ACHIEVING SUSTAINABLE PRODUCT DESIGN THROUGH SUPERIOR MATERIAL INTELLIGENCE AND DIGITAL THREAD INTEGRATION

Ujwal Patnaik – Director, Product Strategy and Pricing, Altair / Nachiket Patil – Product Specialist, Altair / September 12, 2024

Introduction

The demand for sustainability within product design – from both consumers and governing bodies – is at an all-time high. The pursuit of more sustainable products comes as organizations strive to reduce their carbon footprint by focusing on the implementation of material data analysis and optimized product design processes. This approach emphasizes material selection to minimize waste while shifting to a circular economy. This white paper explores how organizations can calculate their carbon footprint by building a custom tool leveraging Altair® Inspire™ Python APIs and accelerate design optimization and studies using Altair SimSolid® a structural analysis tool for rapid design iterations – all while leveraging material data from Altair® Material Data Center™. Material Data Center helps purchasers, engineers, and analysts across the organization collaborate and make decisions from a single data source. By tracking and analyzing material data, companies can optimize production design processes, enhance sustainability, and lower their environmental impact.

Challenges

Sustainability is reshaping global business practices, prompting companies to leverage digital innovation to measure and reduce their carbon footprint. Improving products with more efficient processes – while reducing product development time and overall spending – is every organization's goal. That's why evaluating sustainability early in the concept and design phase is paramount. However, there are challenges when pursuing eco-friendly product designs and calculating carbon footprints, specifically when searching for adequate multiphysics material and sustainability data. The right material is the one that performs best in the manufacturing process and finished product while having the smallest possible carbon footprint. Maintaining a high standard of product development and production while adhering to rigorous sustainability demands can be difficult. Often, this information is limited and not easily integrated with pre-existing organizational CAD solutions. This is where Altair's digital thread capabilities can facilitate end-to-end strategic thinking and connect siloed data sources to streamlined decision-making, helping organizations keep sustainability at the forefront.

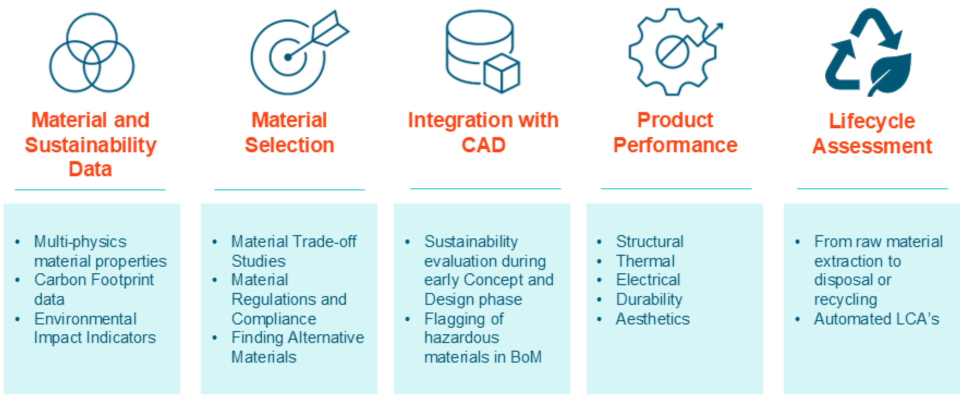
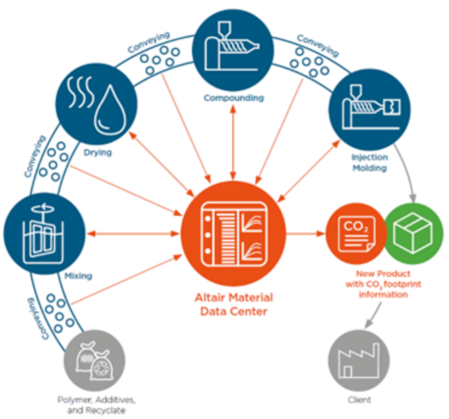


Figure 1 – Challenges: Sustainable Product Design

Design for a Greener Future

Recently, there has been a new perspective on material usage regarding materials' environmental impact. Creating environmentally conscious design best practices is a complex task, intricately interwoven with balancing technological advancements and regulatory compliance. That said, designing for a greener future is becoming more attainable with sustainability data from Altair's enterprise-wide material intelligence platform, Material Data Center. By leveraging Material Data Center's built-in life cycle assessment (LCA) calculator, users can calculate the carbon footprint and global warming potential for manufacturing numerous polymer and composite components, thus ensuring a holistic sustainability assessment (Figure 2).



Compound	Percentage weight	CO2 footprint [kg CO2/kg]	Global warming potential [kg CO2 eq./kg]
ABS	97	3.05	3.52
Calcium carbonate	3	0.06	0.06
Country		**Power mix [kg CO2/kWh]**	**Power mix [kg CO2 eq./kWh]**
Germany		0.523	0.523
Machine	**Power consumption [kWh/kg]**	**CO2 footprint [kg CO2/kg]**	**Global warming potential [kg CO2 eq./kg]**
Hot air dryer	0.05	0.0262	0.0262
Screw extruder	0.32	0.167	0.167
Electric machine	0.41	0.214	0.214
		CO2 footprint [kg CO2/kg]	**Global warming potential [kg CO2 eq./kg]**
Total		3.37	3.82

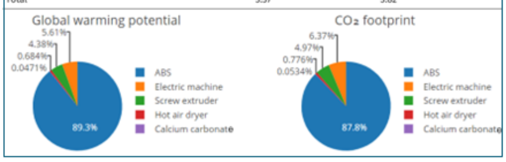


Figure 2 - Holistic Carbon Footprint Assessment for Injection Molding with Material Data Center

Optimizing Material and Profile Selection with Altair SimSolid and Material Data Center

Consistent material data is a prerequisite to sustainable design. Therefore, the first step is to perform a material trade-off study to identify the preferred materials for a given product development workflow. In this example, parametric modeling was performed within Inspire with the material and carbon footprint data derived from Material Data Center. Ultimately, the mechanical analysis was run using Altair SimSolid while an automated report is produced. The report presented optimized material data in a clear and accessible format. The material trade-off study (Figure 3) compares material options for consideration, including the material needed to produce an optimized structure – in this case a rectangular beam – while also providing output data for the structure's carbon footprint, global warming potential, and additional mechanical results such as displacement and stress values. This allows the user to compare material combinations to make an optimal material selection. Here we look at the tradeoffs between mechanical results from CAE simulation and carbon footprints to find out which engineering structures would be best suited for the application's unique needs.

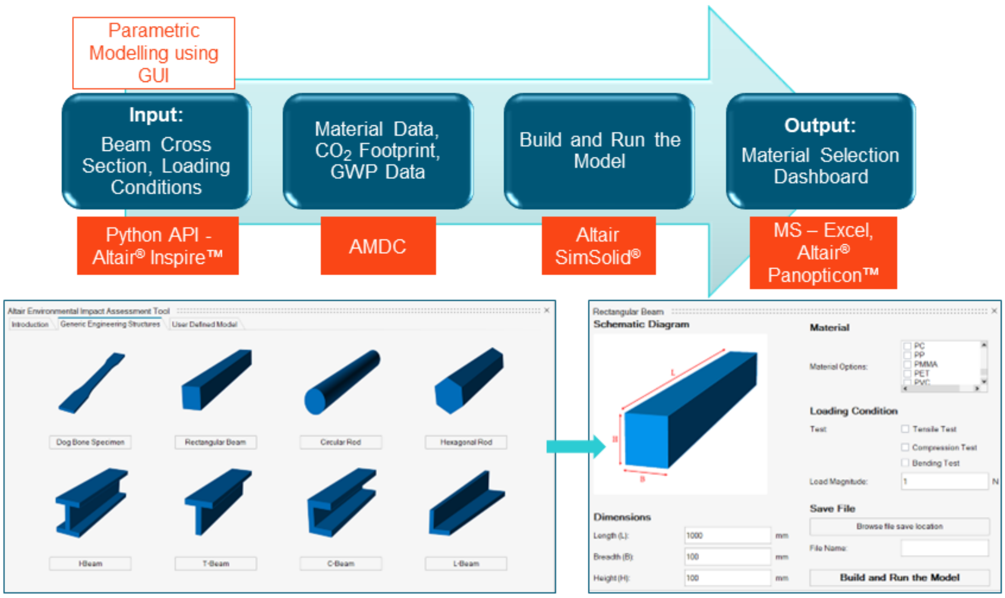


Figure 3 - Optimize material and profile selection using Material Data Center and Altair SimSolid

Additionally, within Material Data Center there are multiple specialized functionalities that allow material data to be displayed and analyzed instantly in several variations. Material specialists can perform trade-off studies in Material Data Center using various tools and graphical representations (Figure 4). Scatter plots can be used to visualize the materials available in the database based on any two material properties. For this case of sustainability-driven material selection, we can have carbon footprint on one axis, and any other mechanical/thermal/electrical material property on the other. We can then zoom into the area of interest and load those materials as advanced search criteria. In advanced search, we can further filter out materials using a predefined numerical range of material properties, and filter out materials based on the desired application domain (like automotive, electrical and electronical, packaging, etc.) Finally, the shortlisted materials can be compared based on the desired material properties using a polar chart. Design engineers can easily review this data and determine the best path forward in their product design and process development planning.

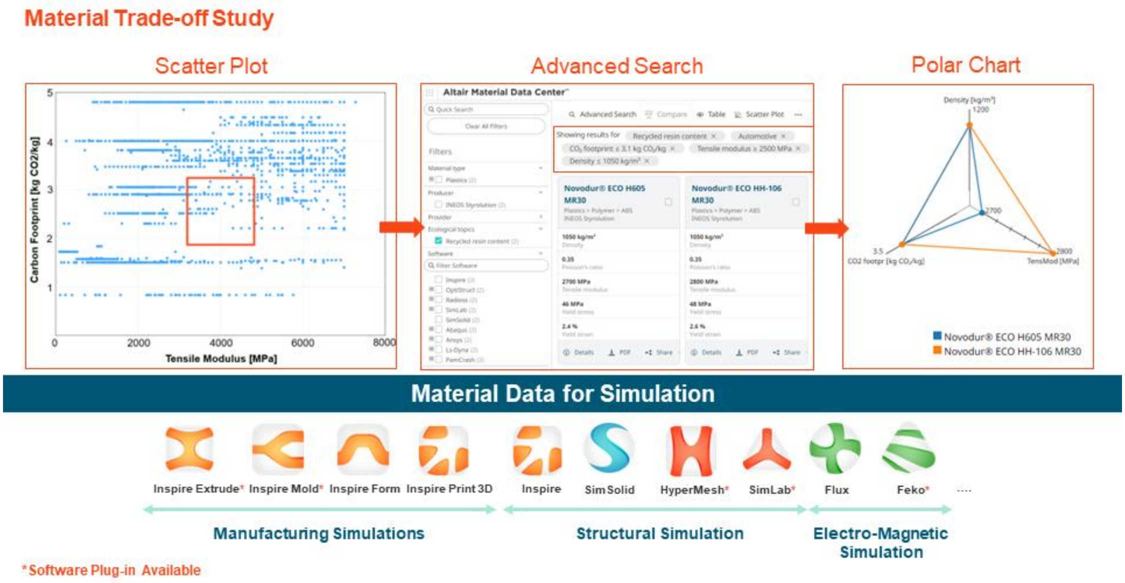


Figure 4 - Material Data Center: Multi-Disciplinary Material Data Solution

Eco-Design Excellence: Seamless Carbon Footprint Analysis with CAD Integration

Calculating the carbon footprint directly from CAD files represents a significant advancement in the pursuit of sustainable product design. The advantage of this method lies in its ability to embed sustainability into the design workflow from the outset. Traditional carbon footprint analysis often occurs after the design is completed, which can limit the opportunities for making impactful changes. In contrast, direct calculation of product carbon footprint from CAD files enables real-time assessment of materials, energy usage, and manufacturing methods, facilitating more informed decisions that can slash a project's carbon footprint. This proactive approach not only supports compliance with increasing regulatory requirements and standards, it also enhances organizations' competitiveness by helping them showcase their commitment to sustainability.

At the component level, having streamlined processes at your fingertips for analyzing product performance allows for more comprehensive decisions. To cater to this requirement, we developed a custom eco-design evaluation dashboard using Inspire Python APIs, which helps select the best material for any part based on two parameters: maximum stiffness and least carbon footprint (Figure 5). The CAD files are uploaded to Inspire with a shortlist of materials selected. In this case, the shortlisted materials for the bumper include acrylonitrile butadiene styrene (ABS), polycarbonate (PC), and polypropylene (PP). The chart shows a comparison of automotive parts based on material data including mass, carbon footprint, and global warming potential. When the carbon footprint analysis runs, it's determined that polycarbonate performs the best based on a lower carbon footprint value (4.490 kg CO_2/kg). Simultaneously, our revolutionary meshless solution, Altair SimSolid, enables a seamless CAD to simulation transition – running a modal analysis quickly to evaluate the natural frequency of the structure in a matter of seconds. Comparing both the results, we can summarize that polycarbonate is both the most environmentally sustainable and structurally sound material.

Bumper

Material Name	Part Mass (kg)	Part Carbon Footprint (kg CO2/kg)	Part Global Warming Potential (kg CO2 eq/kg)	Natural Frequency (Hz)			
				Mode 7	Mode 8	Mode 9	Mode 10
ABS	3.499	10.674	12.335	2.44	6.02	10.01	14.95
PC	1.178	4.490	4.867	4.94	12.20	12.26	30.30
PP	2.935	4.402	5.444	2.17	5.37	8.92	13.33

Figure 5 - Mechanical and Eco-Design Evaluation of an Automotive Bumper

Similarly, at the assembly level, when looking at a product with multiple complexities and interrelating parts, it's important to consider the material selection to optimize the design. In this case, the user can upload an entire CAD assembly with preassigned materials. The custom eco-design evaluation dashboard automatically reads the Bill of Materials (BoM) and calculates the product's carbon footprint and global warming potential in seconds. For example, an electric scooter has multiple parts working together; an eco-design evaluation of the entire assembly (Figure 6) can flag areas that need improvement. We can observe that the lower case has the maximum carbon footprint and therefore is the least sustainable part, having the highest part mass (2.271 kg), highest carbon footprint (5.337 kg CO_2/kg), and highest global warming potential (5.515 kg CO_2 eq/kg). The significance of this method is profound, as it shifts the focus from isolated, individual component assessments to a unified view of the entire assembly's environmental impact. This helps design engineers identify problem areas and work to find alternative designs and materials to optimize assemblies – ultimately creating more sustainable products.

Direct Integration with CAD using Altair® Inspire™

Part Name	Material Name	Part Mass (kg)	Part Carbon Footprint (kg CO2/kg)	Part Global Warming Potential (kg CO2 eq/kg)
Rear Tire	ABS	0.251	0.766	0.885
Front Tire	ABS	0.251	0.766	0.885
Rear Wheel	PMMA	0.091	0.316	0.341
Front Wheel	PMMA	0.091	0.316	0.341
Right Handle	PA66	0.034	0.135	0.226
Left Handle	PA66	0.034	0.135	0.226
Upper Case	PVC	0.939	2.208	2.282
Front Support	PVC	0.122	0.287	0.296
Left Rear Support	PVC	0.096	0.226	0.233
Front Rear Support	PVC	0.096	0.225	0.232
Lower Case	PVC	2.271	5.337	5.515
Fork	PVC	0.264	0.621	0.642
Bushing	PVC	0.053	0.126	0.13
Axis Hand	PVC	0.145	0.342	0.353
Universal Joint	PVC	0.078	0.183	0.189
Axis 1	PVC	0.347	0.817	0.844
Rear Case 1	PA66	0.105	0.42	0.704
Front Case 1	PA66	0.043	0.173	0.29
Front Case 2	PA66	0.048	0.192	0.322
		Total:	13.591	14.936

Summary: Lower Case has the maximum CFP, GWP in whole assembly – Least Sustainable

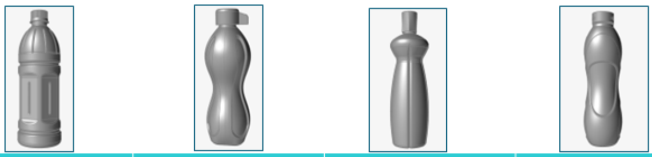
Figure 6 - Eco-Design Analysis of an Assembly

Sustainability-Driven Design Study

A sustainability-driven design study focuses on identifying the most environmentally friendly design by calculating and analyzing the carbon footprint of various design alternatives. One final use case demonstrates a sustainability-driven design study examining four variants of a plastic bottle (Figure 7). Using the same methods seen in the previous examples, designs are compared based on carbon footprint and global warming potential while keeping materials consistent. In this case, polyethylene terephthalate (PET) is assigned to the body of the bottle and polypropylene (PP) for the cap. After the data is automatically generated, it's determined that Design 2 is the most sustainable bottle design since it has the smallest carbon footprint (total CFP 0.041 kg CO_2/kg) and lowest global warming potential (total 0.047 kg CO_2 eq/kg). This type of analysis can give organizations confidence in their sustainability analyses as they move forward in their manufacturing processes.

Direct Integration with CAD using Altair® Inspire™

Material:
Bottle – PET
Cap - PP



CFP (kg CO2/kg)	Design 1	Design 2	Design 3	Design 4
Bottle CFP	2.413	0.037	0.110	0.237
Cap CFP	0.003	0.004	0.014	0.011
Total CFP	2.416	0.041	0.124	0.248

GWP (kg CO2 eq/kg)	Design 1	Design 2	Design 3	Design 4
Bottle GWP	2.790	0.042	0.127	0.274
Cap GWP	0.004	0.005	0.017	0.014
Total GWP	2.794	0.047	0.144	0.288

Summary: Design 2 has least CFP, GWP – Most Sustainable

Figure 7 - Sustainability-Driven Design Study

Accelerating Sustainable Product Development

The functionalities examined within this white paper will aid engineers and companies in their goal of fostering more sustainable product design. Accelerating sustainable product development is not merely something that's nice to have – it's a necessity in today's rapidly evolving global landscape. By harnessing the combination of multiphysics material and comprehensive sustainability data, along with CAE simulations, organizations can significantly enhance their product design processes. These integrated approaches enable more informed decision-making, help reduce environmental impacts, and drive innovation.

As industries strive for greater efficiency and eco-friendliness, embracing these technologies will not only ensure compliance with stringent regulations, it can also help companies better position themselves as leaders in sustainability. The future of product development hinges on our ability to blend material science with cutting-edge simulation tools, ultimately fostering a more sustainable, more resilient world. For more information, visit our web pages for Altair sustainability solutions, Altair SimSolid, and Material Data Center.