility to identify acceptable educational approaches that would be helpful when teaching about electric mobility at various educational levels. The improvement of graduate curricula in advanced automobile industry has been covered in earlier works. The experiences from global initiatives created through partnership with students from various colleges around the world have been recounted in [5].

A Center for Advanced Automotive Technology (CAAT) was formed as an Advanced Technological Education center with financing from the National Science Foundation [6] to support the collaborative work, developing and driving systematic curricula improvements. The center identified curriculum deficiencies with the help of business partners and gave teachers professional development to remedy such gaps. The authors of [7] described a two-year graduate curriculum in smart electromobility. Programs from across the world have been analyzed to determine potential growth areas for electric vehicles and smart mobility. Computer science, mechanical and electrical engineering, law, marketing, and public policy are among the subjects covered in multi- and transdisciplinary courses.

Universities and open-education programs must provide resources to support personal and professional development in order to enable the next generation to meet the skills requirements and challenges of the EV employment market and E-Mobility. Company involvement is crucial in the creation of engineering education programs, even though university curricula shouldn't be wholly determined by how employers view their educational needs. The current article presents an overview of technical skills and job roles based on market demands. This study is based on job descriptions and job postings from EVs firms. The analysis produced a classification of the job duties, technical abilities, and engineering tools necessary for a mechanical engineering

graduate to pursue a career in the field of EVs and EM. This analysis might be helpful for designing new courses, adding existing ones, or revising existing programs domain of electric vehicles.

II. TECHNICAL AND INTERDISCIPLINARY SKILL REQUIREMENTS

Driven by sustainability and shifting customer behavior, the automobile and transportation industries are moving quickly toward a new world. Electric vehicles, autonomous driving operating systems, connected cars, fleet management, mobility fleet sharing, connectivity cloud, onboard sensors, energy/charging stations, smart grid, parking management, and new business models are anticipated to make up the future environment of electric mobility. The technical expertise needed by engineers working in the field of electric vehicles will be the main topic of this article. The major components of different types of electric vehicles including HEV (Hybrid Electric Vehicles), PHEV (Plug in Hybrid Electric Vehicles), and BEV (Battery Electric Vehicles) are shown in Fig. 1. It should be highlighted that multidisciplinary teams are

involved in EVs industry and require engineers with a variety of backgrounds. For instance, to conduct in-depth talks with their counterparts in cross-functional teams, mechanical engineers must have a strong understanding of electrical/electronic systems. Engineers with experience in data networks, electrical engineering, software engineering, signal processing, robotics, artificial intelligence, and cybersecurity technologies are also in great demand. The traditional STEM (science, technology, engineering, and mathematics) talents will continue to be a crucial component of the skill set in this demanding environment.

Also still required will be the "traditional" automotive engineer with in-depth knowledge of mechanical, mechatronic, and materials science. A "universal" engineer with a broader understanding of other technical disciplines will, however, become more and more important in the context of electrified, linked, autonomous, and shared transportation. Companies foresee a broad transition in the required profile from a pure mechanical engineer to one that combines mechanical, electronics, or software engineering [3].

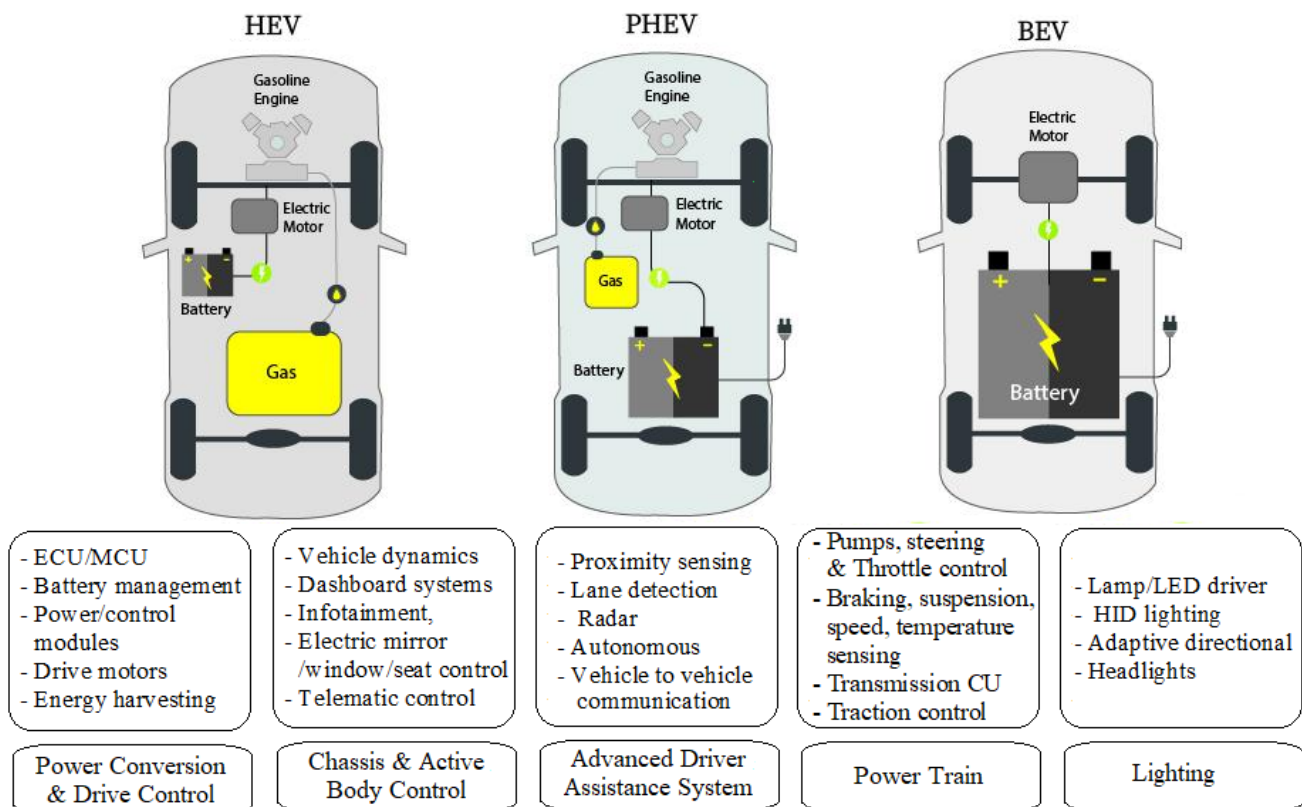


Fig. 1. Major components of electric vehicles, HEV (Hybrid Electric Vehicle), PHEV (Plug in Hybrid Electric Vehicle), BEV (Battery Electric Vehicle).

III. MARKET ANALYSIS OF JOB FUNCTIONS AND REQUIRED SKILLS

The authors made use of LinkedIn, one of the biggest professional networks on the internet, to publicize posts from reputable businesses in the electric vehicle industry. "Engineers, Electric Vehicles, and Electric Mobility" are the search terms. The research produced a wide range of job names, responsibilities, competencies, and prerequisites. The data are filtered and categorized, and it is discovered that

they are highly helpful in emphasizing the key tools and skill needs for engineers to work in this emerging field. Jobs with mechanical engineering background requirements are only considered in the present study. Tables I to VI contain the list of positions that require a mechanical background. The job functions are described, and the knowledge and skill requirements are also given. Other soft skills necessary for the jobs are not included. Because they apply to all job functions, soft skills are not included in this list.

The analysis shows a set of subjects that are essential for knowledge and understanding in the domain of electric

vehicles. Also, engineering software tools have become very essential for an engineering graduate. The software tools required in EVs industry are categorized in the following sections with a brief description of each to highlight the subject area and essential topics supported by this software.

A. Mechanical Computer-Aided Design (MCAD) programs, or CAD software

SolidWorks, Siemens NX, PTC Creo, and CATIA 3D solid modeling are examples of 3D solid modeling software. These resources are essential for any business today that designs and manufactures physical items. Regardless of the complexity of the model, they are used to build exact geometry, carry out simple static structural analysis on components and assemblies, and evaluate the kinematic motion of designs using integrated design animation. Additionally, additive manufacturing design tools are included.

Additionally, programs like ANSYS that use finite-element modeling are crucial for the numerical resolution of a wide range of engineering applications such as static and dynamic structural analysis, heat transfer, fluid flow, acoustics and electromagnetics.

B. Product quality, planning, and management software

Software for advanced product quality planning (APQP) is crucial for the automobile sector. In order to ensure that the product being produced complies with specific quality management standards. The main phases of the APQP process include plan and define, product and process design, and validation, feedback evaluation, and corrective action.

A comprehensive PLM software system called Product Lifecycle Management (PLM) is used to handle an organization's data, content, documentation, and processes. It offers all the resources required for the distribution, transmission, visualization, and publication of the product data. A good example is the Windchill software, which can handle models made with PTC Creo and other important CAD programs.

Design For Six Sigma (DFSS) tools are used to design and build new products or services with at least a 4-Sigma performance. The DFSS strategy uses experiments and data analysis in a systematic manner to design, implement, and improve products and services. By developing products and services that are more useful, practical, safe, and durable, the aim is to decrease waste across all processes and boost customer satisfaction.

Control of requirements is essential to reduce costs, increase efficiency, and improve the quality of products. Engineering Requirements Management tools are used to collect, trace, analyze, and manage changes to product information. An example is Systems Applications and Products (SAP) that is a business application integration software solution for enterprise resource planning (ERP). IBM® Dynamic Object-Oriented Requirements System (DOORS) is another example.

Other software are used for managing the stages and of product development, including requirements capture, problem tracking, workflow automation, and test planning and execution such as TestTrack Quality Management Software (QMS).

C. Product testing software

Another class of software tools provide integrated solution for test-based engineering that combines high-speed multi-physics data collecting with an extensive set of integrated testing, analytics, and modeling tools for a variety of test purposes. An example is Simcenter Testlab.

TABLE I. BATTERY PACKS ENGINEER JOB FUNCTIONS AND REQUIREMENTS

<i>Job Description: Battery Packs Engineer</i>	
Job Functions:	
-	Mechanical design and packaging of battery back components, power electronic enclosures and thermal management systems.
-	Mechanical integration of battery pack components into vehicle platforms.
-	Mechanical structural design, cell mounting, spacing, connecting, cooling, integration of electrical fuses, contactors, wiring, and cooling system.
-	Bill of Materials Management (BOM) and production support.
-	Development of design reports and documentation.
-	Using parametric CAD models for production of design drawings.
-	Implementation of relevant ANSI and ISO standards.
-	Geometric Dimensioning and Tolerancing (GD&T) for multi-part functional assemblies .
-	Tolerance stack up analysis of an assembly requirement.
-	Design for Manufacturing and Assembly (DFMA or DFM/A) in product design.
-	Collaboration with lead engineers and members of multidisciplinary teams (vehicle, modeling, and simulation).
Job Requirements	
Knowledge:	
	Engineering materials - different materials and grades - mechanical simulation techniques and processes - manufacturing processes - automotive standards - design for manufacturability - basic power electronic – electric vehicles systems & architecture – electrical, thermal, and mechanical characteristics of battery cells/modules/packs and testing.
Skills:	
	Background in: modeling, simulation and analysis of durability, thermal, electrical systems - prototype development and component validation – plastic injection mold design - seals, machining, Aluminium die casting - metal stamping.
	Familiarity with: Advanced product quality planning (APQP) procedures and techniques to develop products – Development of CAD models on commercial platforms such as CREO, NX and CATIA - routing wire harnesses, sheet metal parts, plastic parts, and machined items using CAD.

TABLE II. VEHICLE PLATFORM ENGINEER JOB FUNCTIONS AND REQUIREMENTS

<i>Job Description: Vehicle Platform Engineer</i>	
Job Functions:	
-	Lead the development of Vehicle Platform systems through the entire product development process from Project Definition to Product Launch.
-	Develop mechanical system concepts to meet vehicle platform requirements and utilize analytical tools to verify a robust design.
-	Utilize DFMEA and DVP tools to mitigate system design risk throughout the concept, design, and validation phases of the program.
-	Create and maintain up-to-date project schedules and develop mitigation plans as needed to meet program milestones.
-	Coordinate regularly during the development process with other engineering teams.
Job Requirements	
Knowledge:	
	Vehicles components and systems
Skills:	
	CREO / CREO View / Windchill (or similar) - Phase Gate development process - Use of Design for Six Sigma (DFSS) tools.

TABLE III. MECHANICAL DESIGN ENGINEER JOB FUNCTIONS AND REQUIREMENTS

<i>Job Description: Mechanical Design Engineer</i>
Job Functions: <ul style="list-style-type: none"> - Responsible for all mechanical engineering activities from design/construction in the concept phase, the development phase until successful launch of projects for E-Mobility products. - Manage all the engineering changes and problem solving during the development phase in close coordination with other departments and customers. - Perform reviews/clarifications of all technical specifications. - Document technical requirements with mechanical design team to ensure all requirements are clear and covered by the design, including any functional safety requirements applicable or interfacing with the mechanical design in the requirement management system. - Capable to perform a detailed mechanical part and integration of assembly design concept for high power electronics and PCBA. - Discuss mechanical drawings on a mechanical engineering base. - Participate in test phases and steps of the FMEA. - Support manufacturing and assembly plants concerning design changes (CAD, Bill of Materials BOM, and Documentation).
Job Requirements Knowledge: Automotive mechanical systems Skills: Using CATIA software - design, analysis, and integration of mechanical design modules - requirement analysis, specification, testing, and validation of mechanical design - E-Mobility standards - Design tools (NX, DOORS, SAP, TestTrack, ANSYS) - mechanical design involving products like BMS, OBC, DC-DC Converters for E-Mobility automotive systems - calculate or simulate worst-case-tolerance analysis.

TABLE IV. VEHICLE QUALITY ASSURANCE ENGINEER JOB FUNCTIONS AND REQUIREMENTS

<i>Job Description: Vehicle Quality Assurance Engineer</i>
Job Functions: <ul style="list-style-type: none"> - Investigate Root Cause and create Counter measure concern in Process and Customer feedback. - Planning and cooperate with relate function to assurance vehicle. - Improve Team to achieve the Target of Quality.
Job Requirements Skills: Analytic Skill (Root Cause analysis / PDCA - Plan-Do-Check-Act Cycle / Logical thinking / etc.)

TABLE V. VEHICLE DYNAMICS ENGINEER JOB FUNCTIONS AND REQUIREMENTS

<i>Job Description: Vehicle Dynamics Engineer</i>
Job Functions: <ul style="list-style-type: none"> - Testing, data collection, and analysis - Coordinate tests at proving grounds, local roads, and test rigs. - Collect data to correlate vehicle dynamics models. This includes steer robot, ride, NVH, and rig data. - Communicate findings with Vehicle Dynamics, Modeling, Chassis Design, and Chassis Controls teams. - Develop test standards that result in the highest quality data possible. - Document vehicle test configuration to ensure the best correlations possible. - Investigate how different proving grounds alter vehicle attributes. - Make recommendations on ideal proving grounds for different test types.
Job Requirements Skills: Test instrumentation and calibration (Simcenter Test lab hardware/software tools, microphones, and accelerometers).

TABLE VI. THERMAL ANALYSIS ENGINEER JOB FUNCTIONS AND REQUIREMENTS

<i>Job Description: Thermal Analysis Engineer/ Powertrain Cooling Engineer</i>
Job Functions: <ul style="list-style-type: none"> - Oversee and/or support the activities related to thermal design and analysis. - Establish and documents system level design requirements for environmental/thermal engineering, such as performance, environment, functionality, life, envelope, and integration. - Use models and tools to perform and record studies of environmental/thermal components and systems in order to validate or evaluate the design. - Work with project teams to define project goals and product specifications - In partnership with the Industrial Design team, ensure the appropriate tradeoffs are made for cooling system packaging / air flow and vehicle styling - Integrate cooling system technologies into off-road vehicles - Work with Powertrain team in the development, specification, and implementation of cooling systems in support of current and future models - Provide Cooling system technical support to: Project Engineers, Designers, Design Engineers, Purchasing, Manufacturing, Powertrain, Quality Assurance and Service - Use data acquisition to quantify cooling system performance for field development and performance evaluation - Benchmark competitive designs - Analyze manufacturing and field problems and recommend and implement solutions - Cross train and support development and validation of other vehicle subsystems including clutching, drive line, brakes, intake, exhaust, and suspensions.
Job Requirements Skills: Cooling system function, design, and development - Creo-parametric and windchill release system experience preferred - system specifications.

IV. CURRICULUM DEVELOPMENT

The development of curriculum to prepare the mechanical engineering graduates for the emerging market of electric vehicles can take many actions depending on the framework and structure of existing programs. These include:

1. Including Application Problems within Existing Courses

Current course instructions can be modified to incorporate electric vehicle application problems relevant to industrial applications.

2. Development of Open-ended Project Course

The foundation of this course is the creation of a multidisciplinary design and construction team for competitive prototype vehicles. The creation of prototypes, engineering analysis, and testing are all integrated into this course. The students practice hands-on activities for product development, design constraints, market competition, and manufacturing limitations.

3. Vehicle Systems Option in Mechanical Engineering Program

Courses that form the core courses of vehicles systems can be included as an option in the study program. Examples include courses such as electric vehicle systems, vehicle instrumentation, and vehicle Dynamics.

4. Engineering Degree with Electric Vehicle Option

Reviewing the institute's mission, vision, goals, stakeholders, strengths, and distinctive assets will be crucial if the decision is made to start developing courses or

programs in a new field, such as electric vehicle applications. Assessing the current situation, the ideal situation, and solutions to bridge the gap is the first step in including subjects related to electric vehicles. The creation of new courses and programs will probably draw on the strengths and interests of the current professors and staff. The conditions for accreditation should also be taken into account. For instance, a panel of industry advisors from Renault and Toyota North America supports the program at Brunel [8].

V. CONCLUSION

Analysis of job duties and technical competencies based on EV market demands for mechanical engineers is presented in the current article. Following the analysis, job functions, technical skills, and engineering tools needed to build a career for mechanical engineering graduates in the field of EVs and EM are categorized.

The analysis shows a set of subjects that are essential for knowledge and understanding in the domain of electric vehicles. Additionally, it is suggested that the designed curriculum must incorporate new engineering software tools, which have grown to be crucial for a mechanical engineering graduate. These tools include Mechanical Computer-Aided Design (MCAD) programs, or CAD software, product quality, planning, and management software, and product testing software. The present analysis is helpful for creating new programs, adding courses, or upgrading existing ones in the area of electric vehicles. Since technology is expected to continue to advance quickly, future engineers will need to pursue a lifelong education.

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