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"The Effect of Deferent Building Materials on Energy Conservation Using Finite Element Analysis on SolidWorks Software"

Researcher:

Eng. Mohammad Alobaid

Constriction Training Institute

PAAET-Kuwait

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1. Description

Examine a thermal analysis .Numerous analogies exist between thermal and structural analysis for deferent building materials and study the effect of them on buildings energy conservation by using finite elements throw solid works software .

2.Introduction

Finite Element Analysis, commonly called FEA, is a method of numerical analysis. FEA is used for solving problems in many engineering disciplines such as machine design, acoustics, electromagnetism, soil mechanics, fluid dynamics, and many others. In mathematical terms, FEA is a numerical technique used for solving field problems described by a set of partial differential equations. In mechanical engineering, FEA is widely used for solving structural, vibration, and thermal problems. However, FEA is not the only available tool of numerical analysis. Other numerical methods include the Finite Difference Method, the Boundary Element Method, and the Finite Volumes Method to mention just a few. However, due to its versatility and numerical efficiency, FEA has come to dominate the engineering analysis software market, while other methods have been relegated to niche applications. When implemented into modern commercial software, both FEA theory and numerical problem formulation become completely transparent to users.

FEA is a powerful engineering analysis tool useful in solving many problems ranging from very simple to very complex. Design engineers use FEA during the product development process to analyze the designing-progress. Time constraints and limited availability of product data call for many simplifications of computer models. On the other hand, specialized analysts implement FEA to solve very complex problems, such as vehicle crash dynamics, hydro forming, and air bag deployment. This book focuses on how design engineers use FEA, implemented in Solid Works Simulation, as a design tool. Therefore, we highlight the most essential characteristics of FEA as performed by design engineers as opposed to those typical for FEA preformed by analysts. FEA for Design Engineers: Another design tool For design engineers, FEA is one of many design tools that are used in the design process and include CAD, prototypes, spreadsheets, catalogs, hand calculations, text books, etc

3.Methodology

From the perspective of FEA software, each application of FEA requires

steps:

- Preprocessing of the FEA model, which involves defining the model then splitting it into finite elements
- Solving for desired results
- Post-processing for results analysis

We will follow the above three steps in this project . From the perspective

of FEA methodology, we can list the following FEA steps:

- Building the mathematical model
- Building the finite element model by discretizing the mathematical model
- Solving the finite element model
- Analyzing the results

The following subsections discuss these four steps.

Building the mathematical model

The starting point to analysis with SolidWorks Simulation is a SolidWorks model. Geometry of the model needs to be meshable into a correct finite element mesh. This requirement of meshability has very important implications. We need to ensure that the CAD geometry will indeed mesh and that the produced mesh will provide the data of interest (temperature distribution) with acceptable accuracy. it is important to mention that we do not always simplify the CAD model with the sole objective of making it meshable. Often we must simplify a model even though it would mesh correctly, but the resulting mesh would be too large (in terms of the number of elements) and consequently, the meshing and the analysis would take too long. Geometry modifications allow for a simpler mesh and shorter meshing and computing times.

Sometimes, geometry preparation may not be required at all. Successful meshing depends as much on the quality of geometry submitted for meshing as it does on the capabilities of the meshing tools implemented in the FEA software.

Having prepared a meshable, but not yet meshed geometry, we now define material properties (these can also be imported from a CAD model), loads and restraints, and provide information on the type of analysis that we wish to perform. This procedure completes the creation of the mathematical model the process of creating the mathematical model is not FEA specific.

Building the finite element model

The mathematical model now needs to be split into finite elements in the process of discretization, more commonly known as meshing .Geometry, loads, and restraints are all discretized. The discretized loads and restraints are applied to the nodes of the finite element mesh.

Solving the finite element model

Having created the finite element model, we now use a solver provided in SolidWorks Simulation to produce the desired data of interest.

Analyzing the results

Often the most difficult step of FEA is analyzing the results. Proper interpretation of results requires that we understand all simplifications (and errors they introduce) in the first three steps: defining the mathematical model, meshing, and solving. In the Building the finite element model The mathematical model is discretized into a finite element model. This completes the pre-processing phase. The FEA model is then solved with one of the numerical solvers available in SolidWorks Simulation

4. Objectives:

- Get familiar with deferent type of building materials and how it will perform regarding heat insulation and energy conservation .

- Give a design recommendation on using some of building materials regarding heat insulation and energy conservation

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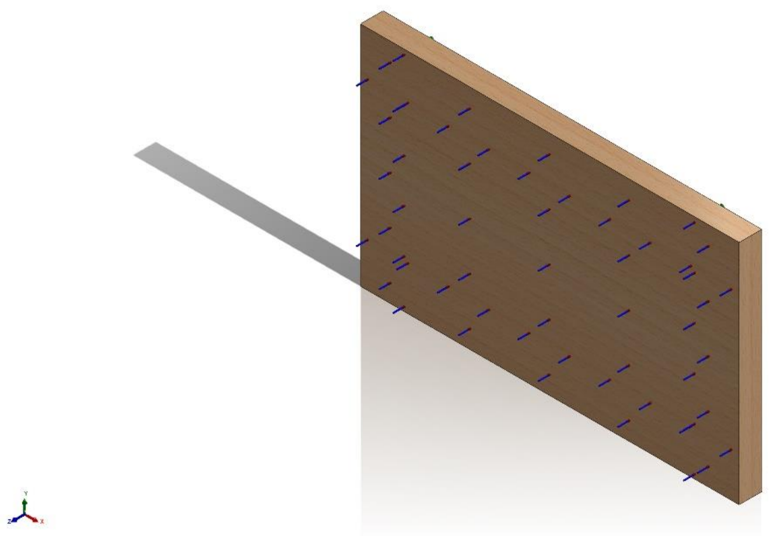
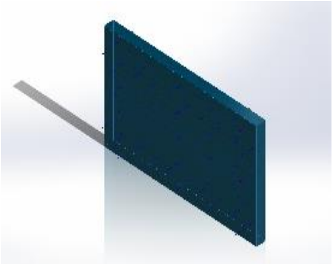
5. Assumptions:

1. **Wood Balsa Case Study**

Model Information



Model name: Wood Balsa
Current Configuration: Default

Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
	Solid Body	Mass:0.719955 kg Volume:0.0045 m^3 Density:159.99 kg/m^3 Weight:7.05555 N	C:\Users\maalo\OneDrive\Documents\test 1.SLDPRT

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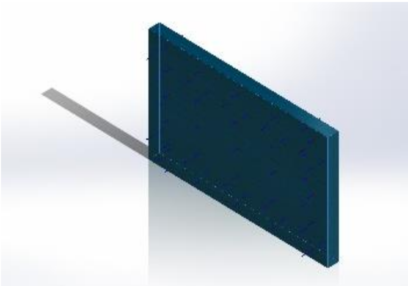
Study Properties

Study name	Wood - Balsa
Analysis type	Thermal(Steady state)
Mesh type	Solid Mesh
Solver type	FFEPlus
Solution type	Steady state
Contact resistance defined?	No
Result folder	SOLIDWORKS document (C:\Users\maalo\OneDrive\Documents)

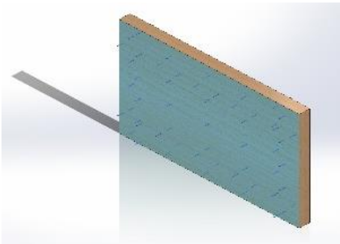
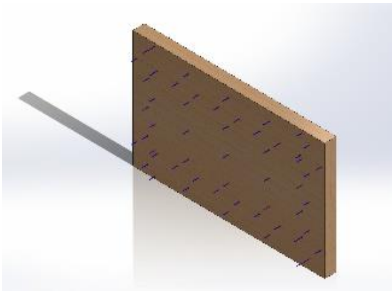
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	Name: **Wood - Balsa** Model type: **Linear Elastic Isotropic** Thermal conductivity: **0.05 W/(m.K)** Mass density: **159.99 kg/m^3** Specific heat: **1 J/(kg.K)**	**SolidBody 1(Boss-Extrude1)(test 1)**
Curve Data:N/A		

Thermal Loads

Load name	Load Image	Load Details
Temperature-1		**Entities:** **1 face(s)** **Temperature:** **70 Celsius**
Convection-1		**Entities:** **1 face(s)** **Convection Coefficient:** **16 W/(m^2.K)** **Time variation:** **Off** **Temperature variation:** **Off** **Bulk Ambient Temperature:** **293 Kelvin** **Time variation:** **Off**

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	16.5126 mm
Minimum element size	16.5126 mm
Mesh Quality	High

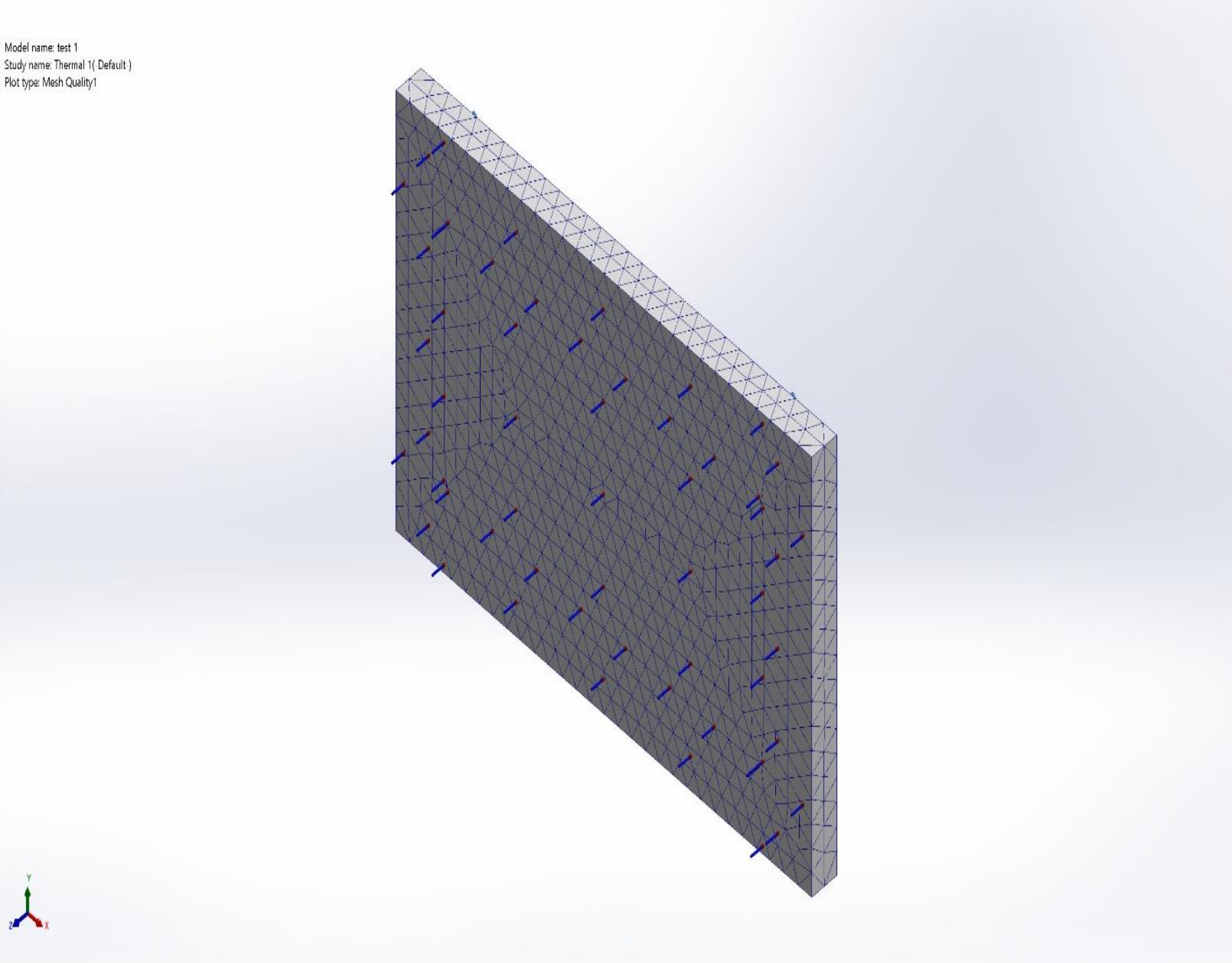
Mesh information - Details

Total Nodes	13093
Total Elements	7602
Maximum Aspect Ratio	3.0759
% of elements with Aspect Ratio < 3	100
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:03

Computer name:	RAZER15

Mesh Quality Plots

Name	Type	Min	Max
Wood - Balsa	Mesh	-	-



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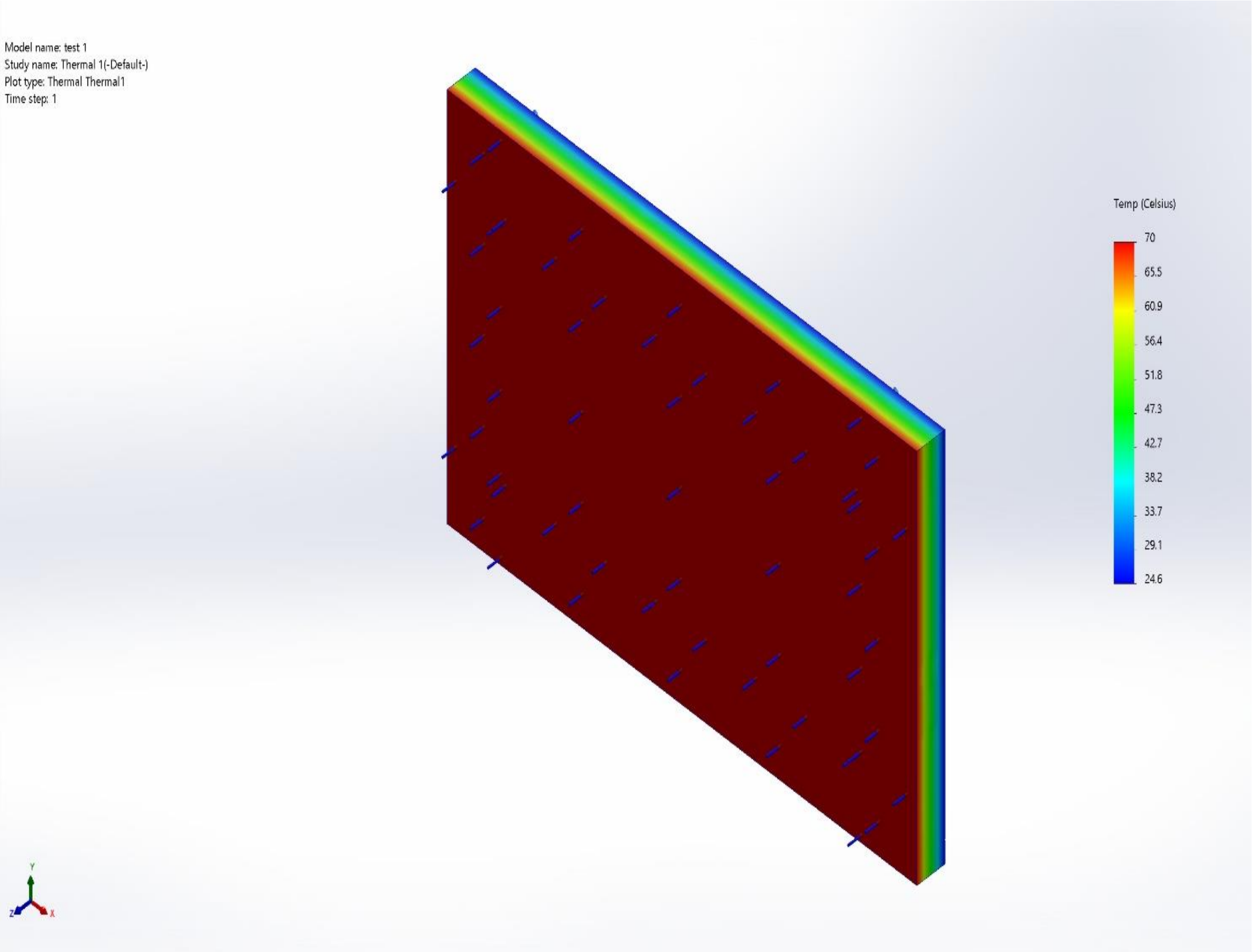
Study Results

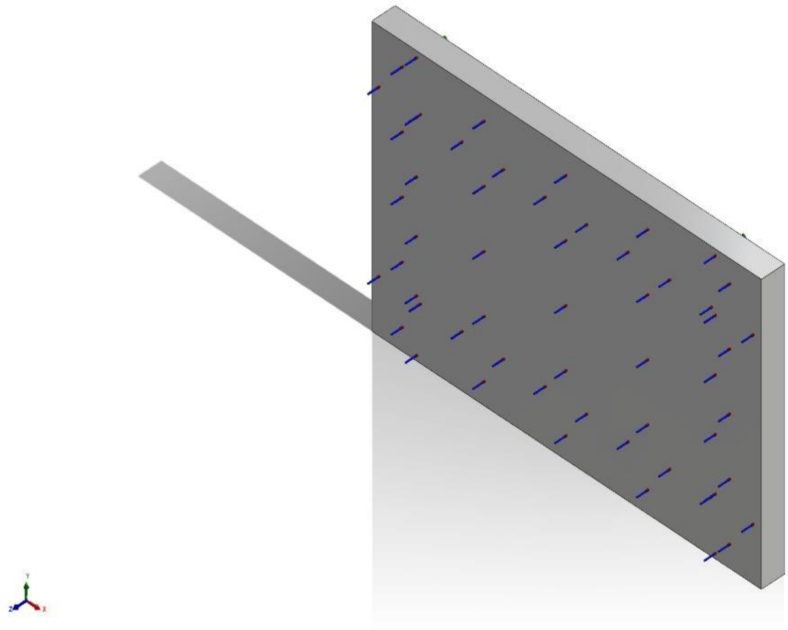
Name	Type	Min	Max
Wood - Balsa	TEMP: Temperature	24.6Celsius Node: 1	70Celsius Node: 3

test 1-Thermal 1-Thermal-Thermal1

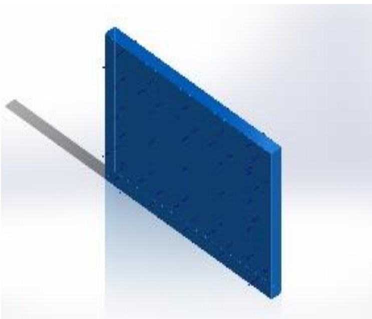


B. PVC Case Study

Model Information



Model name : PVC
Current Configuration: Default

Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
	Solid Body	Mass:5.85 kg Volume:0.0045 m^3 Density:1,300 kg/m^3 Weight:57.33 N	C:\Users\maalo\OneDrive\Documents\test 1.SLDPRT

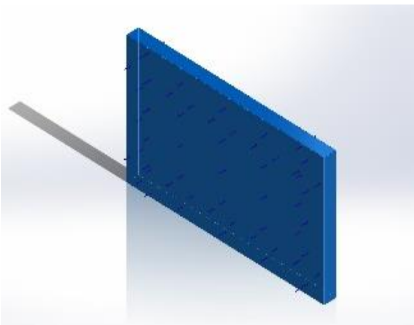
Study Properties

Study name	PVC
Analysis type	Thermal(Steady state)
Mesh type	Solid Mesh
Solver type	FFEPlus
Solution type	Steady state
Contact resistance defined?	No
Result folder	SOLIDWORKS document (C:\Users\maalo\OneDrive\Documents)

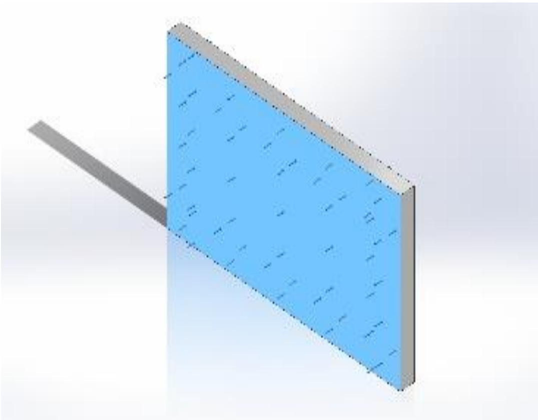
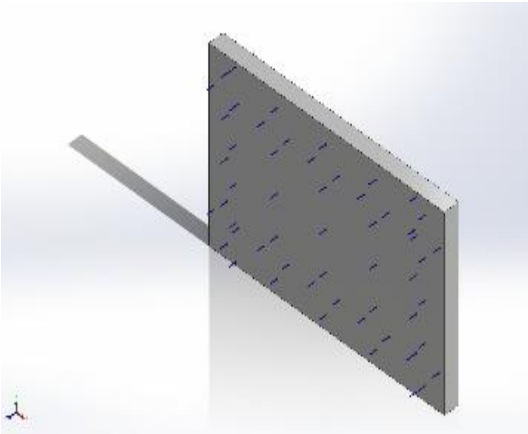
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	Name: **PVC Rigid** Model type: **Linear Elastic Isotropic** Thermal conductivity: **0.147 W/(m.K)** Specific heat: **1,355 J/(kg.K)** Mass density: **1,300 kg/m^3**	**SolidBody 1 (Boss-Extrude1) (test 1)**
Curve Data:N/A		

Thermal Loads

Load name	Load Image	Load Details
Temperature-1		**Entities:** 1 face(s) **Temperature:** 70 Celsius
Convection-1		**Entities:** 1 face(s) **Convection Coefficient:** 16 W/(m^2.K) **Time variation:** Off **Temperature variation:** Off **Bulk Ambient Temperature:** 293 Kelvin **Time variation:** Off

Mesh information

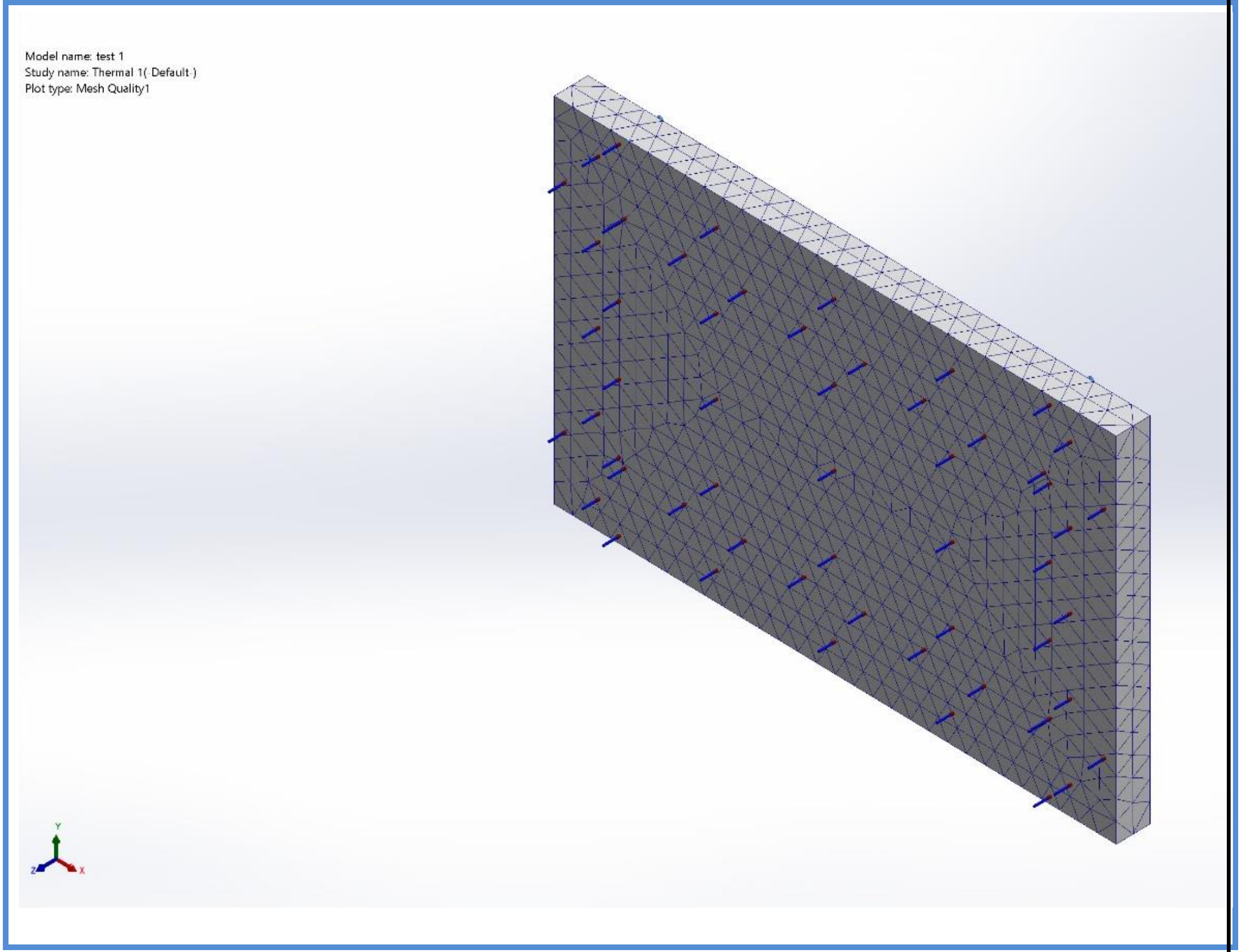
Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	16.5126 mm
Minimum element size	16.5126 mm
Mesh Quality	High

Mesh information – Details

Total Nodes	13093
Total Elements	7602
Maximum Aspect Ratio	3.0759
% of elements with Aspect Ratio < 3	100
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:03
Computer name:	RAZER15

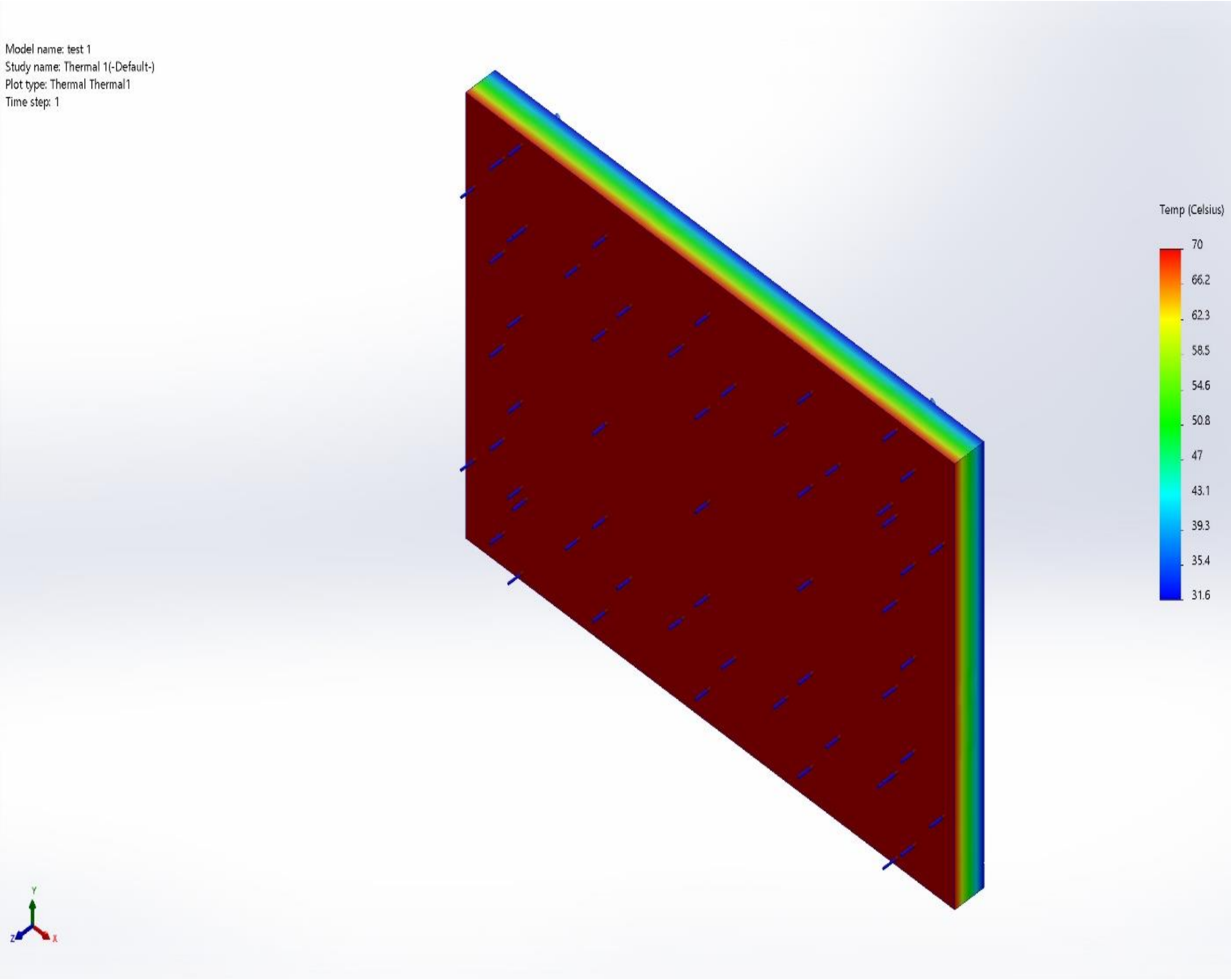
Mesh Quality Plots

Name	Type	Min	Max
Quality1	Mesh	-	-


Model name: test 1
Study name: Thermal 1(-Default-)
Plot type: Mesh Quality1
Y
Z
X

Study Results

Name	Type	Min	Max
PVC	TEMP: Temperature	31.6Celsius Node: 1	70Celsius Node: 3



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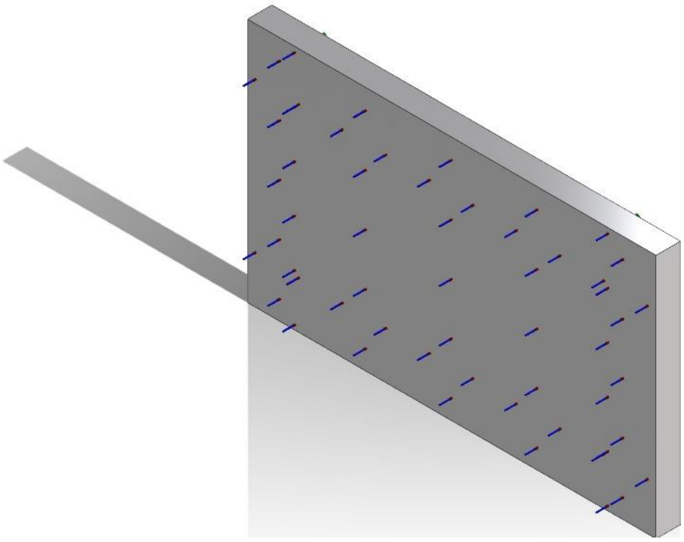
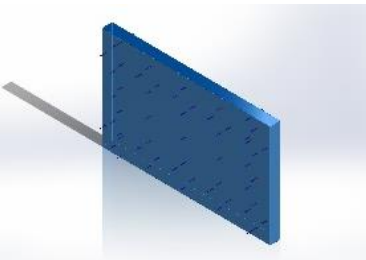
C. Ceramic Case Study

Model Information



Model name: **ceramic**
Current Configuration: **Default**

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
	**Solid Body**	Mass:10.35 kg Volume:0.0045 m^3 Density:2,300 kg/m^3 Weight:101.43 N	C:\Users\maalo\OneDrive\Documents\test 1.SLDPRT

Study Properties

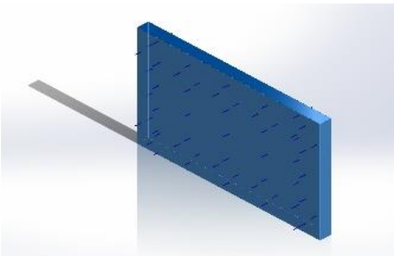
Study name	Ceramic
Analysis type	Thermal(Steady state)
Mesh type	Solid Mesh
Solver type	FFEPlus
Solution type	Steady state
Contact resistance defined?	No

Result folder	SOLIDWORKS document (C:\Users\maalo\OneDrive\Documents)

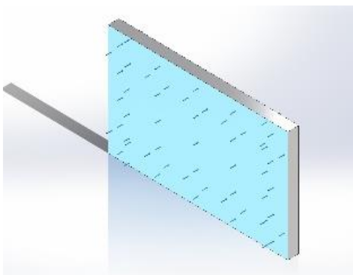
Units

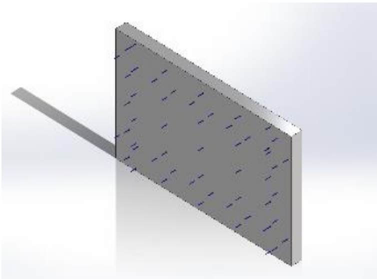
Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** **Ceramic Porcelain** **Model type:** **Linear Elastic Isotropic** **Default failure criterion** **Mohr-Coulomb Stress** **Thermal conductivity:** **1.4949 W/(m.K)** **Specific heat:** **877.96 J/(kg.K)** **Mass density:** **2,300 kg/m^3**	**SolidBody 1(Boss-Extrude1)(test 1)**
Curve Data:N/A		

Thermal Loads

Load name	Load Image	Load Details
Temperature-1		**Entities:** **1 face(s)** **Temperature:** **70 Celsius**

Convection-1		**Entities:** **Convection Coefficient:** **Time variation:** **Temperature variation:** **Bulk Ambient Temperature:** **Time variation:**	**1 face(s)** **16 W/(m^2.K)** **Off** **Off** **293 Kelvin** **Off**

Mesh information

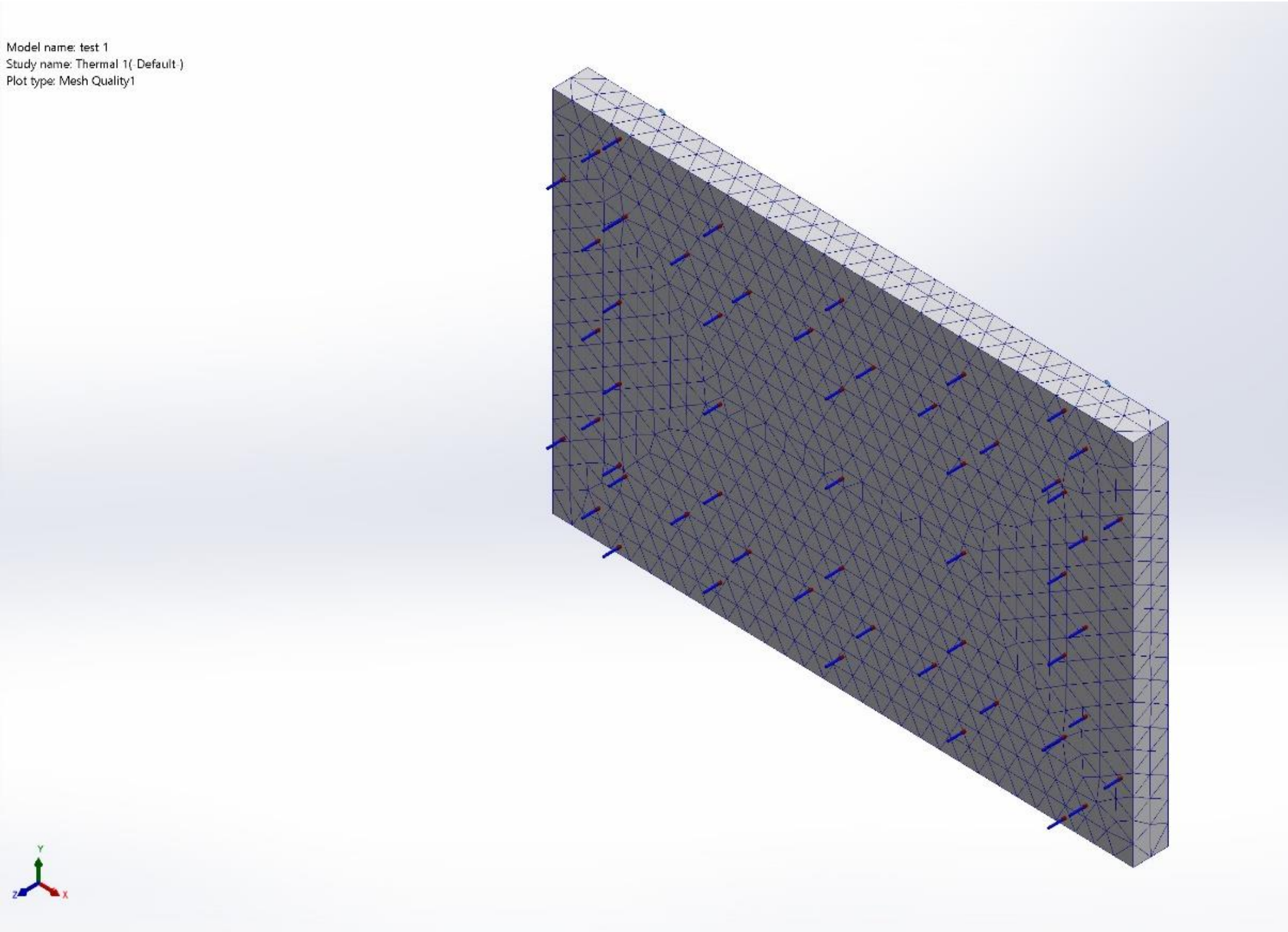
Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	16.5126 mm
Minimum element size	16.5126 mm
Mesh Quality	High

Mesh information - Details

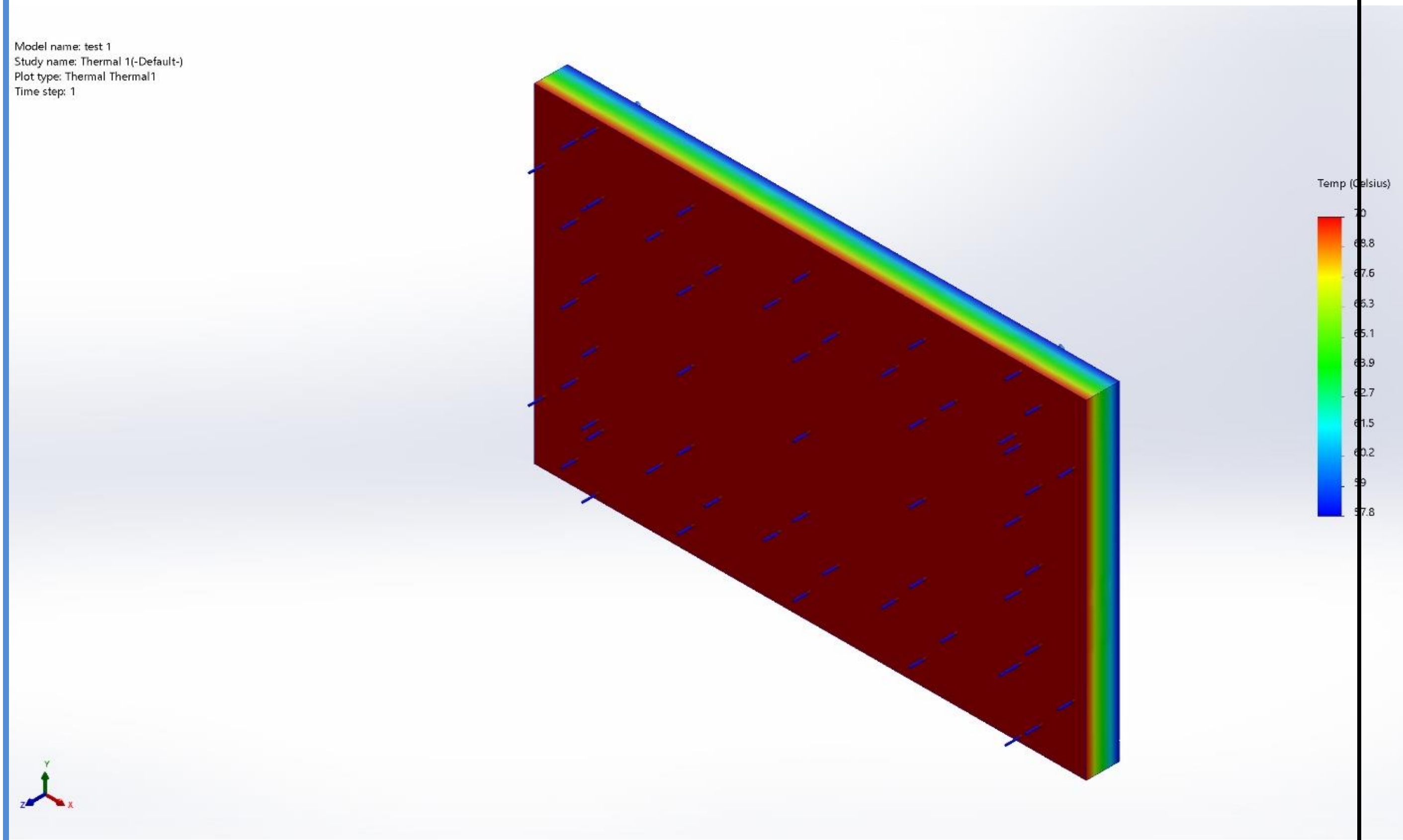
Total Nodes	13093
Total Elements	7602
Maximum Aspect Ratio	3.0759
% of elements with Aspect Ratio < 3	100
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:03
Computer name:	RAZER15

Mesh Quality Plots

Name	Type	Min	Max
Quality1	Mesh	-	-



Study Results name	Type	Min	Max
Ceramic	TEMP: Temperature	57.8Celsius node 1	70Celsius node 3



6. Discussion :

When comparing the thermal properties of ceramic, PVC, and wood, several key differences emerge that highlight their suitability for various applications:

I. **Thermal Conductivity**:

- Ceramic: Generally has a higher thermal conductivity (ranging from 1.4 to 30 W/m·K depending on the type) compared to PVC and wood. This makes ceramics suitable for applications requiring efficient heat dissipation or insulation.
- PVC: Has a lower thermal conductivity (approximately 0.15 W/m·K), making it a good insulator and suitable for use in applications where heat retention is desired.
- Wood: Exhibits moderate thermal conductivity (0.05 to 0.17 W/m·K for hardwoods and softwoods), which is relatively low but higher than PVC. This makes wood useful in building and construction for its insulating properties.

I. Specific Heat Capacity:

- Ceramic: Typically has a specific heat capacity ranging from 0.8 to 1.2 kJ/kg·K, which varies depending on the type of ceramic.
- PVC: Possesses a specific heat capacity around 1.33 kJ/kg·K, indicating its ability to store heat energy, albeit less than wood.
- Wood: Generally has a higher specific heat capacity (1.2 to 1.5 kJ/kg·K), allowing it to absorb more heat before increasing in temperature, which can be beneficial in thermal regulation applications.

III . Thermal Expansion:

- Ceramic: Typically has a low thermal expansion coefficient (around 5 to 10 × 10^{-6} /°C), making it stable under temperature changes and suitable for high-temperature applications.
- PVC: Exhibits a higher thermal expansion coefficient (50 to 150 × 10^{-6} /°C), which means it can expand and contract significantly with temperature changes, a factor to consider in construction and piping.
- Wood: Has an anisotropic thermal expansion, with different coefficients along the grain (3 to 5 × 10^{-6} /°C) and across the grain (20 to 70 × 10^{-6} /°C). This variability must be accounted for in design to avoid warping or structural issues.

7. Conclusion:

Ceramics, PVC, and wood each offer distinct thermal properties making them suitable for different applications. Ceramics are ideal for high-temperature environments and where dimensional stability is crucial. PVC's excellent insulating properties and ease of fabrication make it suitable for electrical and plumbing applications. Wood's natural insulating properties and aesthetic appeal make it valuable in construction and furniture, though its anisotropic thermal expansion needs careful consideration in design. Selecting the appropriate material depends on the specific thermal requirements of the application, balancing conductivity, heat capacity, and expansion characteristics.

8. References :

SolidWorks Essentials: A Step-by-Step Approach to Design and Simulation

by Alex Ishikawa (Author)

Thermal Analysis with SOLIDWORKS Simulation 2022 and Flow Simulation 2022

by Paul Kurowski (Author)

"تأثير مواد البناء المختلفة على حفظ الطاقة بإستخدام تحليل العناصر المحدودة على برنامج سوليد وركس"

إعداد الباحث:

المهندس محمد العبيد

دراسة التحليل الحراري. هناك العديد من أوجه التشابه بين التحليل الحراري والتحليل الهيكلي لمواد البناء المختلفة ودراسة تأثيرها على توفير الطاقة في المباني باستخدام تحليل العناصر المحدودة من خلال برنامج سوليد وركس