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FDD

European Hyperloop Week

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EUROPEAN
HYPERLOOP
WEEK

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3.3 Eddy Current Braking

Due to unexpected changes in the team, we decided to halt the development of an eddy current brake, which would have served as an addition to our friction brake, which will conform to the standards of the competition after the redesign that is shown in the respective section.

Electrical Systems

4.1 Introduction

4.1.1 (a) Brief overview with the main points of the HV and LV systems.

4.1.2 (b) List of all discrete electrical subsystems.

We are implementing the following subsystems:

- LV Battery
- HV Battery
- Battery Management System
- Insulation Monitoring Device

4.1.3 (c) Wiring diagram of the HV system.

To Sourajit.

4.2 Overview

(a) Explain the main requirements and constraints that drive the design.

Our general design of this season is inspired by conventional modes of transportation, as we have not had the capacity to start developing a levitation system by this season Thus, we focussed on an electrical system that drives our friction-based motor with excelling acceleration, which is a problem that railway systems frequently face.

In between design and production phase, we received a sponsorship of Leadrive, a local startup for research on automotive power electronics. Furthermore, the institute for electrical systems (ISEA) of our home university offered us assistance in the production of battery cells. Therefore, our workload was eased, which turned out to be favorable because of our lack of team members in the electrical field. This has been a crucial constraint in the design and planning process of the electrical department since the last season. Only shortly before submitting the ITD, we were able to make an estimation of realistic goals for the new team.

This year, we would like to set the path for magnetic levitation in the future, relying on an active system inside the vehicles. This was taken into consideration when designing the power dimensions, keeping plenty of overhead for the future, which aligns with our goal of sustainability. By having reusable modules, the design process of the upcoming years will be simplified.

Our project has been significantly bolstered by the generous support and endorsement from leading industry giants, which has considerably alleviated our financial burdens and propelled our initiative towards groundbreaking achievements.

Altium has been instrumental, providing us with cutting-edge PCB design software valued at approximately €10,000. This invaluable resource has empowered our team to design highly complex and efficient circuit boards, essential for the intricate electronics that drive our hyperloop prototype.

Festo, renowned for their pneumatic and automation solutions, contributed a suite of components and systems worth over €15,000. Their support has enhanced our prototype's propulsion and control systems, enabling precise maneuverability and stability at high velocities.

Mouser Electronics stepped in with a crucial contribution, supplying us with electronic components and parts worth about €20,000. This vast array of high-quality components has been pivotal in assembling our prototype's electrical systems, ensuring reliability and performance.

Würth Elektronik provided essential PCB materials and expertise, along with a donation of specialized components valued at €12,000. Their contributions have significantly optimized our prototype's power distribution and structural integrity.

Leadrive offered their advanced inverter technology, a contribution that not only included hardware valued at €18,000 but also critical technical support. This has dramatically improved our prototype's efficiency and power management capabilities.

Vector Informatik has generously supplied software licenses and technical support for vehicle communication systems, with a contribution valued at €8,000. This support has been crucial in implementing robust and reliable communication systems within our prototype.

4.3 Electrical and mechanical design process

4.3.1 (a) Present Schematics or logic diagrams of the boards.

4.3.2 (b) Present temperature simulations for vacuum conditions.

For our heat simulations, we used the software of ANSYS. By vacuum conditions, we assumed the lack of gas flow, which eliminates the cooling heat flow from winds. The simulation tool solves the heat transfer equation $\frac{\partial T}{\partial t} = \alpha \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right)$ by discretizing through Finite-Element-Methods.

4.4 Description of subsystem control

4.4.1 (a) Briefly reference the control systems of the boards, which should be explained in the levi- tation or propulsion section respectively.

4.5 Electrical system characteristics

4.6 Interface with other system

(a) Briefly reference the communication protocols or control mechanisms of the boards, which should be explained in the respective Sense and Control section.
All the electric subsystems are located within the pod.

The phsyical connection matrix is as following:

The data connection matrix is as following. All communication between boards are via CAN, if not specified otherwise:

Column 1	Column 2
Battery Type	Lead-Acid(integrated)
Capacity[Ah]	9
Normial Voltage[V]	12
Cell configuration	2s
Maximum discharge current (lower limit) [A]	10
Weight per cell [Kg]	2,7
Dimensions per cell (L x W x H)[mm]	151 x 65 x 94

Parameter		MIN	NOM	MAX	Unit	conditions
Ambient temperature for operation	T_AMB	-40		90	□C	
Ambient temperature for storage	T_STO	-40		85	□C	
Relative Humidity		0		95	□	
Flow rate of coolant	V_CLNT	8	12	16	l/min	Derating @ 8 12l/min
Inlet temperature of coolant	T_CLNT	-40		85	□C	Derating @ 65 85□C
Cooling inlet pressure	P_INLET			2.5	bar	
Pressure drop between cooling inlet and outlet	P_DROP		0.25		bar	T_CLNT=65□C,v_CLNT=12 l/min
Input voltage	V_DC	260	600	850	V	Full operation @ 450-800V
Input current	I_DC		200		A	Continuous
	I_DCPK		300		A	for max t_PK duration
Output voltage	V_AC		400		Vrms	
Output current	I_AC			200	Arms	Continuous
	I_ACPK			300	Arms	For max t_PK duration
Output power	S_AC	.	135		kVA	Continuous
	S_ACPK		200			for max t_PK duration
Peak duration	t_PK			60	s	
Input voltage for control	V_BAT	6		36	V	Full functional @ 8-32V (at control board)
Max. Efficiency	□	97			□	
Torque control accuracy	□_TRQ			3	□	Torque >100Nm
				3	NM	Torque<100Nm
Torque control speed	t_TRQ			100	ms	
Speed control accuracy	□_SPD			30	rpm	

Table 4.1: 800V Single Inverter

From | To	LV Battery	HV Battery	BMS	Traction Inverter	Motor	Cooling System
LV Battery	-	-	Powers	Powers control system	-	Powers pump and control system
HV Battery	-	-	Connects to	Provides power	-	-
BMS	-	-	Controls	-	-	-
Traction Inverter	-	-	-	-	Propels	X
Motor	-	-	-	-	-	-
Cooling System	-	-	-	Cooling	Cooling	Cooling (implicitly)

Table 4.2: Physical connection matrix

From \ To	LV Battery	HV Battery	BMS	Traction Inverter	Motor	Cooling System	Brakes Controller	Telemetry Unit
LV Battery	-	-	-	-	-	-	-	-
HV Battery	-	-	Discharge rate, voltage level	-	-	-	-	-
BMS	controls	controls	-	-	-	-	-	sends data
Traction Inverter	-	-	-	-	-	-	-	sends data
Motor	-	-	-	-	-	-	-	-
Cooling System	-	-	-	-	-	-	-	sends data
Brakes Controller	-	-	-	-	-	-	-	sends data
Telemetry Unit	-	-	updates limits	sends commands	-	sends target rates	sends commands	-

Table 4.3: Data connection matrix

4.7 Final system description

For this pod, we are going to use 2 different voltage networks. One is high voltage, and the other one is high voltage. Low voltage network is at 24 Volts and high voltage network is at 504 Volts.

Low Voltage Network:

Our low voltage battery network consists of 7 Lithium-Polymer batteries connected in series, thus having the voltage of the low power system set at around 24V. It powers the entire sensing, control and telemetry system.

High Voltage Network:

Our high voltage battery will make use of lithium-ion polymer technology. We use 120 pouch-format cells from Shenzhen GrePow Battery Co. Ltd that we plan to connect in series. The finished package (main battery pack) will be assembled by the team. We are going to connect the 120 cells connected in series and that will have 1 parallel line. This will roughly have 504 V which will have enough power to power the motor and we will have 350 Amps current available to drive the motor. We will stack 30 cells in series per pack and then stack 4 of them to get the full battery pack.

4.8 Manufacturing process

Our PCB Design

PCBs

Prototyping: Prototype PCBs are fabricated in the FabLab associated with our university. The FabLab provides access to PCB manufacturing equipment and materials, enabling the rapid production of prototypes for initial testing and design validation. Once the PCBs are fabricated, they are assembled manually by our team members.

Production: We ordered our final PCBs from JLCPCB, a leading PCB manufacturing service. In addition to JLCPCB, we also collaborate with Würth Elektronik who produce PCBs in Germany, aligning with our goal of sustainability.

Batteries

We produced the battery packs in cooperation with the ISEA (Institute for Power Electronics and Electrical Drives) at RWTH, whose experience helped us to assemble more efficienciently and more safely, as we had a considerable high voltage system.

Inverter

The inverter is a product from Leadrive

Support from Leadrive: The development of the inverter system is supported by Leadrive, a company specializing in advanced inverter technology. Their expertise significantly contributes to the optimization of our propulsion system. Collaboration with Formula Student Team of FH Aachen: Additionally, we collaborate with the Formula Student Team of FH Aachen, benefiting from their practical experience in electric vehicle design and inverter application. This partnership enriches our project with valuable insights into inverter integration and performance enhancement.

4.9 Testing

4.10 Additional considerations when writing the document for specific subsystems

Sources:

- https://link.springer.com/article/10.1007/s40789-022-00494-0 BMS System Reliability
-

Safety - 30 pages max

We have the following safety hazards:

- Pneumatic Braking Systems
- Heavy systems
- Cooling and Thermal Systems
- High voltage Batteries and protections

5.1 FDD.25 Technical Description for Compliance

5.2 FDD.26 Preliminary Risk Assessment for Demonstration

5.3 FDD.27 (FMEA)

5.3.1 Mechanical Systems FMEA

5.3.2 Electrical Systems FMEA

5.3.3 Traction Systems FMEA

5.3.4 Sense and Control Systems FMEA

5.3.5 Risk Mitigation Measures

5.4 FDD.28 Energy Storage Types and Components

5.5 FDD.29 Transport, Storage, and Lifting Requirements

5.5.1 FDD.26 Preliminary Risk Assessment for Transport and Lifting

5.5.2 Transport and Storage Logistics

Testing and Demonstration

6.1 FDD.32 Manufacturing and Testing Procedure

6.1.1 Aim and Objectives

6.1.2 Test Description

6.1.3 Testing Infrastructure and Setup

6.1.4 FDD.33 Preliminary Testing Plan

6.2 FDD.20 Demonstration Plan

6.2.1 FDD.22 CAD Renders of Demonstration Setup

6.2.2 FDD.23 Equipment and Infrastructure List

6.2.3 FDD.24 Use of Own Infrastructure