Audi Development Camp

Project assignment v1.2

Section 1: Project goal and general information
Participants are expected to solve a comprehensive engineering task in teams of up to 5 students by optimizing a drivetrain system for a four wheel drive small sportscar platform for competitive purposes. Mass production and street use homologation of the final product is not required. The optimized powertrain will be tested virtually in two separate laps on the Nürburgring Nordschleife racetrack with two battery management strategies: qualifying and race.

Participants are allowed to work on the project until 2019. July 18th 12:00 CEST, and their final presentation until 2019. July 19th 8:30 CEST.

This document details the restrictions which allow the completion of the task within the given timeframe as well as maintain realistic boundary conditions and ensure solutions not far removed from reality.

Adherence to rules and regulations detailed below is mandatory. Projects violating the principles detailed below will be penalized.

Signature of a non-disclosure agreement is required to participate in the program regarding confidential company information. Infringement upon the agreed terms may have legal consequences.

Section 2: Project elements and requirements
In order to provide a comprehensive and realistic development scenario, multiple topics are considered throughout the project. Evaluation will be based on these subtasks summarized in a project report and two presentations. Tasks and their subtasks are as follows:

- Task 1: Engine simulation
  - Task 1.1: Conrod optimization
  - Task 1.2: Intake system optimization
- Task 2: Laptime simulation
  - Task 2.1: Control systems optimization
**Task 1: Engine simulation**

Teams are provided with the CAD model of an Audi EA211 3-cylinder 1.0 TFSI engine without the turbocharging system. Using AVL Boost software, teams must modify the engine for natural aspiration, including intake and exhaust systems. Limitations on engine modification are summarized in the list below.

Fixed engine parameters:

- Bore/stroke ratio: original value
- Configuration: 3 cylinders, 4 valves per cylinder
- Fuel data: Lower heating value: 11.8 kWh/kg
- Lambda value: limited to a maximum of 1.4
- Maximum fuel flow: 25 kg/h
- Conrod length/crank radius ratio: original
- Firing order and firing intervals: original
- Valve clearances: original
- Piston to valve minimum distance: 1.5 mm
- Knocking intensity control number: 100
- Heat transfer: use provided model in AVL Boost
- Camshaft scaling: adhere to scaling rules in AVL Boost
- Friction mean effective pressure (FMEP): use provided model in AVL Boost

Variable engine parameters:

- Cubic capacity
- Piston crown
- Compression ratio
- Exhaust flange
- Flow coefficient: must be validated in 3D CFD (See subtask 1.2)
- Valve size
- Valve overlap
- Complete valve timing
- Length and diameter of intake snorkel
- Volume of air cleaner
- Length and diameter of connecting pipe
- Volume of intake plenum
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- Length and diameter of intake runner
- Intake flange surface: movable up to 5 mm in normal direction
- Length and diameter of exhaust pipe
- Length and diameter of exhaust silencer inlet pipe
- Volume of exhaust silencer
- Length and diameter of exhaust silencer outlet pipe

The modified engine model from AVL Boost will be used for laptime simulations in IPG CarMaker. To ensure proper transmission of data, the following two datasets are required to be output from AVL Boost and imported into CarMaker:

- Torque look-up table: based on engine speed (rpm) and throttle position
- Specific fuel consumption table: based on rotational speed (rpm) and output engine torque (Nm)

Subtask 1.1: Conrod optimization

Racing conditions permit higher engine speeds than road restrictions. In order to optimize and fine-tune the engine, the original connecting rods may be modified using the provided limitations on sizing above. Finite element method must be used in Abaqus software to ensure proper strength of the design, while a fatigue analysis performed on efatigue.com must ensure that the designed conrod withstands $10^6$ cycles of loading. Material may only be chosen from those available on efatigue.com.

Subtask 1.2: Intake manifold and/or port optimization

As the original engine is turbocharged and is modified for naturally aspirated operation, the original configuration of the cylinder head has significant development potential. Teams may use 3D CFD simulation to optimize the provided intake port geometry.
Limitations:

- Water jacket in cylinder head must have minimum 3 mm wall thickness
- Cylinder head casting must remain the same: modifications made must be manufacturable by machining
- Steady flow approach in 3D CFD simulations is sufficient

If the flow coefficient is modified in AVL Boost, then the team must prove their design using STAR-CCM+ software.

**Task 2: Laptime simulation**

As a systems engineering challenge, teams must integrate the optimized internal combustion engine into an Audi TT quattro model with a chosen electric motor and battery concept. Individual input parameters into IPG CarMaker are included in Appendix 1., detailing parameters that may be changed using sound engineering reasoning. Parameters not included in Appendix 1. are to be assumed fixed, this includes but is not limited to engine position and orientation, gearbox position and orientation, drive type, electric motor location, battery location, fuel tank location, suspension parameters and tire parameters. Goal of the simulation is to complete two laps of the Nürburgring Nordschleife with two battery conditions:

- Qualification lap: battery SOC may be 0% at the end of lap
- Representative race lap: battery SOC must be equal at start and finish

A weighted average of the two lap-times will be calculated and used as evaluation basis based on the following formula:

\[
Time = \frac{0.3 * t_{Quali} + 0.7 * t_{Race}}{2}
\]

A total of 30 points are awarded for Task 2. 15 points may be earned for the theoretical background and another 15 points for the achieved laptime. Based on laptimes, an order between teams will be defined with the following points awarded:

- 1st Place: 15 points
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- 2nd Place: 10 points
- 3rd Place: 6 points
- 4th Place: 4 points

Overall fuel tank mass is included in the starting weight of the vehicle and will not change with volume. Fuel consumed during the lap will not decrease the vehicle mass.

Battery pack

Two battery cells are provided to assemble the battery pack of the vehicle. Cell data is provided in Appendix 2. Battery pack location or inertia may not be modified, and it is assumed that the chosen pack fits into the vehicle envelope. Battery mass is variable and is equivalent to the cumulative weight of the cells used.

Electric motor

An electric motor is provided to the teams with its base parameters. The given motor can be scaled to fit the desired model. Appendix 3 is an Excel table which includes the scaling rules as formulas. Battery voltage, motor length and a general scaling factor are variable and the spreadsheet calculates motor parameters with given input data. Any combination of input variables may be used provided the motor maximum rpm does not exceed 50000 rpm. Teams are responsible to use parameters conforming this rule.

Subtask 2.1: Control systems optimization

Having selected the elements of the hybrid system, participating teams are expected to develop a control scheme to efficiently use the on-board power to achieve the lowest laptime on track in each condition. Different control schemes may be used for qualification and race purposes. Following options are permitted for designing the desired control system:

- CarMaker’s own user interface
- CarMaker’s FMU Plug-in
- MATLAB Simulink
Section 3: Mass scaling rules
Component scaling results in weight penalty that is incurred to limit performance on track. Mass scaling for the combustion engine, battery pack and e-motor are applied with the following rules:

> Combustion engine: engine and component mass directly proportional to engine capacity
  > Base engine mass: 100 kg
> Battery: overall mass is the cumulative mass of cells used
> E-motor: mass scaling included in Appendix 3.: E-motor data

Section 4: Evaluation
Teams may earn a total of 150 points during the 4 week program. Points are awarded for the tasks and subtasks as follows:

> Engine simulation (Task #1): 30 pts
> Conrod optimization (Task #1.1): 15 pts
> Intake manifold optimization (Task #1.2): 15 pts
> CarMaker simulation (Task #2): 30 pts
> Control systems optimization (Task #2.1): 15 pts
> Design freeze presentation: 15 pts
> Final Presentation: 30 pts

SUM: 150 pts
Note: team with more than 4 members will be considered in the evaluation process. Deliverables for evaluation:

> Simulation input and output files:
  > AVL Boost
  > IPG CarMaker
  > STAR-CCM+
  > Abaqus
> Presentations:
  > Design freeze
  > Final
Project report

All evaluations focus on engineering reasoning. Proper scientific and engineering methods are expected.

Section 4.1: Presentations

Teams are expected to showcase their work in two presentations: design freeze and final. Design freeze presentation occurs on July 10th, 2019. Design freeze presentations must not exceed 15 minutes, followed by 15 minutes of questions. Final presentations are performed in front of an esteemed jury on the 19th of July, 2019. Final presentations must not exceed 25 minutes, followed by 15 minutes of questions.

Section 4.2: Project report

Theoretical reasoning behind engineering decisions is the focus of the evaluation and points will be awarded for sound judgment and proper decision making processes. In order for our jury to evaluate teams on their engineering competencies, all the work done throughout the project must be summarized in a 10 page project report, including any figures. Engineering drawings of any self-designed components must be included as appendices, outside document size limitations. Formatting requirements:

- Minimum font size: 11
- Line spacing: 1.3

Document structure and content is up to teams to decide. Deadline of submission is 18th of July, 2019, 12:00 CEST. Late submissions are going to be penalized.

Section 5: Prizes

A main prize will be awarded for the team with most points in the competition. Main prize is a DTM race weekend in Hockenheim with accommodation and VIP entry. Details of travels and accommodation will be finalized with the winners after the competition.

Three special prizes will also be awarded for excellence in disciplines relevant to the project. These prizes are as follows:
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- Best teamwork: rewarded with an Audi Gift Pack
- Best systems integration: rewarded with tickets for each team member for Formula Student Symposium 2019
- Outstanding professionalism in presentations: rewarded with an Audi Gift Pack

Special prizes are awarded by the jury and are announced at the final ceremony.

Official changes to these rules will be posted in an updated version of this document which will be uploaded to audicamp.sze.hu as well as distributed to team responsibilities. The website will only contain the most recent version.