Hydrogen Concept Challenge 2024

CV Powertrain Concept Contest

version 1.0 April 25th, 2024

Goal of the contest

The goal of the contest is to develop and present a concept for a hydrogen CV powertrain of a Formula Student car. The vehicle has to have performances comparable to or better than those of a gasoline fuelled CV in all dynamic and static disciplines. The contest should prepare the teams for a future hydrogen category and support the construction of a hydrogen-powered vehicle.

The teams are requested to submit a document of a maximum of 10 pages in text form with pictures and/or diagrams as a PDF (Word file export as PDF) containing the main results of the concept study. At the event, there will be a judging with hydrogen experts.

Boundary conditions

For the development of the hydrogen CV powertrain following boundary conditions have to be assumed:

- Fuel hydrogen grade 3.0 (gaseous form)
- Maximum hydrogen mass flow 7.5 kg/h
- Maximum air mass flow unlimited
- Displacement limited to 1600 cc
- Number of cylinder unlimited
- Boosting is permitted
    - Turbocharging and/or supercharging of any kind and drive system is allowed
    - Boosting systems can be driven by any means e.g. belts, gears, electrically or any combination of drive systems
- Direct injection allowed
- It is allowed to intake and/or inject in the combustion chamber non-combustible substances with the goal of reducing the knock tendency . This will be allowed for hydrogen CV cars only.
- It is allowed to use an existing chassis which already took part in FS events

It is not mandatory but recommended to use, as a base for the modification:

- A commercial motorcycle engine with integrated gearbox
- An existing CV Formula Student car which passed scrutineering and finished Endurance

It is expected from the teams to discuss the above-mentioned boundary conditions, especially whether they are fair with regards to the current EV category in terms of performance.

Content of the concept study

The concept study should include the following points from the next chapters. This is merely a guideline on how the industry proceeds when developing and preparing a presentation of a drivetrain concept. The teams are welcome to use it as a guide, but are free to decide for themselves where they want to focus or what they only want to touch on briefly due to time constraints.

Packaging of hydrogen parts

A packaging investigation has to carried out in order to investigate the position and geometrical dimensions of all the major components including:

- Hydrogen tank and related valves
- Engine and gearbox
- Intake system including piping, air filter and intake plenum
- Exhaust system including exhaust manifold, muffler and all connected heat shield
- If present, boosting system including charge air cooling
- Cooling system including radiators, fan, expansion tank(s), catch tank(s) and piping

It is expected that relevant rendering pictures out of an appropriate CAD system will be provided to identify critical areas and confirm the feasibility of the design. CAD models may also be submitted on a voluntary basis so that officials can consider possible chassis adaptations when creating future rules.

Performance analysis

A performance analysis has to be carried out in a relevant commercial 1D-CFD software (e.g. GT-Power of Gamma Technologies, Boost of AVL or similar).

Prior of the analysis, realistic assumptions have to be taken regarding:

- Pressure loss in the intake and exhaust line
- Combustion duration
- Limits of the combustion timing and fuel to air ratio (such as pre-ignition, knock, peak cylinder pressure or exhaust temperature)
- Discharge coefficient of intake and exhaust port
- Injection pressure and Injector mass flow
- Friction losses

Based on these assumptions and the main engine geometrical dimensions, the main components of the engines have to be dimensioned, with particular focus on following components:

- Selection of the suitable turbocharger or supercharger (if necessary)
- Diameter and length of intake runners
- Number and volume of intake plenum
- Diameter and length of exhaust primary and secondary pipe
- Intake valve lift curve
- Exhaust valve lift curve

At least, for the target configuration of the engine, following parameters have to be calculated over engine speed:

- Power
- Torque
- Brake specific fuel consumption or brake efficiency
- Lambda

- Volumetric efficiency
- Intake manifold pressure and temperature
- Exhaust manifold pressure and temperature
- Combustion duration
- Position of 50% combustion point
- Peak cylinder pressure

If not burnable substances are used to control the knock level, the mass flow over the engine speed has to be calculated.

It is expected for teams with boosted engines that the team knows the characteristics of the turbocharging or supercharging machine, which is planned to be used, including efficiency map and operating limit (charger speed, compressor outlet temperature, turbine inlet temperature).

Cranktrain and valvetrain analysis

On the basis of the results of the performance analysis, are the forces within a feasible range for your engine.

Cooling system analysis

On the basis of the results of the performance analysis, a dimensioning of the cooling system of the vehicle has to be performed.

The system has to be designed in a way to be able to withstand a typical 22 km Endurance run with air temperature of 40°C at 660 m above sea level (altitude of Spielberg near Knittelfeld).

In particular following component has to be dimensioned:

- Water pump
- Radiators
- Oil heat exchanger
- Fans
- Piping

If a hybrid system is used, the cooling system has to be dimensioned with the hybrid system in mind.

Fuel tank analysis

The gas cylinder/tank must be a part available for purchase by anyone, designed and constructed for the pressure used, certified by an accredited testing laboratory in the country of origin and marked or stamped accordingly. The tank should have a quick connector to allow the removal of the tank for refueling in less than 15 minutes.

At least the following questions should be answered in your concept:

- How much (in grams) of hydrogen does your powertrain consume at a typical 22 km Endurance run with air temperature of 40°C at 660 m above sea level (altitude of Spielberg near Knittelfeld)?
- What is the volume and dimensions of a 350 bar hydrogen tank that you need for this amount of hydrogen?
- What types of tanks are suitable for Formula Student and which specific model and manufacturer are you choosing?

Safety analysis

- How do you protect the hydrogen tank and the engine from damage in the event of an accident? How do you protect the driver from the risks that can occur in the event of an accident with a damaged hydrogen tank or engine?
- Which pressure regulator do you choose that can be mounted directly on the gas cylinder/tank?
- Show a diagram of the shutdown circuit including all the parts that are needed for a safe hydrogen powertrain.
- Safety concept for handling of hydrogen over the entire season from build to transport, testing, competition,...
- Safety concept to convince the university that building, storing and servicing a hydrogen vehicle is safe.
- Detailed procedure for how to fully inert the H2 system after a dynamic event and vice versa.

Cost analysis

An estimation of the cost of the powertrain has to be provided. This includes a definition of the supplier of the main components and their respective cost. The cost analysis has to consider the cost connected to safety measures to handle hydrogen at assembly and testing at university.

At least the price for following component has to be estimated:

- Base engine (including gearbox)
- Hydrogen injection system
- Engine management system
- Turbocharger (if present)
- Cooling system
- Tank and pressure regulator

The team can also provide an estimate of the costs and timetable for the following activities, which is optional:

- Definition of the powertrain
- Design of the system (including simulation activities)
- Design of the components (including simulation activities)
- Purchasing of the component
- Test at component level
- Assembly of the engine
- Calibration of the system
- Performance test at engine test bed
- Durability test at engine test bed
- Durability test in vehicle

It is not necessary to perform all of the abovementioned activities.

Evaluation methodologies and criteria

Methodologies

The powertrain concept will be evaluated by a jury of experts on the basis of the submitted report and a presentation at the event side.

The report of the hydrogen CV powertrain has to be submitted prior to the event and will be evaluated by an expert jury. Submission of concept paper in text form with pictures and/or diagrams as a PDF (Word file export as PDF) (up to 10 pages) per email to hydrogen@fs-world.org until 2024-07-07 23:59.

At the event, each single concept will be presented. The team has 15 min to introduce with a presentation or a video of the hydrogen CV powertrain concept. Afterwards a 15 min question and answer session will follow.

Personal discussion per appointment at FS Austria on 2024-07-24

Personal discussion per appointment at FS East between 2024-07-30 and 2024-08-01

Personal discussion per appointment at FS Alpe Adria on 2024-08-22 or 2024-08-23

Personal discussion per appointment at FS Portugal between 2024-09-04 and 2024-09-06

The presentation will be held separately for each team.

Criteria

The jury will assume that the team knows the physics behind the combustion engine, the peculiarity of the hydrogen and the methodology of the engine development.

Imagine your presentation at the event being to senior technical leaders and management of your employer. Your job is to present the result of your concept analysis and be prepared for detailed questions with supporting material.

Obviously in case of question the team is allowed to show detailed simulation results, design specifications or CAD results to clarify the results of the analysis.

The jury will evaluate the work according to following criteria:

- Is the engine concept able to achieve the project target?
- Is the engine concept a good compromise in terms of performance, cost and development time and risk?
- Did the team evaluate all relevant technical solutions?
- Did the team understand the specific challenges and needs that come with converting an engine to hydrogen combustion?
- Did the team show engineering understanding of the problem and provided innovative solutions?
- Did the team highlight the main concept criticalities and/or risk? Does the team have a realistic plan to deal with them?
- Is the development and validation plan SMART (specific, measurable, achievable? Realistic and time-bounded?)
- Do the results of the concept study look realistic and match with expert expectations?

Special award and prize money

Special awards and prize money will be published by the events individually. Please check for this event handbooks, event-websites and social media.