

The Battery Designer Tool

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Learning objectives for this Lecture Unit

Ansys software mentioned	•	Ansys Granta EduPack [™] , a teaching software for materials education	
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Intended Learning Outcomes				
Knowledge and Understanding	Knowledge of different battery cells and how they can be combined			
Skills and Abilities	Ability to select battery cells to modules for applications			
Values and Attitudes	Awareness of how battery performance changes with configuration and cell types			

Resources

- Paper: <u>The Synthesizer Tool Model Writer's Guide</u>
- Level 3 Industrial Case Study: <u>Battery Designer and Materials for Transportation</u>



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Outline of lecture unit



- Background to batteries
- Relevant data
 - Power Systems-Storage
 - Battery cells
- Battery Designer synthesizer models
 - Cell to module
 - Module to pack
- Example of module design: eScooter



Granta EduPack databases with battery data

Introductory

Advanced



- The Elements database All relevant elements for batteries
- Sustainability Level 3 Energy Storage database
- All five Specialized Advanced databases Battery Cells data and The Battery Designer tool

Background: materials for electrification of transport

- Huge growth of electric and hybrid vehicles
- Many battery types contain toxic elements:
 - Lead,
 - Cadmium
 - Mercury
- Some contain critical elements:
 - Lithium
 - Cobalt
- Most electric motors contain magnets
- These have rare earth elements:
 - Neodymium
 - Samarium
 - Dysprosium



Top 5 Countries: China, Germany, USA, France, UK

The Power Systems-Storage datatable



Battery (Exponential)

Specific power = power per mass, promotes <u>acceleration</u> Specific energy = stored energy per mass, promotes <u>range</u>

Li-ion batteries perform better than others, but without the need for lead or cadmium



The Battery cells datatable

Browse		×	ကြ Home	🗟 Lithium-ion (NMC) Cyli ×						
Database	Level 3 Sustainability	Change	Lithium	-ion (NMC) Cylindrical 2	000 mAh					
Table:	Battery Cells	~								
Subset:	All cells	~	Datasheet vie	w: All properties		Show	(Hide	Find Si	milar 🔻	
Batt	ery Cells		Lithium-ion	(NMC) > Cylindrical >						
> 📄 A	kaline Manganese									
12 📄 Le	ad Acid		General							
🕑 🛄 Li	thium Manganese Dioxide		Manufacturer grades							
🕞 🛅 Li	thium-ion (LCO)			5						
D 📄 Li	thium-ion (LFP)		Panason	ic Corporation: UR18650RX						
D 📄 Li	thium-ion (NCA)		Shandon	g Goldencell Electronics Techn	ology Co., Ltd.: HTC	NR18650-21	00m/	h-3.6V		
🔺 📄 Li	thium-ion (NMC)									
_ ▲ 🖿	Cylindrical		Cell chemistry ((i)	Lithium	Nicke	el mangane	se cobalt oxide		
	g 2000 mAh					(NMC)				
	g 2200 mAn		Dealerson	-1.1.	<u> </u>	,				
	g 2500 mAn		Rechargea	able	0	~				
	4500 mAb (large)		Cycle life		(i)	500	-	1e3	cycles	
	5000 mAh		Specific er	hergy	i	151	-	182	Wh/kg	
Þ 📄	Pouch		Energy de	nsity	(i)	395	-	477	Wh/l	
	Prismatic		Specific po	ower	(i)	457	-	553	W/kg	
	ercuric Oxide Zinc ickel Cadmium		Power der	nsity	 (i)	1.2e3	-	1.45e3	W/I	
	ickel Metal Hydride			lotey	0					
Image: Simple state s	lver Oxide		Size							
🕑 🛅 Zinc Air		Cell geom	etry	i	Cylindr	ical				
D 📄 Zi	nc Chloride		Weight	•	<u>(</u>)	44	-	46.2	g	
			Length		(i)	65.2	-	65.3	mm	
			Diameter		 (i)	18.2		18.5	mm	
			Volume		 	1 69e4		1 76e4	mm^3	
			· oranie		•	1.0004		1.7004		

Cylindrical cell

- Generally lower cost
- High mechanical stability
- Most commonly available
- Used in EVs

Prismatic cell

- High mechanical stability
- High packing density
- Used in phones

Pouch cell

- Low mechanical stability
- High packing density
 - Used in drones and R/C



Coin cell

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- Small
- Inexpensive
- Used in small appliances







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Battery cell technology – 200 years of development

The Ragone plot is suitable for comparing performance of energy-storage devices, as well as energy devices such as engines, gas turbines, and fuel cells. The vertical axis describes how much <u>energy</u> is available per unit mass, while the horizontal axis shows how quickly that energy can be delivered, the <u>power</u> per unit mass.







^{18650 - 18} mm diameter, 65 mm long



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Images from Ansys Granta EduPack software

Ragone plots for rechargeable batteries



LCO=Lithium Cobalt Oxide LFP=Lithium Iron Phosphate NCA=Nickel Cobalt Aluminum Oxide NMC=Nickel Manganese Cobalt

Lithium-ion type batteries are superior in both energy and power performance.

Heavy metal batteries have considerably less energy storage capacity per weight.

Energy density and Power density for rechargeable batteries





Battery Designer models and building blocks for transportation





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What is the Synthesizer tool?



Battery Designer: Assumptions and calculations

> <u>Tools</u> > <u>Synthesizer Tool</u> > <u>Synthesizer Reference</u> > Battery Designer: Assumptions and calculations



Granta EduPack Help

The equations used by the Synthesizer tool's Battery Designer, and full details of the assumptions the models make.

The models in the Battery Designer are heavily simplified and designed to allow rapid comparison between different cells, configurations and thermal management systems. Assumptions used by model **Energy and Power calculations** Thermal Management model Calculations used by model Cell to Module calculations Discharge, Energy and Power Thermal Management Module to Pack calculations Summary of data and inputs required Cell to Module (by number of cells) Cell to Module (by performance) Module to Pack (by number of modules) Module to Pack (by performance)

Synthesizer model: Cell to module options

(1) By number of cells

Cell to Module (by number of cells)						
Combine multiple battery cells into a module. This contains several pre-defined configurations: I ndustrial (cylindrical): Rack mounted design, Sheet steel enclosure, Single BMS, Integral heating pads / thermal monitoring. Automotive (prismatic): Similar to designs used in vehicles in India, Heavy duty sheet steel enclosure, Single BMS / contactor, Forced air induction cooling, Open design for ease of maintenance, Simple and rugged. Shrink wrap (cylindrical): Lightweight design, Shrink wrapped, Single BMS, Integral thermal cutout / fuse, Designed for high volume / low cost. NOTE: Modules must have integer numbers of cells. If values in a specified range are too close together, some generated modules may have identical numbers of cells. If this is the case, only one record for each instance will be created.						
Module						
Module name *						
Battery cell	Browse for a record	Browse				
Number of cells						
Number of cells in series	1 Number of values: 3					
Number of cells in parallel	1 Number of values: 3					
Discharge						
Discharge current	1 A Number of values: 3					
Configuration						
Custom configuration						
Or pre-defined module						
Thermal management system (TMS)						
Cooling system type	None 👻					
This model will generate 1 rec	ords Previous Create	Cancel				

(2) By performance

Cell to Module (by performance)						
Combine multiple battery cells into a module. This contains several pre-defined configurations: Industrial (cylindrical): Rack mounted design, Sheet steel enclosure, Single BMS, Integral heating pads / thermal monitoring. Automotive (prismatic): Similar to designs used in vehicles in India, Heavy duty sheet steel enclosure, Single BMS / contactor, Forced air induction cooling, Open design for ease of maintenance, Simple and rugged. Shrink wrap (cylindrical): Lightweight design, Shrink wrapped, Single BMS, Integral thermal cutout / fuse, Designed for high volume / low cost. NOTE: Modules must have integer numbers of cells. If values in a specified range are too close together, some generated modules may have identical numbers of cells. If this is the case, only one record for each instance will be created.						
Module						
Module name *						
Battery cell 🔋 E	Browse for a record	Browse				
Performance						
Should last for at least	1 min Number of values: 3					
with Current	1 A Number of values: 3					
and Voltage	1 V Number of values: 3					
Configuration						
Custom configuration						
Or pre-defined module						
Thermal management system	TMS)					
Cooling system type	None 🔻					
This model will generate 1 recor	ds Previous Create	Cancel				

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Synthesizer model: Cell to module specifications

Specify your required module properties, then click Create to synthesize the Module record(s). The records will be added to the Battery Cells table under My Records > Synthesized > Modules. Click Previous to go back and choose a different model.

Module

Enter a Module name; this is used to name the synthesized records. Click Browse... to select a Battery cell from the Batteries datatable.

1. Cell to Module (by number of cells)

Enter the required Number of cells in parallel and Number of cells in series

Discharge

Enter the target Discharge current for the module. You can enter a single value or a range (e.g. 0.1-0.2 A).

2. Cell to Module (by performance)

Enter the target Discharge time, Current and Voltage for the module. You can enter a single value or a range (e.g 12-20 V).

Modules must have integer numbers of cells. If the target ranges are too close together, some generated modules may have identical numbers of cells. If this is the case, only one record for each instance will be created.

Synthesizer model: Cell to module configurations

Configuration

Select the Pre-defined module checkbox to select one of the pre-defined configurations: Industrial, Automotive, or Shrink wrap.

Select the Custom configuration checkbox to specify module properties in the Packaging section. If both checkboxes are selected, the Pre-defined configuration will be applied. If neither checkbox is selected, the Custom configuration will be applied.

Packaging

Click Browse... to select a Casing material and Insulation material, and enter the corresponding Wall thickness or Insulation thickness. Specify the Cell spacing within the module.

Thermal management system (TMS)

Select a cooling system from the list:

- None
- Passive air cooling
- Active air cooling
- Liquid cooling
- Dielectric cooling



Synthesizer model: Module to pack

				×		
Module to Pack				0		
	Combine multiple battery modules into a	ı pack.				
Pack						
Pack name 😽	t					
Battery module	Browse for a record			Browse		
Number of Modules						
Discharge current	10 A					
Specify by performance						
Or specify by number in series and parallel						
Packaging						
Casing material	Browse for a record			Browse		
Wall thickness	1 mm					
Insulation material	Browse for a record			Browse		
Insulation thickness	5 mm					
Module spacing	1 mm					
This model will generate 1	records	Previous	Create	Cancel		

A Module consists of multiple connected cells in a casing with insulation and optional cooling system.

A Pack consists of multiple connected modules in a casing with insulation and optional cooling system.

Synthesizer model: Module to pack model

Specify your pack requirements, then click Create to synthesize Pack record(s). The records will be added to the Battery Cells table under My Records > Synthesized > Packs. Click Previous to to go back and choose a different model.

Pack

Enter a Pack name (this will be used to name the synthesized records), and click Browse... to select a Module from the browse tree. You can use a cell record from the data-table, or your own synthesized Module record.

Number of Modules

To calculate number of modules from performance requirements:

1.Select the Specify by performance checkbox

2.Edit the target Voltage window, Discharge time and Discharge current as a single value or a range (e.g. 3.3-3.7 V)

To calculate pack performance from number of modules: 1.Select the Specify by number in series or parallel checkbox 2.Edit the Number of modules in series and Number of modules in parallel

If both checkboxes are selected, the synthesized records will be specified **by performance**. If neither checkbox is selected, the synthesized records will be specified **by the number of modules in series or parallel**.



Example – Battery module for e-scooters

Objective: Maximize energy density, limited volume

Requirements:

- Li chemistry cells, Geometry: Cylindrical
- 1000 cycles, 3yr life span (every day usage)
- Supplies 36 V, 10 A
- 30-90 minutes use



Cell to Module (by performance)



This contains several pre-defined configurations: Industrial (cylindrical): Rack mounted design, Sheet steel enclosure, Single BMS, Integral heating pads / thermal monitoring. Automotive (prismatic): Similar to designs used in vehicles in India, Heavy duty sheet steel enclosure, Single BMS / contactor, Forced air induction cooling, Open design for ease of maintenance, Simple and rugged.

 Shrink wrap (cylindrical): Lightweight design, Shrink wrapped, Single BMS, Integral thermal cutout / fuse, Designed for high volume / low cost.

NOTE: Modules must have integer numbers of cells. If values in a specified range are too close together, some generated modules may have identical numbers of cells. If this is the case, only one record for each instance will be created.

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Module Module name High Energy Battery cell 🔋 Lithium-ion (NMC) Cylindrical 5000 mAh Browse... Performance Should last for at least 30:60:90 Number of values: min 10 with Current Number of values: 36 and Voltage V Number of values: Configuration Custom configuration ✓ Or pre-defined module Pre-defined configuration Shrink wrap Thermal management system (TMS) Cooling system type Passive air cooling This model will generate 3 records Previous Create Cancel

Combine multiple battery cells into a module.



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Example – Battery module for e-scooters





7 x 10-stack Li-ion



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Summary

- The Battery Designer is an early-stage battery pack design tool for initial comparisons across different module and pack configurations.
- It uses simplified models and selection data from commercially available cell types to estimate key performance metrics, taking choice of cell, configuration, casing and insulation materials, and thermal management system into account.
- A database of products, such as the battery cell one, will evolve with time and results will depend on which systems are available. It is also fundamentally different in selection than selection of materials based on material properties. Ashby charts and a performance index technique can still be used.
- Additional materials considerations could be explored with the Ansys Granta EduPack software:
 - Material selection for lighweight of the structural casing
 - Quick Eco Audit of e-transport systems vs conventional power
 - Critical materials/supply chain risks of battery elements and their substitutes

The initial versions of Battery Designer and the Batteries data-table were developed as part of the MAT2BAT collaborative R&D project (Innovate UK, Faraday Challenge competition, Project no 133723), and subsequently further developed and integrated by Granta Design Limited, an ANSYS Inc. subsidiary.

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