CAE simulation 6

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ID : 21800773

Subject : Turbine blade analysis

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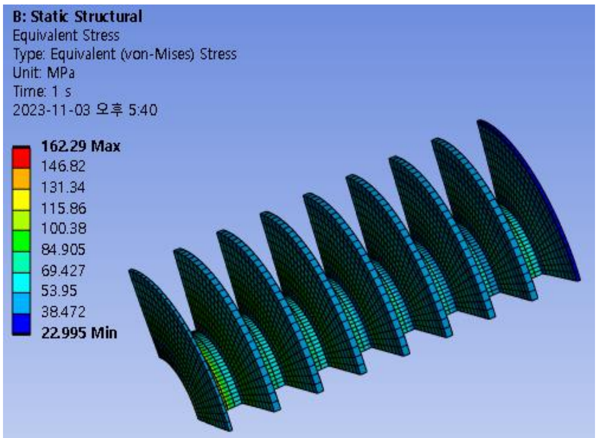
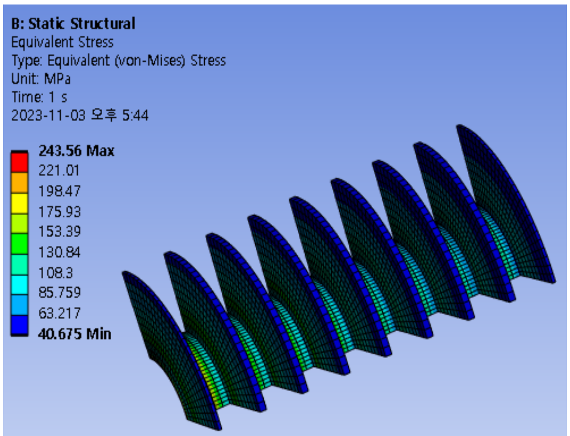
1. Change the material from aluminum alloy to structural steel. Explain differences in the temperature distribution and maximum stress with values of thermal conductivity(k), thermal expansion coefficient (α), and elastic modulus(E).

Table 1. Comparison of equivalent stress according to the material

Aluminum alloy	Structural steel
	

As can be seen in the **Table 1**, structural steel has higher equivalent stress compared to the aluminum alloy when it comes to heat transfer analysis. To get proper analysis, comparison of thermal properties between structural steel and aluminum alloy (6061-T6) must be analyzed.

Table 2. Comparison of thermal properties between structural steel and aluminum alloy

Material Property	Structural Steel (SS400)	Alluminum Alloy (6061-T6)
Thermal expansion coefficient (α)	1.2 x 10^{-5} $°C^{-1}$	2.3 x 10^{-5} $°C^{-1}$
Thermal conductivity (k)	60.5 $W.m^{-1}.°C^{-1}$	temperature dependent
Specific Heat (C_p)	434 $J.Kg^{-1}.°C^{-1}$	875 $J.Kg^{-1}.°C^{-1}$

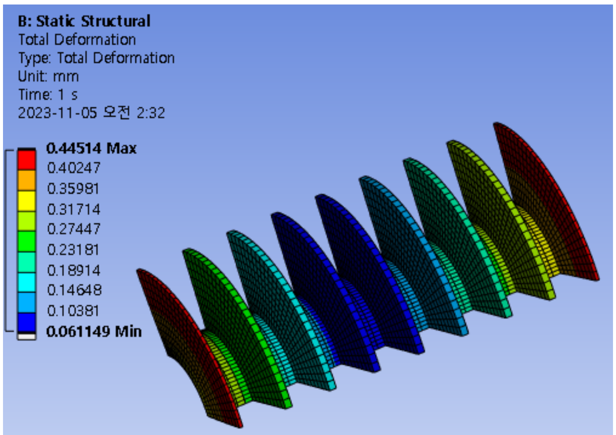
$$\Delta L = \alpha \cdot L \cdot \Delta T$$

$$\epsilon = \frac{\Delta L}{L} = \alpha \cdot \Delta T$$

$$\sigma = E \cdot \epsilon = E \cdot \alpha \cdot \Delta T \ : \textit{thermal expansion and stress}$$

Structural steel has $200\ [GPa]$ elastic modulus, which is about three times larger than that of aluminum alloy, which is $70\ [GPa]$. And thermal expansion coefficient of aluminum alloy is higher than that of structural steel, which is about twice higher value. That means that in the same thermal condition, structural steel has higher thermal stress than aluminum alloy. And, in terms of ΔL, under the same length and thermal conditions, a material with a larger thermal expansion coefficient will have a larger strain. As can be seen in **Table 3**, aluminum alloy has greater length deformation.

Table 3. Comparison of total deformation according to the material

<table>
<tr><th>Aluminum alloy</th><th>Structural steel</th></tr>
<tr><td>


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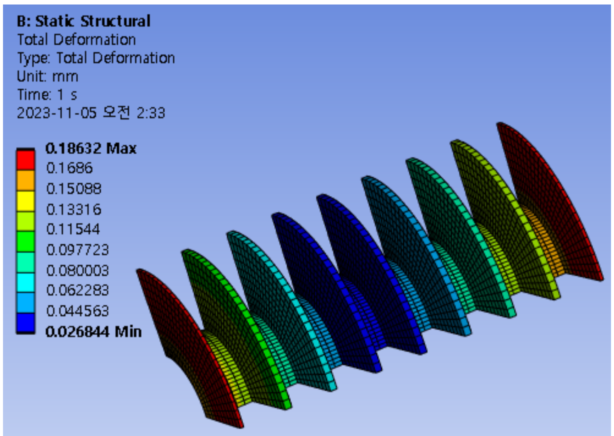

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2. Try a transient heat transfer (initial temperature of $22℃$) and transient structural analysis. Discuss on the difference between the steady and transient analysis.

In the transient heat thermal, the result shows that it takes about only $1\ [sec]$ for reach to the steady state of equivalent thermal stress. As same with steady thermal condition, each side of the blade was set with frictionless support. And the result is as follows:

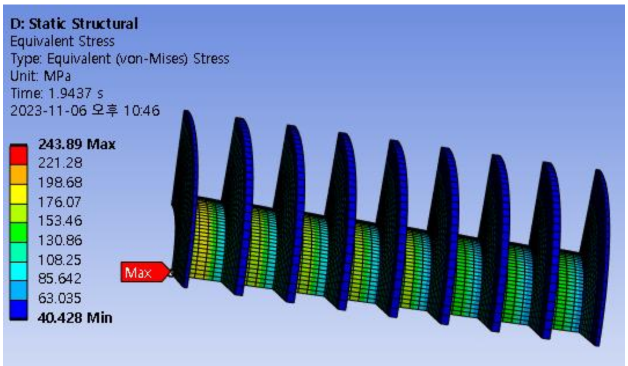

Figure 1. Equivalent stress in transient heat thermal condition (steady state)

Figure 1 shows that final equivalent stress with transient heat thermal condition, which is the equivalent stress in the steady state, is equal to that with steady thermal condition. However, in the transient condition, we are interested in the change of equivalent stress. The result with tabular data is as follows:

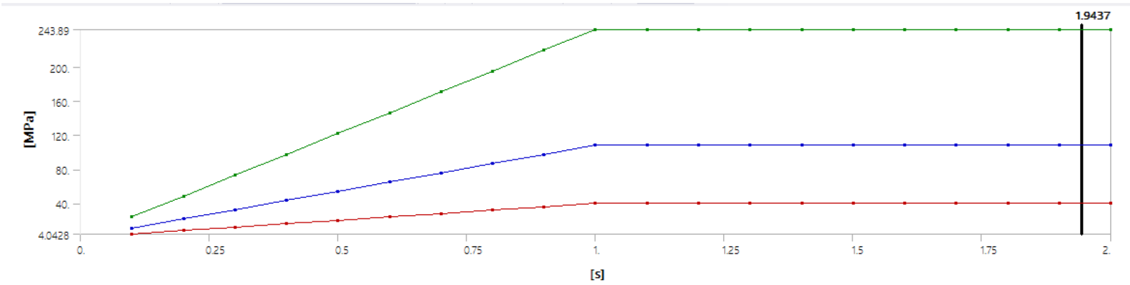

Figure 2. Transient heat: temperature result

Tabular Data

	Time [s]	Minimum [MPa]	Maximum [MPa]	Average [MPa]
1	0.1	4.0428	24.389	10.861
2	0.2	8.0856	48.778	21.721
3	0.3	12.128	73.167	32.582
4	0.4	16.171	97.556	43.443
5	0.5	20.214	121.95	54.303
6	0.6	24.257	146.33	65.164
7	0.7	28.3	170.72	76.024
8	0.8	32.342	195.11	86.885
9	0.9	36.385	219.5	97.746
10	1.	40.428	243.89	108.61
11	1.1	40.428	243.89	108.61
12	1.2	40.428	243.89	108.61
13	1.3	40.428	243.89	108.61
14	1.4	40.428	243.89	108.61
15	1.5	40.428	243.89	108.61
16	1.6	40.428	243.89	108.61
17	1.7	40.428	243.89	108.61
18	1.8	40.428	243.89	108.61
19	1.9	40.428	243.89	108.61
20	2.	40.428	243.89	108.61

Figure 3. Detailed tabular data