Testing Various Insulation Types To Evaluate Their Effects On Heat Transfer Across A Sand Battery Using FEA & CFD

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Aim of the Project

The Aim of the project is to Carry out FEA & CFD analysis to evaluate the Heat transfer across a sand battery and compare the results to conclude which form of simulation is more accurate for simulating heat transfer across a porous medium. To also perform an Eco-Audit on the sand battery and evaluate the C02 and energy usage and possible find an improved material for the sand battery tank

Background

A sand battery is a thermal storage device that is powered using renewable energy. The reason for sand being a good choice for thermal storage is its ability to contain and trap heat for long periods of time which solves the issue of excess renewable energy generated being wasted due to no proper storage methods. When the heat energy is needed from the sand battery it can be released on demand and used freely. To test the insulations ability to keep in heat FEA thermal analysis could normally be used and still can be but due to sand being a porous medium CFD simulations are carried out and will be compared to FEA simulations of the sand battery to evaluate if FEA simulation is effective for porous materials.

An Eco-Audit for the sand battery is also carried out to evaluate the environmental impact.

Methodology

Theory & Calculations

$$r_{cr,cylinder} = \frac{k}{h}(m)$$

Photo of:Critical Radius formula

The formula used to determine the critical radius of the insulation is seen above. This calculation determines the thickness the insulation can be before heat is actually lost to due to insulation.

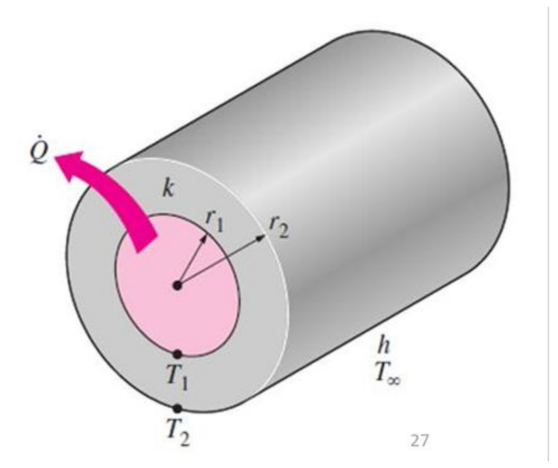

Photo of: thermal resistance network problem

The rate of heat transfer (Q) is to determine the amount of heat being transferred across the body. A big influence on the ability for heat to transfer through a body is that bodies resistance to conduction and convection (r conv & r cond)

$$R_{cond} = ln\left(\frac{r_o}{r_i}\right)\frac{1}{2L\Pi k} \qquad R_{conv} = \frac{1}{hA_s}$$

Photo of: thermal resistance formulae

Eco-Audit

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	End of life
1	Handle	Stainless steel	Virgin (0%)	0.082	Roll forming	Recycle
1	Tank	Stainless steel	Virgin (0%)	34	Extrusion, foil rolling	Downcycle
1	Lid	Stainless steel	Virgin (0%)	4.2	Casting	Downcycle
1	AL PLEX PIPPING	Cast Al-alloys	Virgin (0%)	0.152	Extrusion, foil rolling	Downcycle
1	AL PLEX PIPPING	Polyethylene (PE)	Virgin (0%)	0.054	Polymer molding	Recycle
1	Polyerethane Insulation	Polyurethane (tpPUR)	Virgin (0%)	5.12	Polymer extrusion	Recycle

Photo of: Eco-Audit Components

Transport

Name	Transport type	Distance (km)
Tank, Lid and Handle	Sea, container ship	661
Tank, Lid and Handle	Light commercial vehicle	138
Polyurethane Insulation	Light commercial vehicle	15.3
Al Plex Pipping	Light commercial vehicle	116

Photo of: Eco-Audit Transport

All material were considered virgin materials meaning they were not previously used for anything. The transport included the sand battery tank which came Norwich in England and all other components were purchased within Ireland.

Results

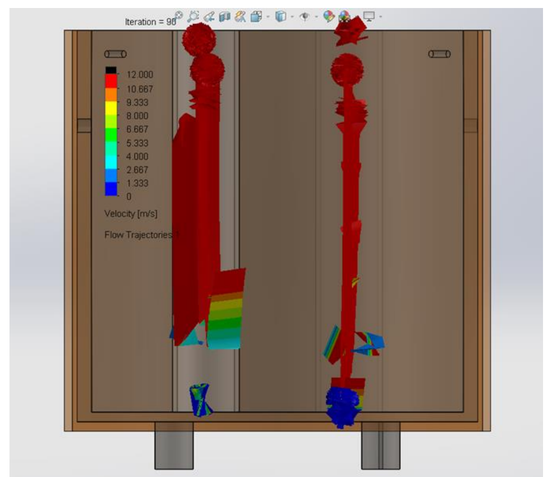

Photo of: CFD Flow Trajectory

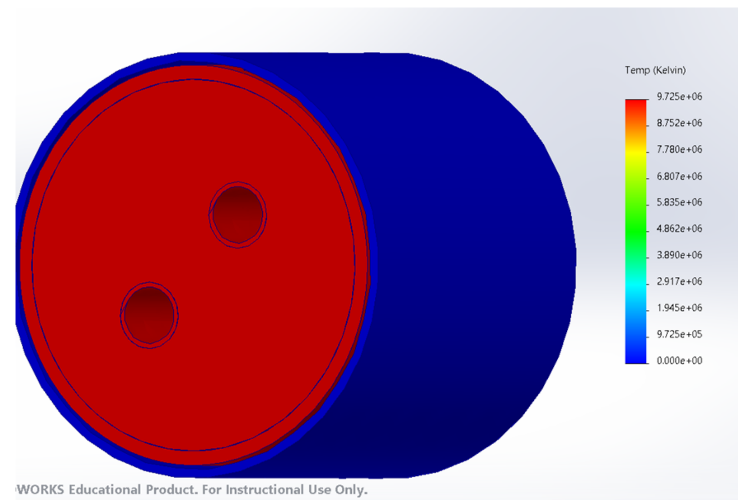

Photo of: Thermal Analysis results

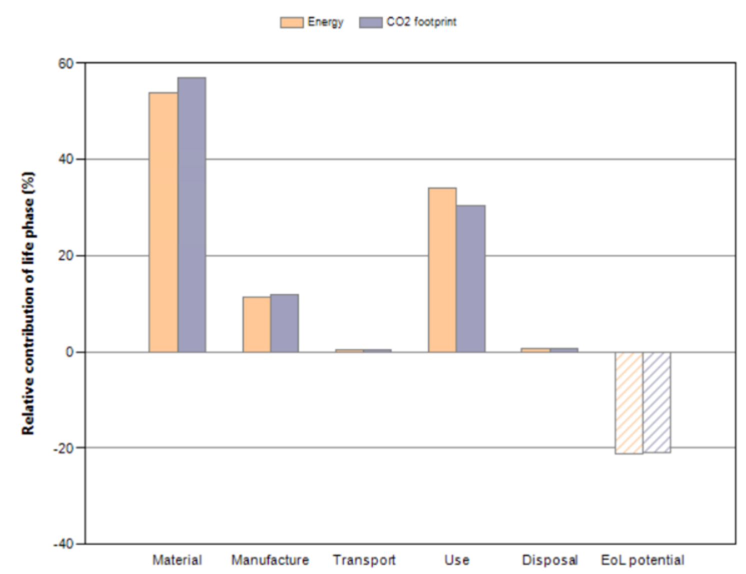

Photo of: C02 vs Energy usage as a percentage

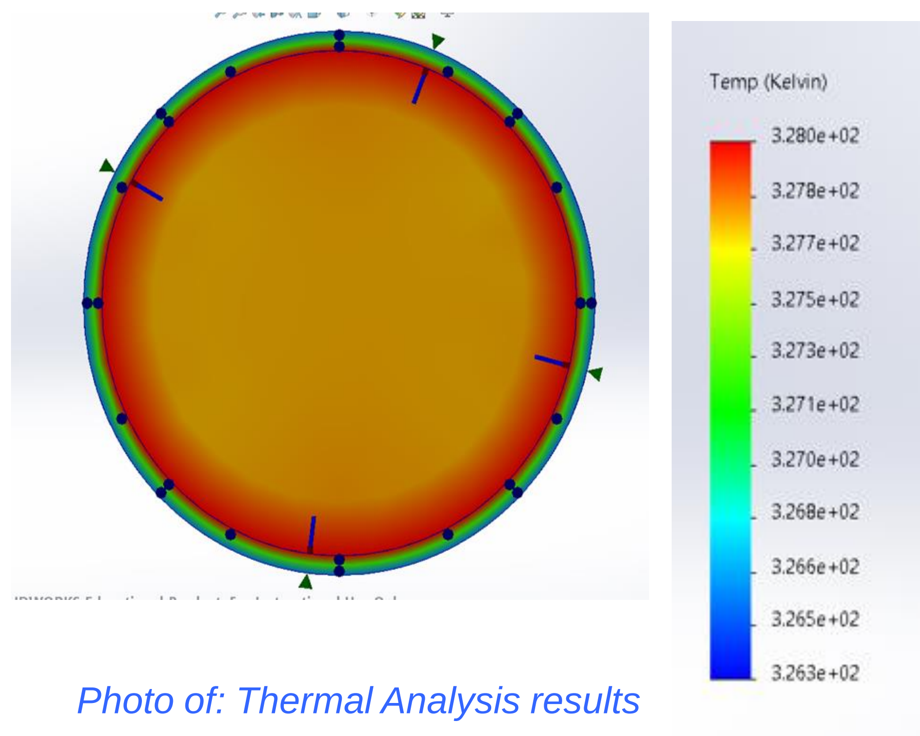

Photo of: Thermal Analysis results

Conclusion & Recommendations

The thermal loads were not applied the correct way to simulate the heat transfer desired leading to inaccurate results. The Eco-Audit provided the amount of C02 produced and amount of energy used to produce the sand battery. The CFD flow trajectory is inconsistent with the actual sand battery prototype

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