BLASCH
PRECISION CERAMICS

Where your ideas take
SHAPE in **CERAMIC**

"Improving Thermal Conditions and Reducing Process Costs for Core Setters in Aerospace and IGT Applications"

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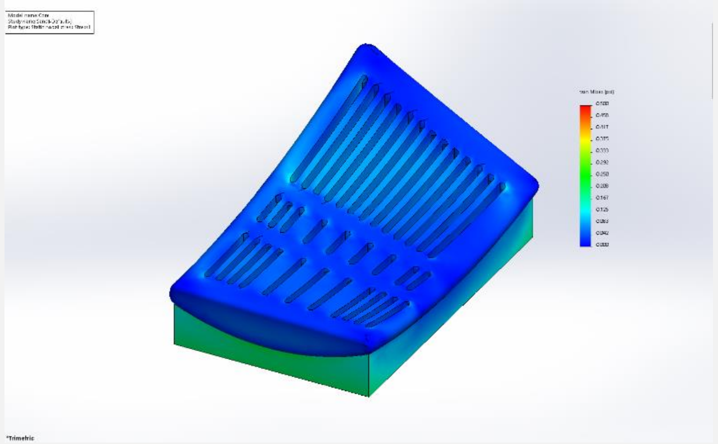
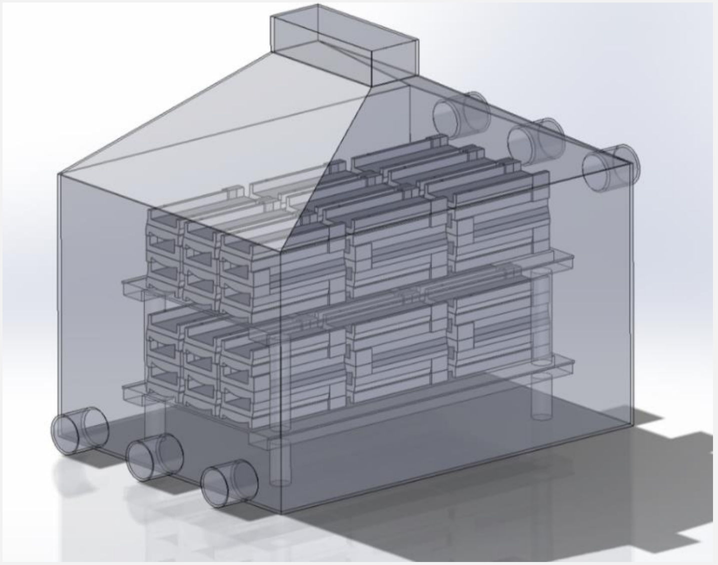
ICI Technical Conference 2019, St. Louis MO

Agenda:

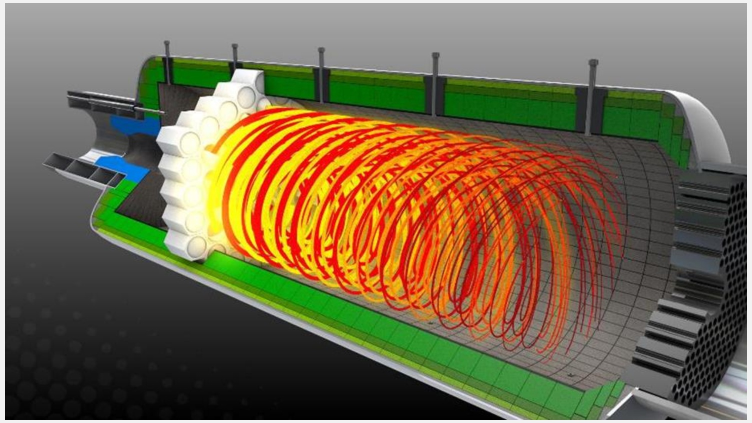
- Introduction of Blasch Ceramics
- Review ways to sinter cores
- Evaluate these processes for thermal efficiency
- Explore kiln loading and weight reduction options for setters and the cost saving potential for both
- Review core setter material selection

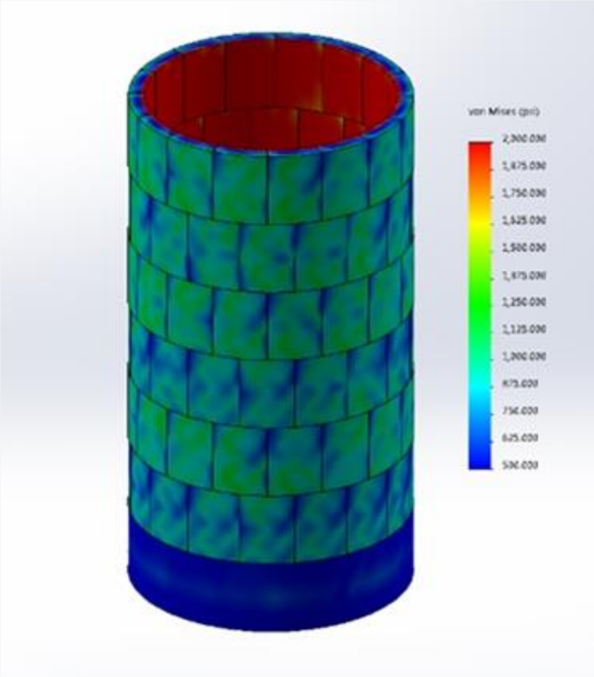




Blasch Precision Ceramics:

- Founded in 1979 (Celebrating 40 years)
- Employee-owned manufacturer of engineered industrial ceramic shapes and systems
- Headquarters in Albany, NY with production, sales and representation world wide
- ISO 9001 Certified since 1999
- Provide products for the Specialty Alloy, Investment Casting, Chemical / Petrochemical, Process Heating, Power Generation and Mining Markets.
- Manufacturer with significant engineering, design and research & development capability, and systems design experience





Blasch Precision Ceramics:

Products for Specialty Alloys (Investment Casting/Super Alloy Production)

InterLok™ Segmented Linings

ProCaster™ Crucibles

Atomization Nozzles

Core Setters

Launders and Tundishes

Sample Cups

Setters and Kiln Furniture for cores and core setters

Stopper Rods

Previously in our paper,

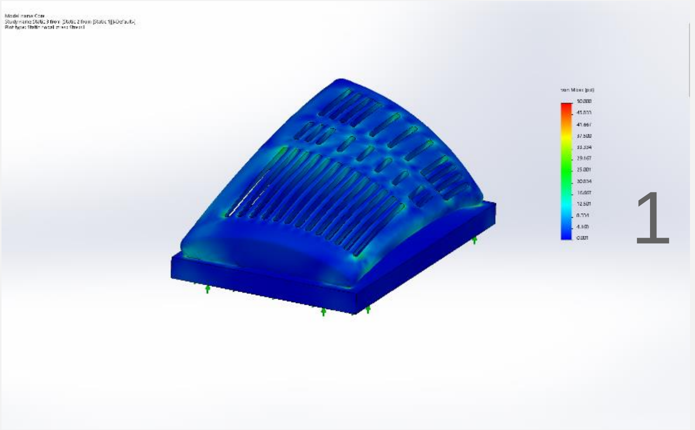
“Effects and Analysis of Thermal Stresses on Core Setters for Aerospace Applications”

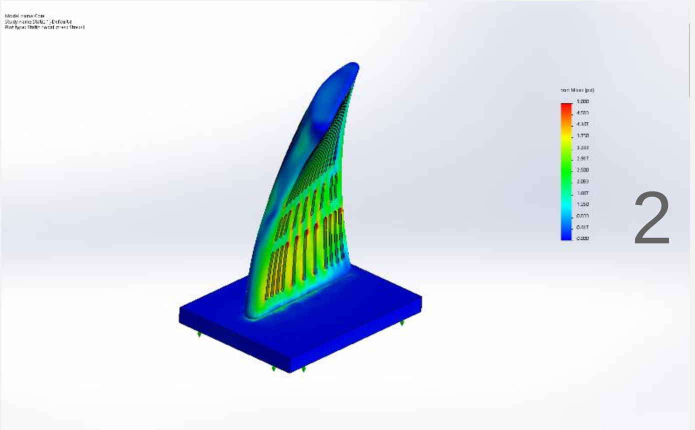
- **We analyzed thermal stresses on Core Setters with various sintering configurations.**

- **Our results showed where stresses formed in cores, and how providing support and encapsulation of the core part in a 3D geometry matched core setter can counteract these stresses.**

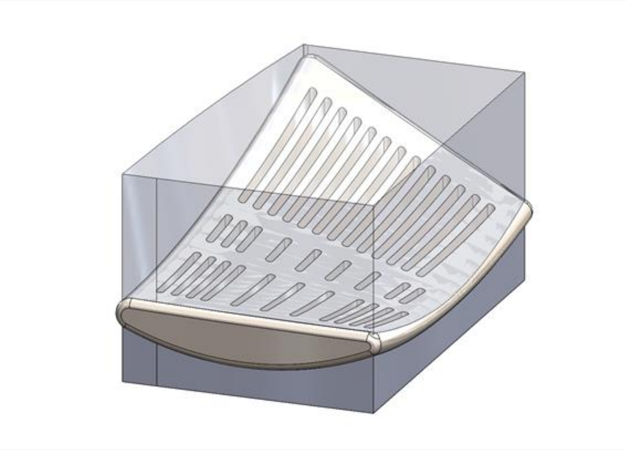
- **In review: Casting and sintering of the ceramic core will cause stresses in the ceramic. In addition, having higher variabilities in the sintering, can result in higher variabilities in the stresses and geometry deformation in the ceramic cores.**

Firing Methods:





Minimum support



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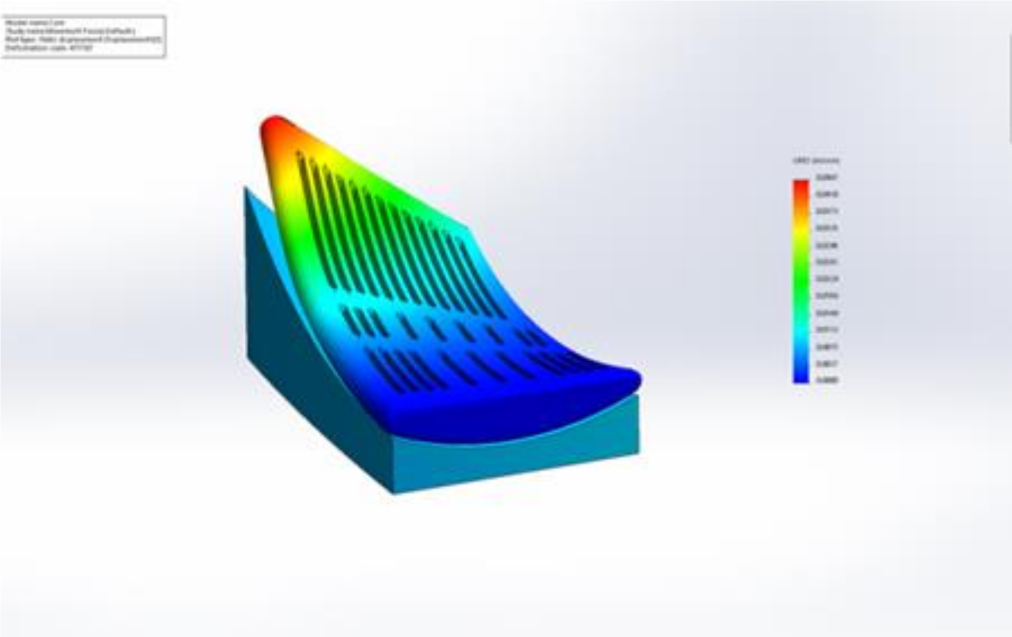
Ceramic 3D geometry setter fully supported

Core sintering and Kiln orientation

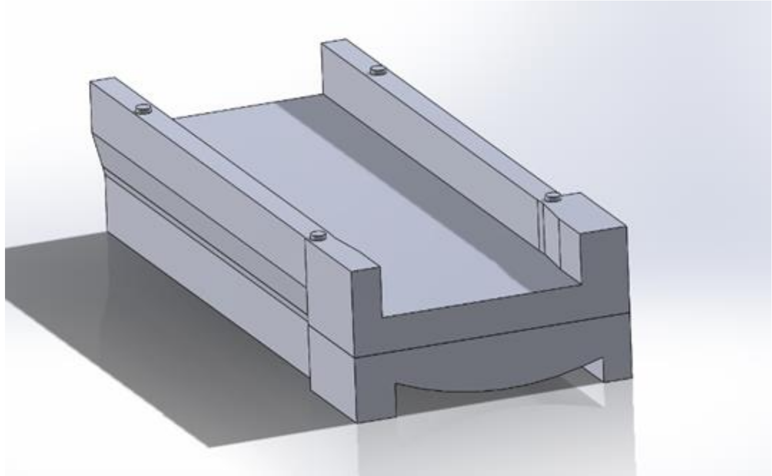
Given the issues caused by heating variability in the sintering process:

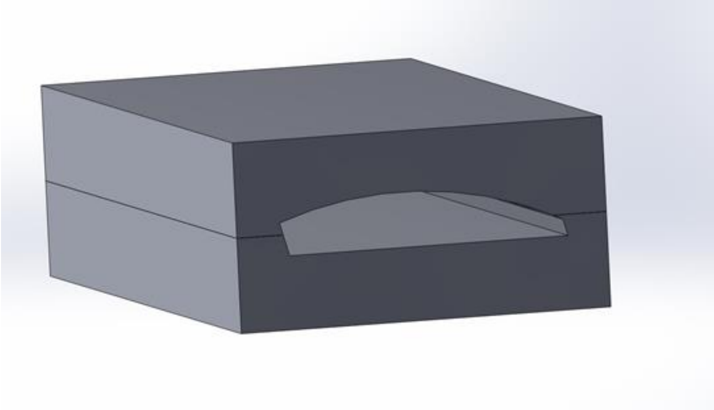
We can summarize that having more consistent and even heating through the ceramic core when being sintered, we can reduce stresses and improve part consistency.

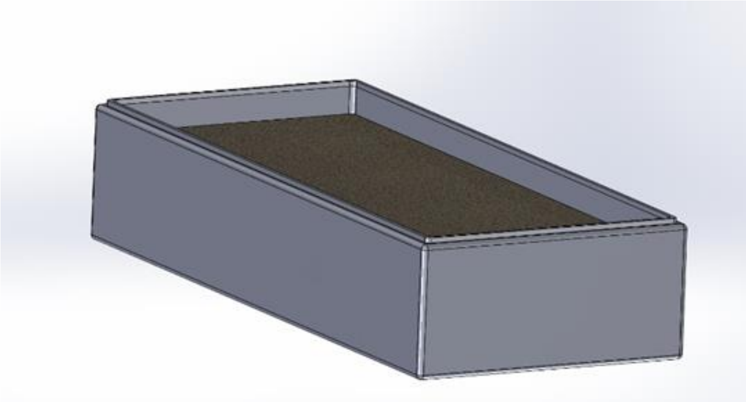
What ways can this consistency be improved?



Core sintering and heat transfer







Different ways to sinter cores:

- To start we will evaluate the thermal profile of a ceramic core in a thermally optimized core setter, an unoptimized core setter and a core in sand (grog) while being sintered.

- Top we have a ceramic core setter which has geometry optimized for even thermal heat transfer accomplished by keeping an even wall thickness in the part profile.

- Middle, we have a ceramic core set in a not thermally optimized core (block) setter

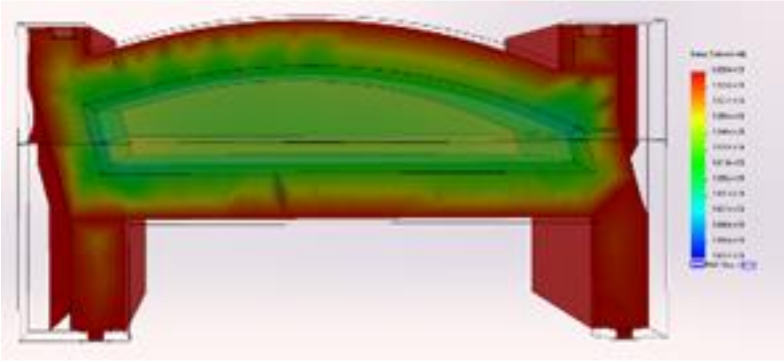
- Bottom, we have a ceramic core set in a sagger filled with sand (grog).

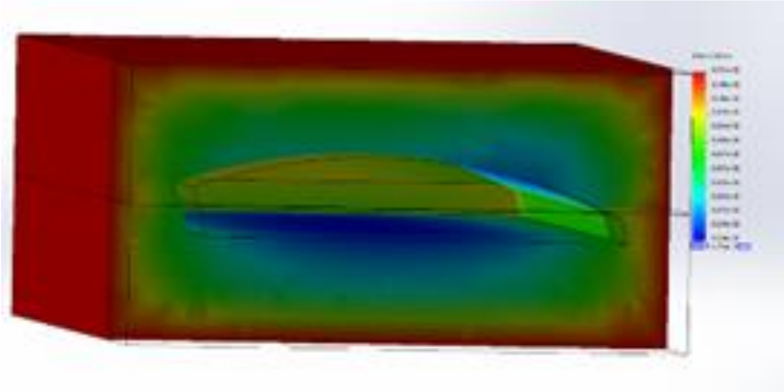
Core sintering and heat transfer

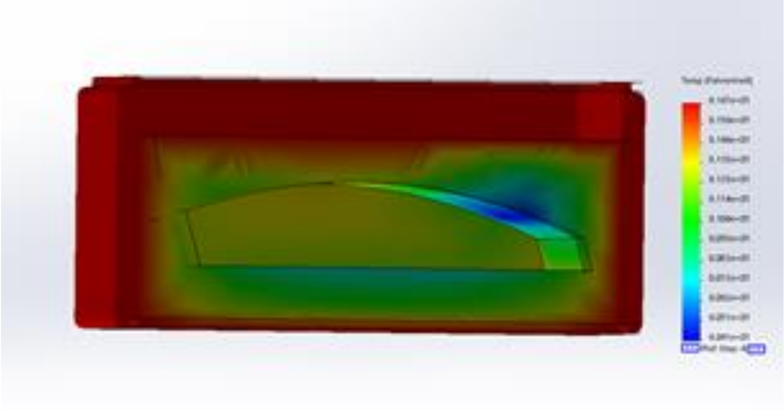
In this Finite Element Analysis (FEA) these items are heated from the outside with thermal energy. In this case 1500F (820C).

- In the top example, a core in a core setter with an optimized wall thickness has reached a higher internal temperature sooner. This is due to the reduced total mass of part, requiring less thermal energy to be heated. Also, we can notice the more uniform thermal temperature profile of the setter around the core.

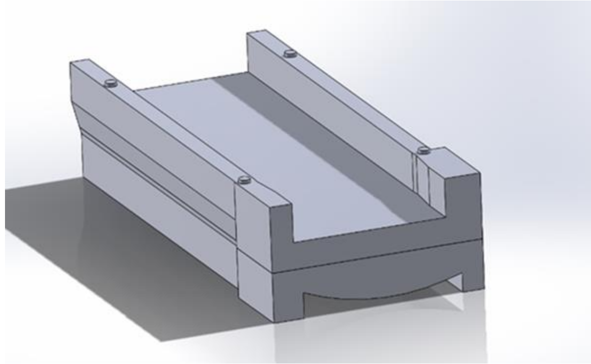
- Conversely in an non thermally optimized core block setter (middle) and sagger filled with sand / grog (bottom) we can see the blue spots in areas around this setter example and the example of the core in sand (grog).
- This variance is caused by the relatively uneven thermal mass of these unoptimized setters, which require more heat (thermal energy) in the thicker areas to bring the core up to the same sintering temperature.

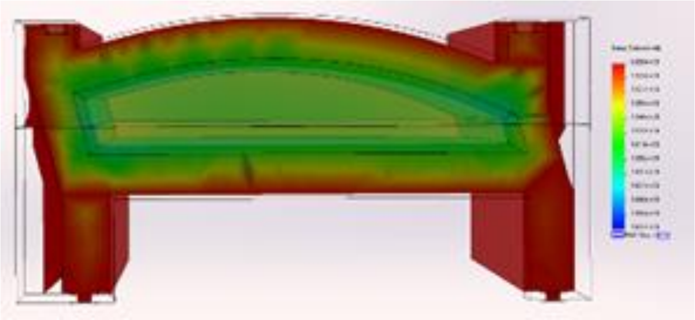


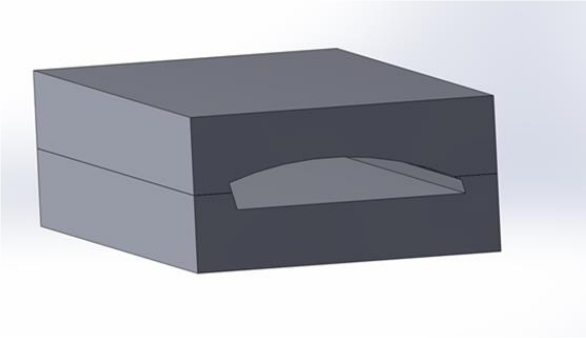


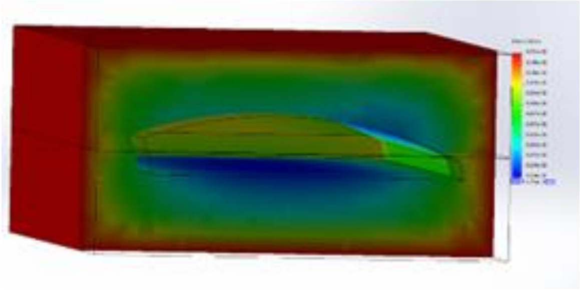


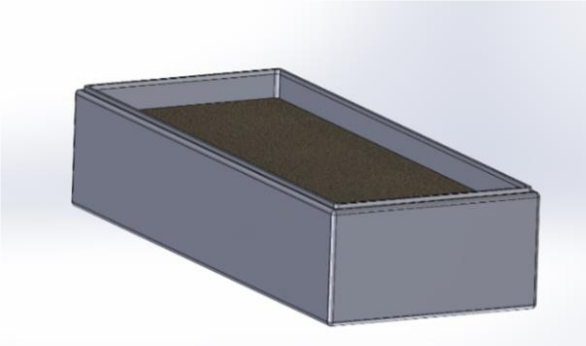
Core sintering and heat transfer

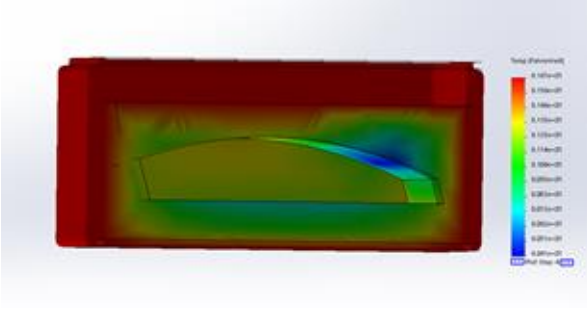












From this review, the analysis is showing that having the core set into a thermally optimized ceramic core setter during processing, will provide a more even sintering temperature quicker, along with using less thermal energy to get to the planned sintering temperature required

Kiln Loading Optimization

- Now that we have optimized the geometry that we are firing the ceramic core in, let's review different organization profiles where we can improve and optimize the orientation of the parts in the kiln used for sintering

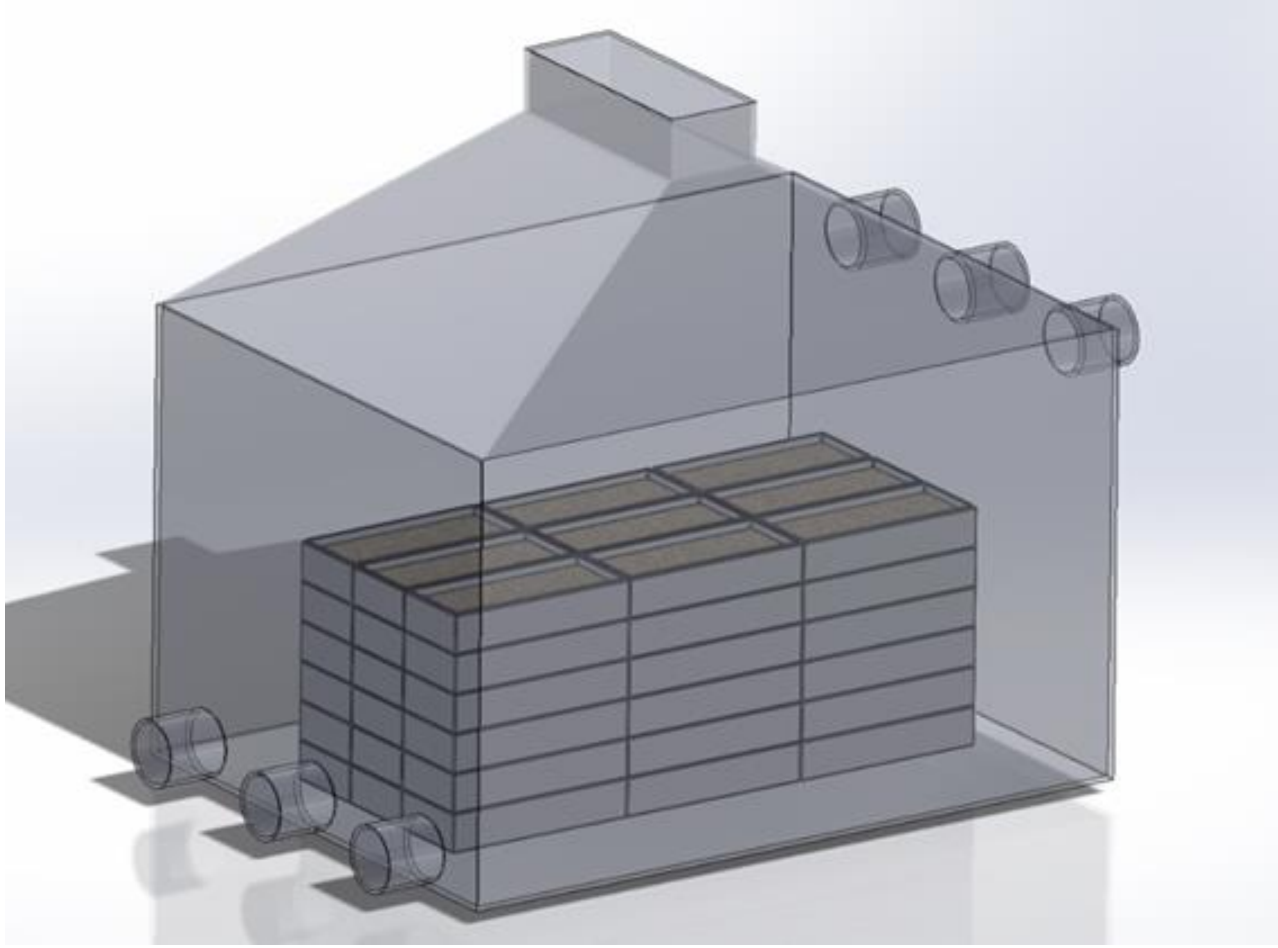
- We will assume that our kiln is evenly heated with no apparent "dead spots" for heating. An example of this even flow is shown here in this Computational Fluid Dynamics (CFD) model

Kiln Loading Optimization

- With an evenly heated kiln, we can focus on setting up and loading parts into the kiln for the best orientation for even heating and load optimization

- In this example we show an orientation of saggers with sand / grog are set into the kiln tightly spaced together

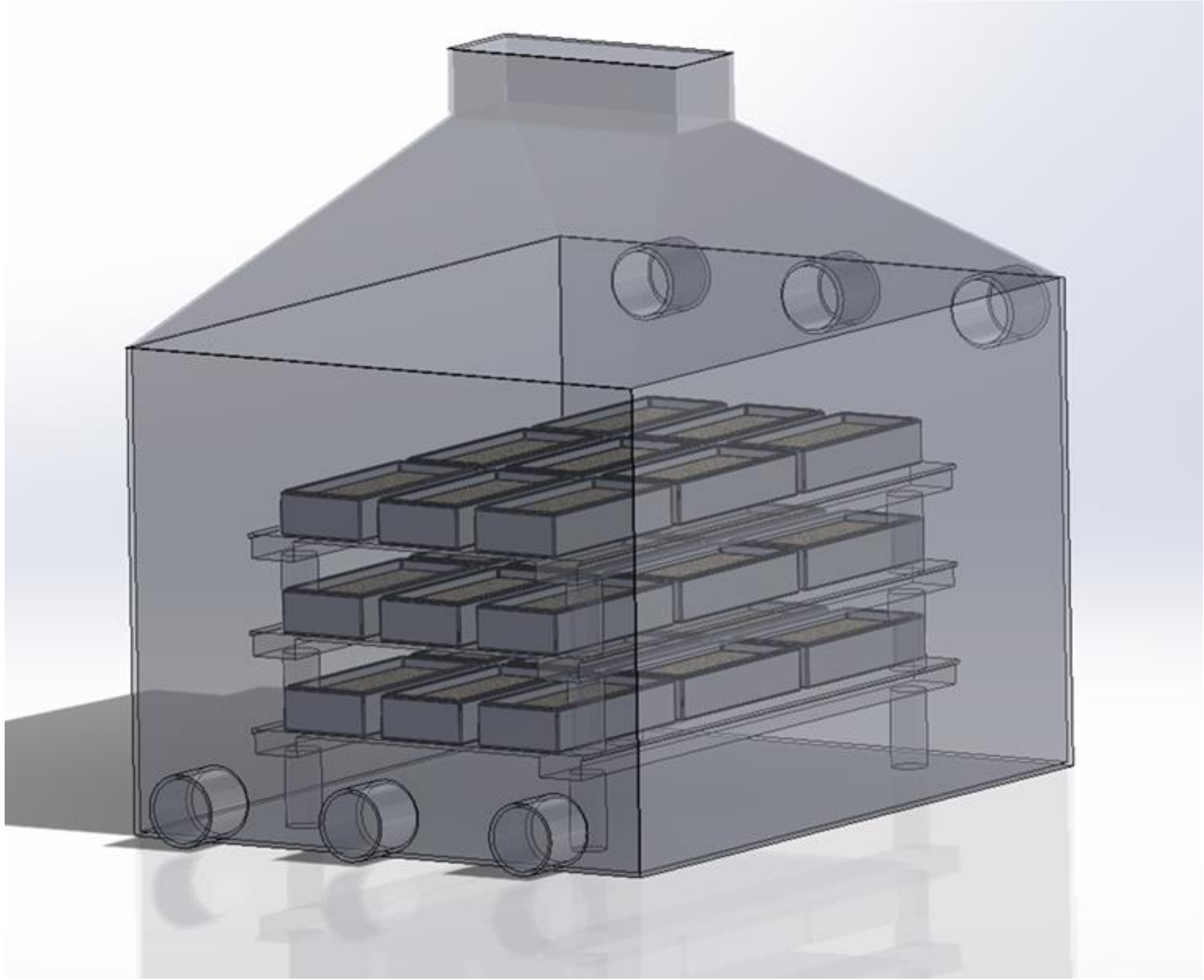
- With the layout as shown, the heat profile for the large block of setters will act as one large object for heating, and similar to the FEA shown for the individual saggars, there are going to be large variants in the temperature distribution and more energy required to bring the center saggers up to the required temperature.



Kiln Loading Optimization

- In this next example, the saggars are spaced with gaps around them. This is done by using kiln furniture interlocking beams and plates.

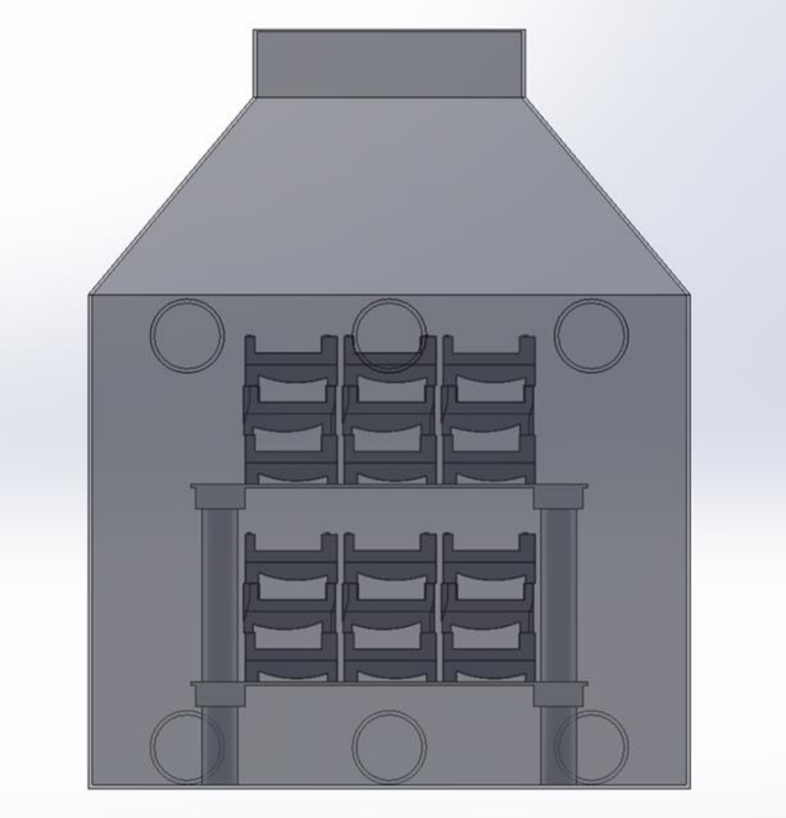
- The kiln furniture structure allows this orientation, and in addition, is made from a thermally conductive ceramic which assists in heat transfer.

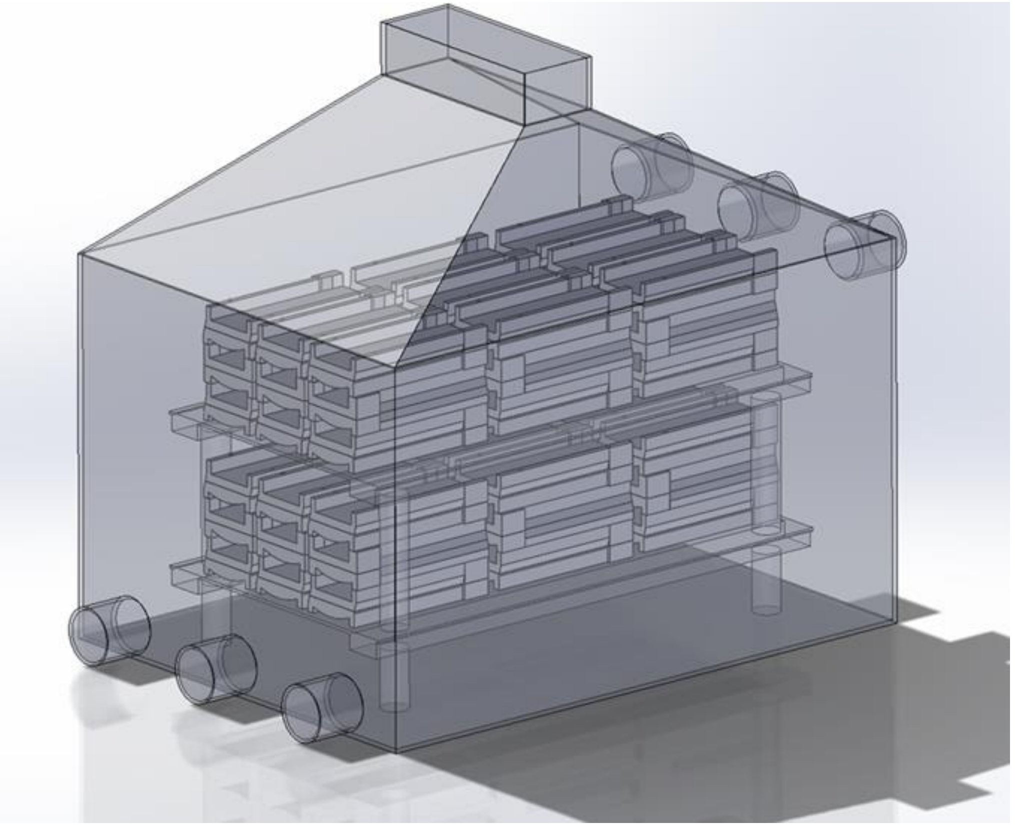


Kiln Loading Optimization

- In this next example, we show a similar stacked kiln orientation, but now utilizing the optimized ceramic core setter

- This orientation using the optimized ceramic core setter design, we have integrated stacking capabilities into the core setter which allows increased heat transfer around the setter and reduces the amount of kiln furniture required to accomplish this.

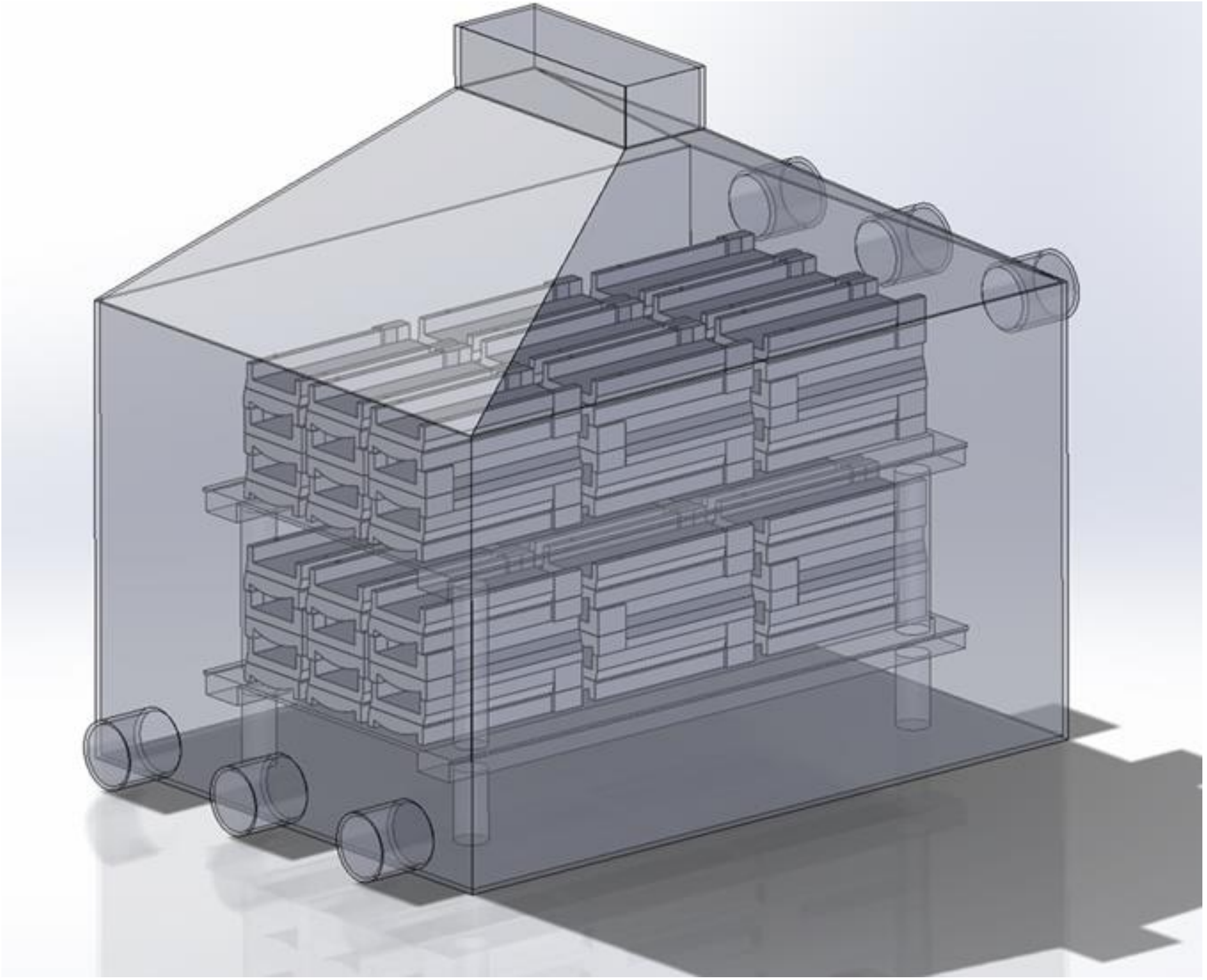




Kiln Loading Optimization

- From the provided examples, we see that organizing the kiln using a planned kiln furnace layout and even spacing of parts will allow the parts to have more even heating and will allow better thermal profiles for sintering no matter what type of core firing technique is utilized.

- By adding stackable design features into the core setter, we can optimize the thermal profiles even further.

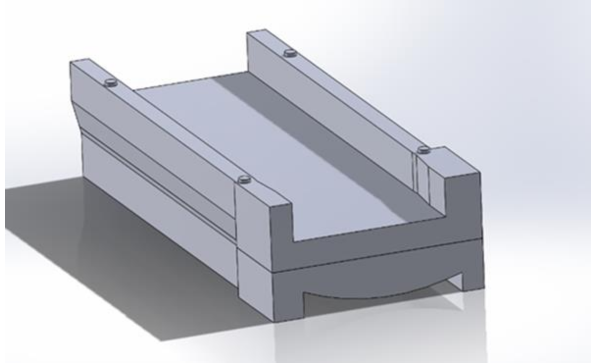


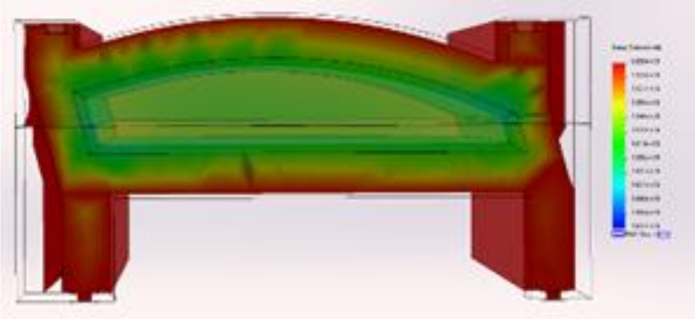
Cost Savings & Optimization – Increased Yield

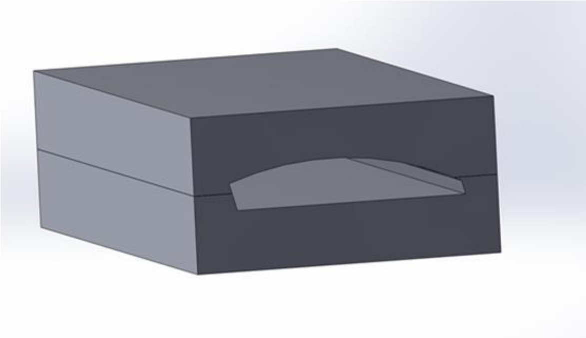
Even sintering from an optimized ceramic core setter during processing, will provide a more even sintering temperature.

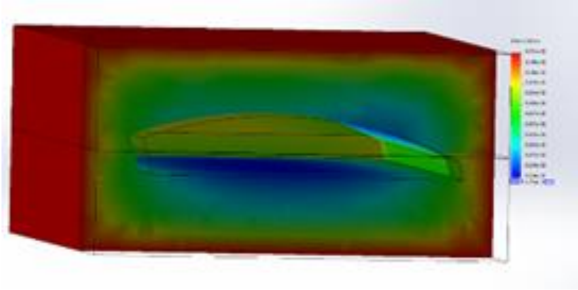
With even sintering, thermal variance is reduced and core part yields are increased.

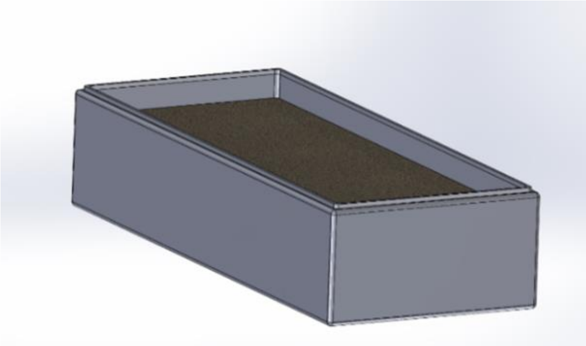
Every process is different, but an yield increase of even 5% can be a very dramatic improvement to the foundry for keeping delivery dates and reduction in production costs.

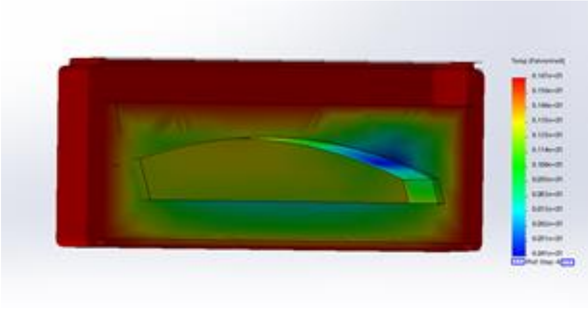












Cost Savings & Optimization – Reduced Mass = Reduced Energy Required

In our example we have reduced the core setter from a basic solid to an optimized shape, reducing the mass by 40%.

6” X 6” X 12” Core setter “box” = 45 lbs (20kg)

40% reduction of 45 lbs = 18 lbs reduced per core setter pair

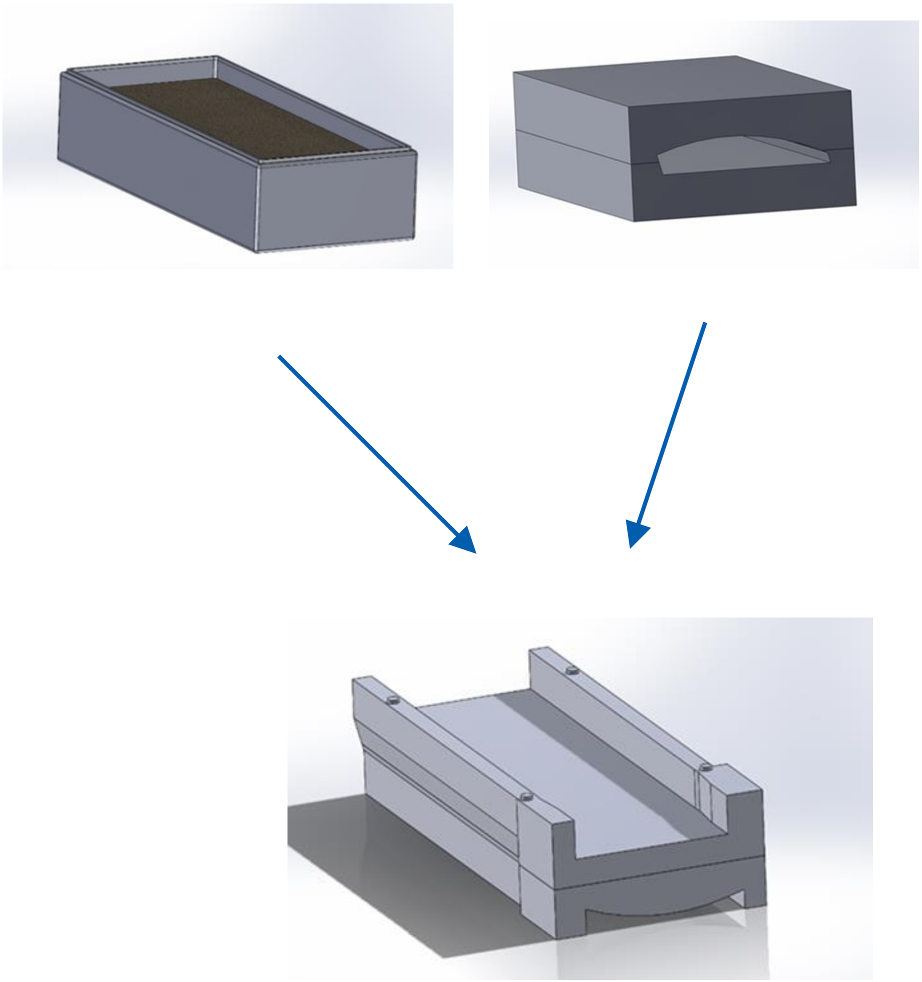
In a loaded batch kiln: 225 core setter sets X 18 lbs = 4050 lbs

4050 lbs of extra material heated to 1832 F (1,000 C)

Energy Required = Mass*specific heat*temperature increase

Energy Required = 4,050lbs *0.21 BTU/lbF X 1832 F

Energy Required = 1,558,116 BTU per firing



Cost Savings & Optimization – Reduced Mass = Increased Throughput

Continuing:

3 firings per week in example kiln = 156 firings per year

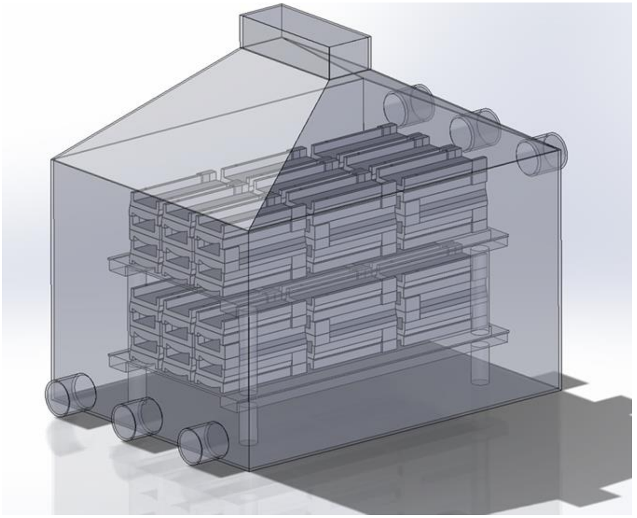
Energy Required = 1,558,116 BTU per firing X 156 = 243,066,096 BTU per kiln

With 4 kilns you could save nearly one billion BTU per year

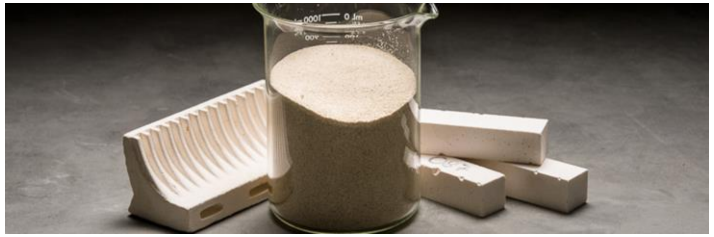
This also effects throughput

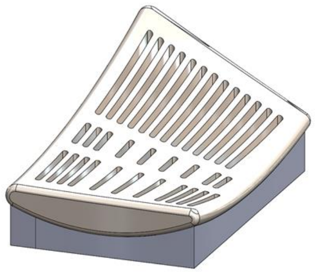
Reduction in kiln and setter mass can allow you to reach your required process temperature in the core sooner.

Reaching the required process temperature sooner can allow a faster kiln cycle time in turn, reducing sintering time and increasing kiln throughput



Core Setter Material Selection





What are the best characteristics for the material used for the core setter and the material properties that would be ideal for the application?

- Thermal Shock resistance:

The environment of the kiln sintering process requires heat cycling from ambient temperature to 1,200C, so the ceramic must be highly resistant to thermal cycling, called thermal shock

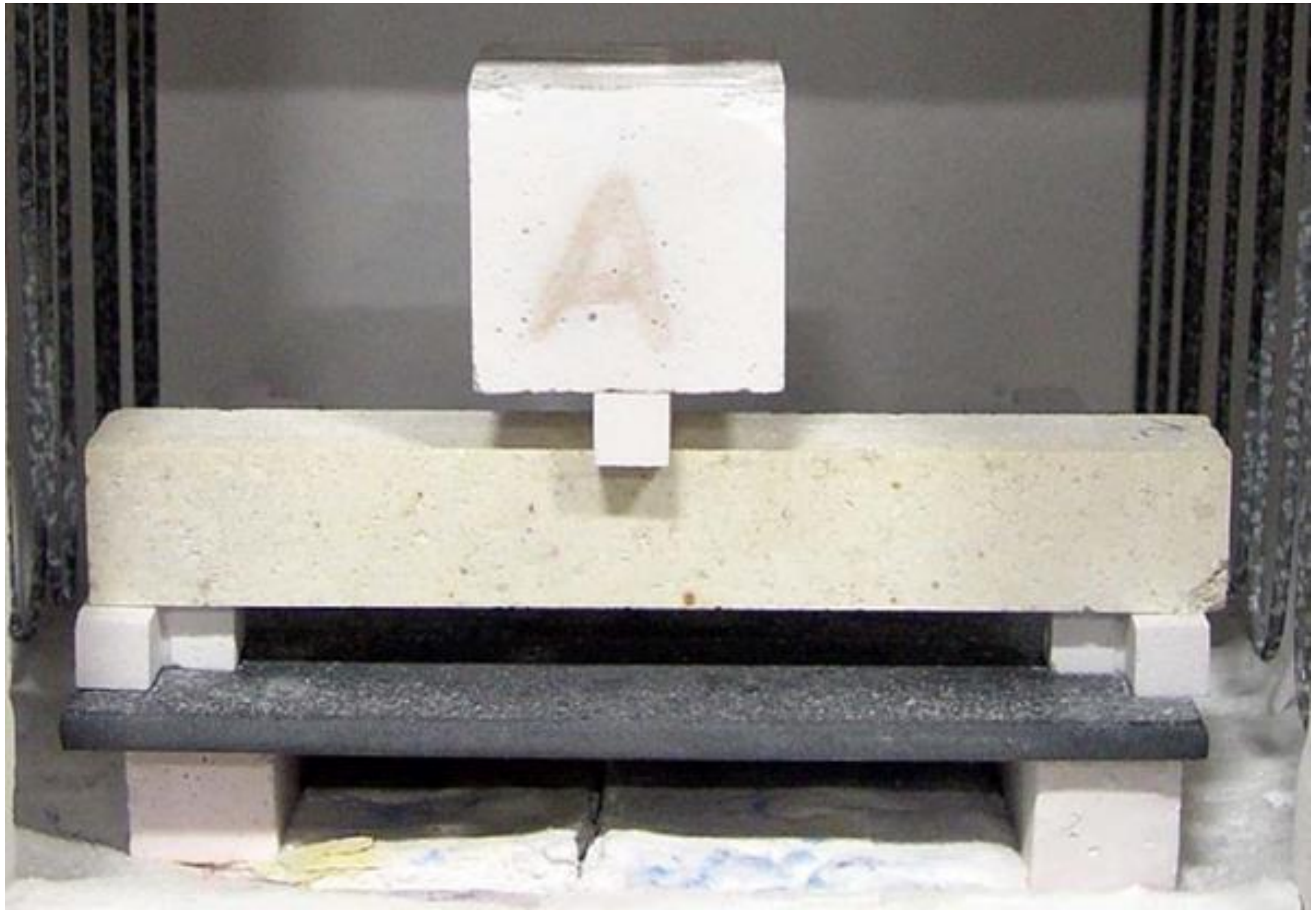
- Part geometry tolerance:

As the designs of aerospace blades cores designs continue to evolve, they are increasing in complication and the designs of the cores follow. To provide a matched 3D designed core setter to properly hold the core, high as-cast tolerances are required in the core setter for the part to function properly. Cast part tolerances near the range of .005" per inch (.5%) are needed in the core setter. Thus a production process must be used for the core setter forming process that can attain these tolerances

Core Setter Material Selection

- Ceramic creep resistance:
As the ceramic core setter thermally cycles multiple (hundreds) of times, the ceramic needs to resist any movement or change in tolerance through these cycles

This phenomenon can be tested by doing a three point bend creep test. In this test a single point weight it placed on a test bar of material, and the material is heated for multiple hours. The test bar is then measured for movement. The setup of this test is shown here

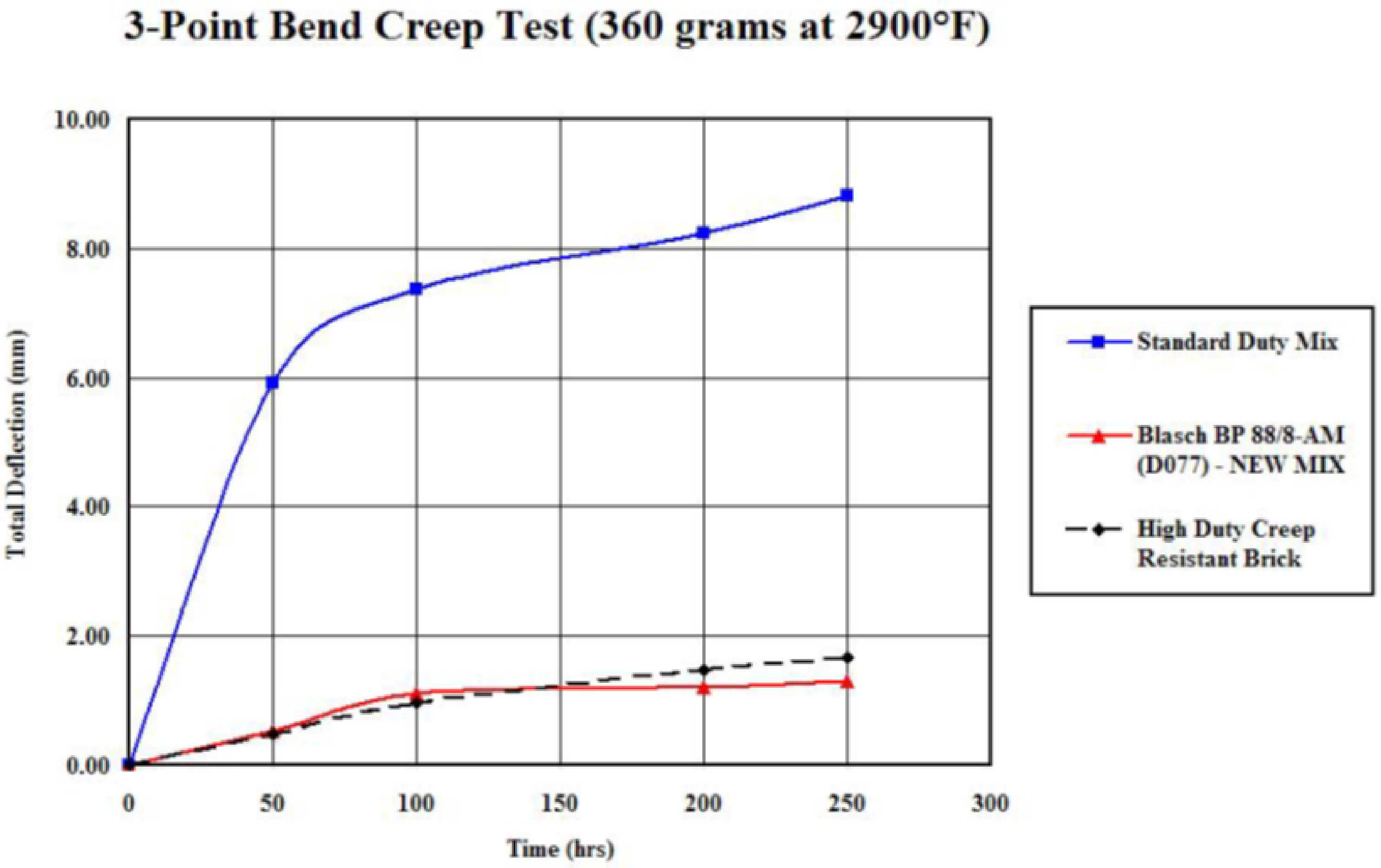


Core Setter Material Selection

- Ceramic creep resistance:

As we develop materials for core setters, the creep test is a great developmental tool.
Blasch recently developed a new material which was creep tested along with two other materials for reference as shown in the graph here.

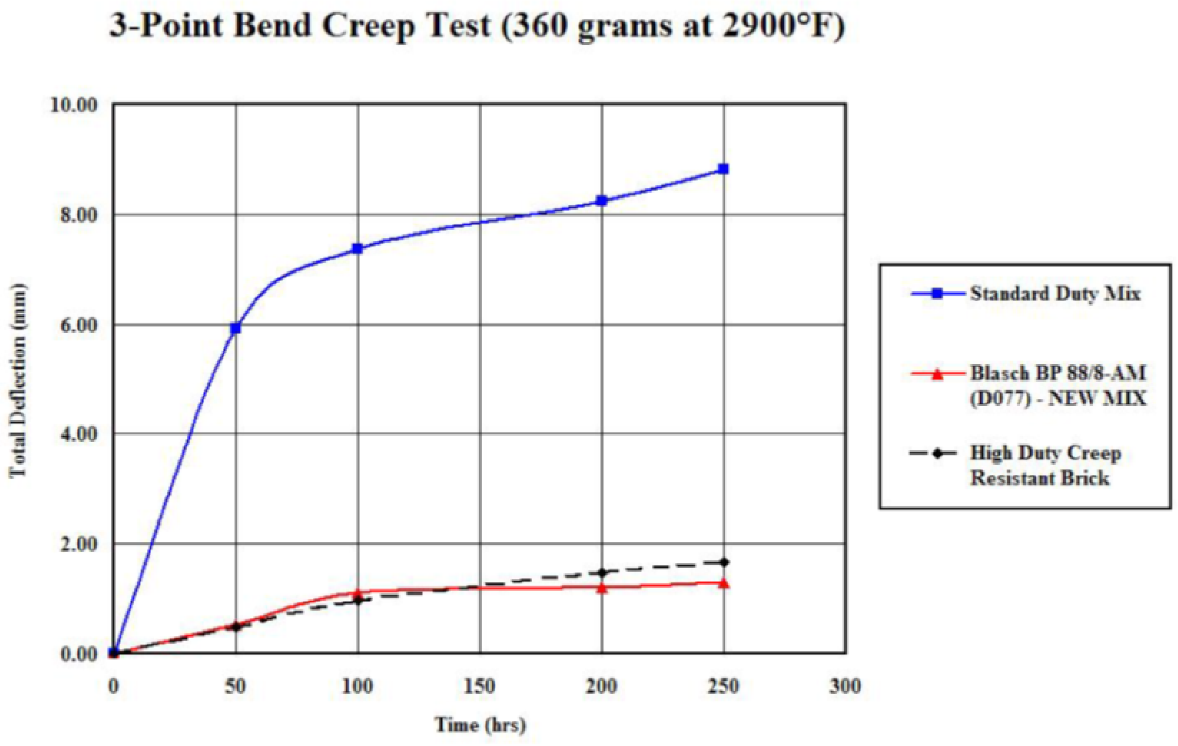
Lower creep is better in this graph



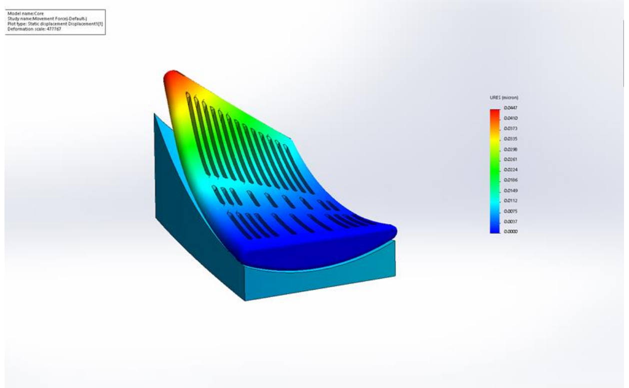
Core Setter Material Selection

Of the three materials tested:
- A standard shop castable refractory material (Blue line)
- An industry standard high duty creep resistant brick material that can not be produced in complex shapes (Black line)
- New Blasch developed material which can be used to produce complex shapes with tolerances near .005” per inch (Red line)

As shown by total deflection over time (less deflection being better) this newly developed material showed a substantial improvement over a current industry standard creep resistant brick material. This improvement has also been realized in the production and use of core setters made from this material. Results have shown improvement in core setter life and high tolerance stability over repeated firings.



Core Setter Material Selection

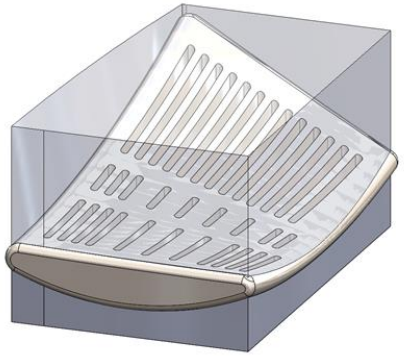


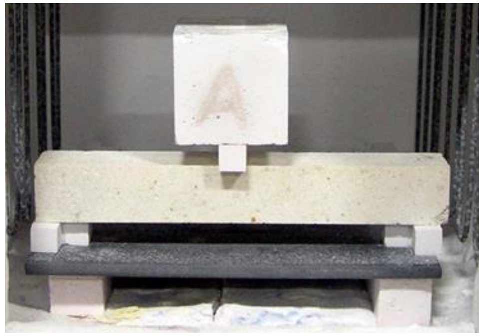
What are the best characteristics for the material used for the core setter and the material properties that would be ideal for the application?

- Thermal Shock resistance: HIGH

- Part geometry tolerance capability: HIGH

- Ceramic creep resistance: HIGH



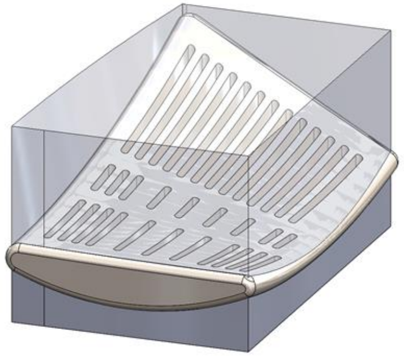


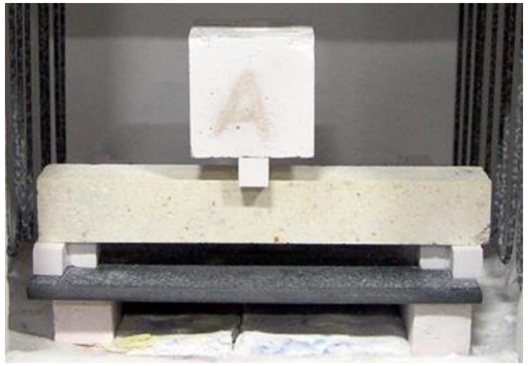
Where your ideas take
SHAPE in CERAMIC

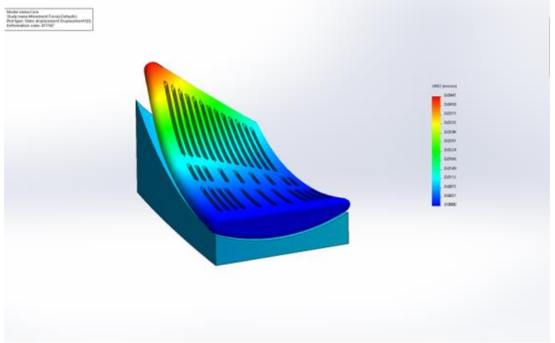
Now knowing the optimal process for holding the cores while sintering, and ways to optimize the core setters and kiln orientation for the sintering process, we found substantial ways to reduce energy costs and increase throughput in the kilns

We also have learned the importance in using a core setter material that is optimized for holding cores through repeated cycles while sintering

Blasch has over 40 years in ceramic materials and processes. Let us share this knowledge to help improve your foundries core sintering process, and to increase the life of your molten metal refractories







Thank You

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