Effects and Analysis of Thermal Stresses on Core Setters for Aerospace Applications

Authors:
Philip Geers – Blasch Precision Ceramics
William Russell – Blasch Precision Ceramics

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Ceramic Properties

Ceramic cores, like other fired ceramic shapes are weakest in their green (unfired) condition.

During this weakest state, physical stresses (gravitational and other) can affect the ceramic body causing deformation.

Stresses in Ceramic Parts

Ceramic shapes can develop internal stresses through the production (forming) process, drying process, firing (sintering) and finally the cooling process.

Examples of these stresses are residual stresses and pyroplastic deformation.

Residual stresses develop in the tiles independently of the applied forces, and arise during the temperature changes during processing. As the body can have temperature disparity of hundreds of degrees while sintering, the stresses are absorbed by the tile while it remains plastic and are realized after the tile becomes fully solid. These stresses are exacerbated by complicated geometry and size variance.

Ceramic deformation and stresses during firing can be caused by gravity, and Pyroplastic deformation during the sintering process. Pyroplastic deformation occurs due to viscous flow or dislocation motion in the ceramic. These properties vary depending on the ceramic composition used, but effect all ceramics. The effects of these stresses can be seen in simple pyrometric cones used commonly in refractory sintering.

While Pyrometric cones slump due to the development of a glass phase, not sintering and their deformation is a function of temperature. This example roughly shows that different ceramics (different ceramic cone compositions) are affected differently by the same temperature exposure.

Stresses in Ceramic Cores

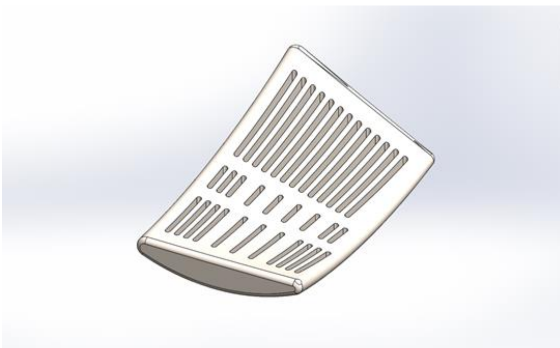
Ceramic cores are affected by both these stresses, and the variability caused by these effects can alter the geometry and tolerances of ceramic cores, negatively affecting their properties, increasing scrap and variability in the final casting.

In this study we will review FEA (Finite Element Analysis) of the stresses on these core bodies and processing methods to help constrain and control these variances.

Here is 3D Image of generic core.

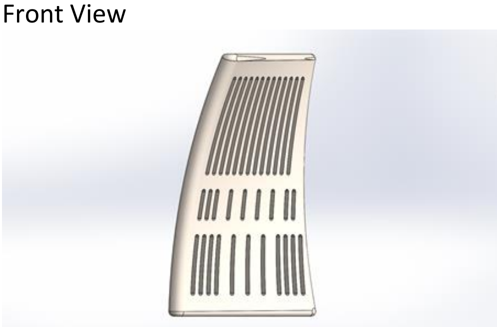
For this model the core is roughly 4 inches wide and 7 inches long.
The end profile rotates 30 degrees along a curve.

ISO View



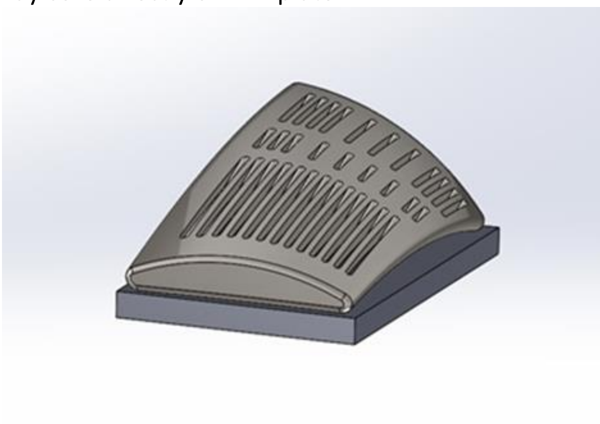
Side View

Front View



Firing Method 1:

Lay core directly on kiln plate.

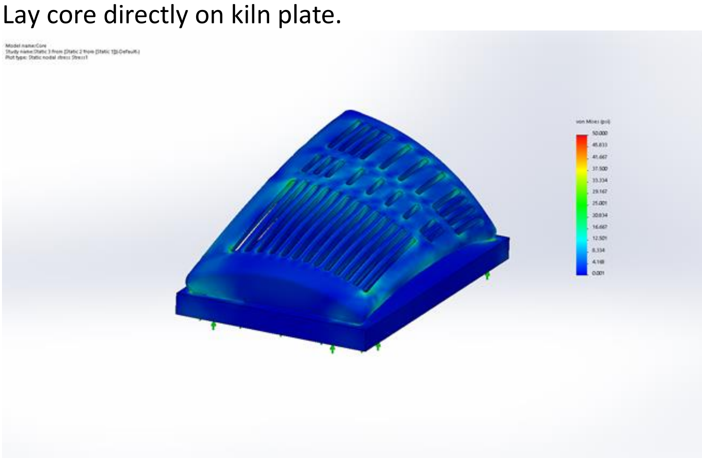


Advantages:

- Fast
- Not geometry dependent
- Can maximize firing capacity with kiln furniture

Firing Method 1 FEA:

Lay core directly on kiln plate.



Only external force besides uniform temperature is gravity.
The corners of the features show highest stress concentrations
Max von Mises stress seen by this part is more than 50 PSI
Image scale 0 - 50 PSI

Firing Method 2:

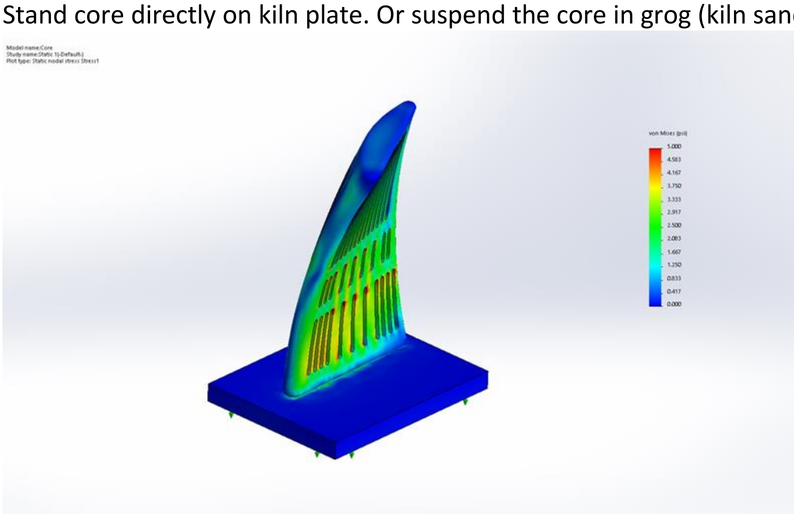
Stand core directly on kiln plate. Or suspend the core in grog (kiln sand) during firing.

Advantages:

- Fast
- Maximize firing capacity
- Stresses in Ceramic Cores

Firing Method 2 FEA:

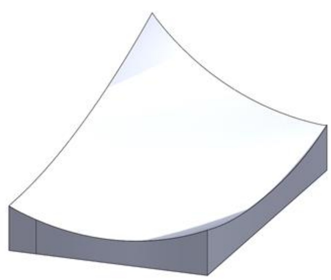
Stand core directly on kiln plate. Or suspend the core in grog (kiln sand) during firing.

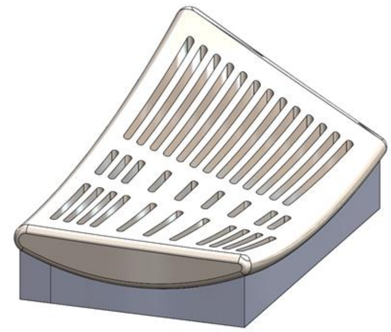


Only external force besides uniform temperature is gravity.
The corners of the features show highest stress concentrations
Max von Mises stress seen by this part is more than 5 PSI
Images scale 0 – 5 PSI

Firing Method 3:

Fully Supported Profile using Ceramic Core Setter.

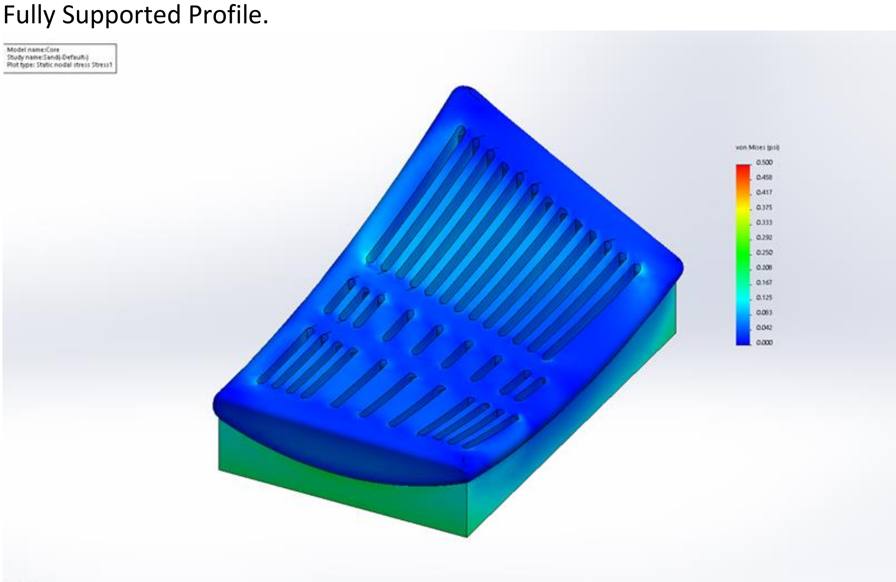




Advantages:
Core stability in firing

Firing Method 3 FEA:

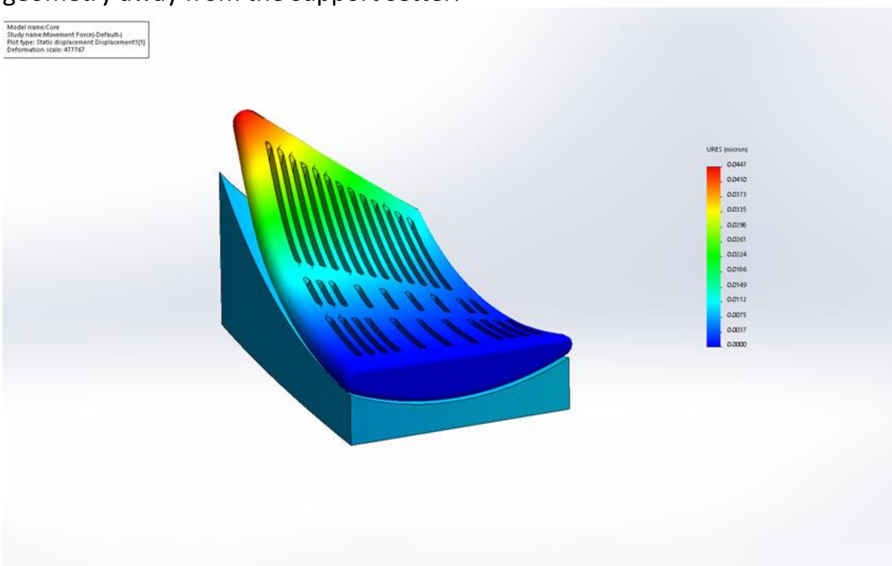
Fully Supported Profile.



Fully Supported Profile.
Image scale 0 – 0.5 PSI

As shown in the FEA, while the even support of the ceramic core setter has removed associated stresses from gravitational effects, what about internal stresses of the ceramic?

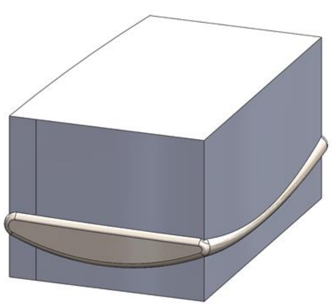
Here a small residual stress has built up in the ceramic core causing movement / deformation in the geometry away from the support setter.

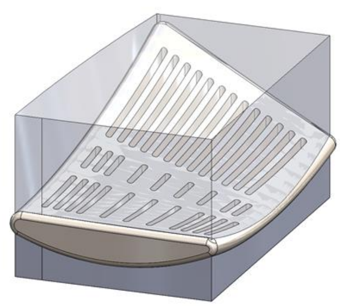


Note the upper left corner now being deflected away.

The practice of putting the ceramic core in a grog (kiln sand) filled tub can be used to reduce this, but the internal stresses may be higher than the resistance from the grog and this same deformation can occur.

Now an upper ceramic setter is added, which mass is greater than this internal stress.





This “setter sandwich” uses the force of the upper setter to counter the ceramic core stress and keeps the part at its intended geometry and
tolerances while the part is sintered.

3D Ceramic Core Setters

By using these different analysis studies, we have shown how we can best combat the inherent stresses in producing, processing and sintering ceramics cores. This is to use 3D matching ceramic setters to encapsulate the ceramic core during the sintering process.

What properties are required for a ceramic core setter to effectively work in the ceramic core sintering (firing) environment?

-Resistance to slumping and movement after repeated firing.
-High tolerance capability of the ceramic setter.
-The ability to make complicated geometry to match the ceramic core.

Blasch has 36 years of ceramic setter experience to assist you in your ceramic core setter requirements.