

What Every Investment Caster Should Know About Thermal Expansion of Shells

by Tom Branscomb,
Buntrock Industries

Thermal expansion is a very important property of materials and must be considered for most applications. A common example is expansion joints in bridges and highways. The concrete and steel must be allowed to expand and contract or cracking and ultimately failure will occur in the structure or road. Relating to investment casting, every caster is familiar with the issue of wax thermal expansion causing cracks during dewax.

When considering the ceramic shell for investment casting, there are several compelling reasons to have a good understanding of shell thermal expansion.

1. Thermal (heating and cooling) of the shell
2. Final dimension of the casting
3. Wax tooling from other shops
4. Changing materials for the shell
5. Shell distortion at moderate temperatures
6. High-temperature stability

Thermal expansion of ceramic shells is measured using an instrument called a dilatometer. One common instrument is made by The Orton Ceramic Foundation (see photo).



ABOVE: Orton Dilatometer 1600C.
INSET: Sample, holder and rod.

A prepared sample is placed in the alumina tube holder. An alumina rod is in contact with the sample and the movement of the rod is measured with a sensitive LVDT. The sample is heated by a silicon carbide tube furnace (photo inset). Since the LVDT is measuring the movement of the entire system, an alumina standard is used and a correction factor is determined first.

Experimental Results

Many investment casting foundries producing castings for general commercial applications use either alumino-sili-

cate slurries or fused silica slurries with either fused silica or alumino-silicate stucco. For this study, only materials from CE Minerals were used. Three slurries were made with fused silica, Mulgrain 47, and Mulgrain 60 flour. Each used Bindzil 830 colloidal silica, water, and polymer. Wax strips were dipped in the slurries and stuccoed with fused silica, Mulgrain 47, or Mulgrain 60 sand. Thermal expansion was then determined for each combination. The results are presented in Figures 3, 4, 5 and 6.

Significant differences in expansion that occur when different stuccoes are



Figure 3. Thermal expansion of fused silica slurry with fused silica, Mulgrain 47, and Mulgrain 60 stucco.

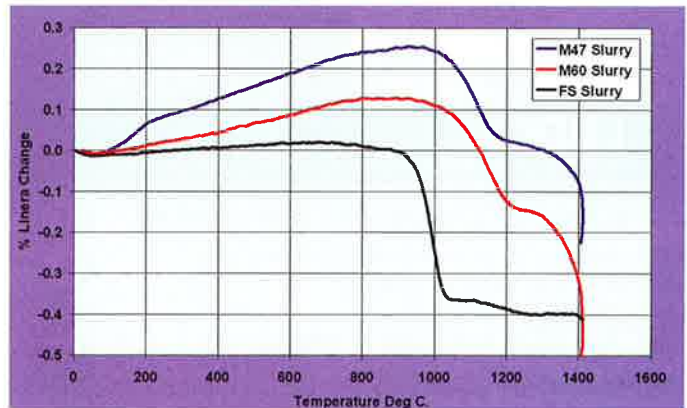


Figure 4. Thermal expansion of shells made with different slurries all using fused silica stucco.

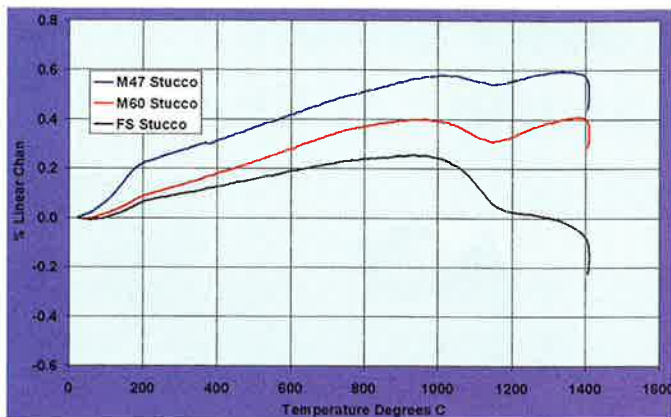


Figure 5. Thermal expansion of shells made with Mulgrain 47 slurry and various stuccoes.

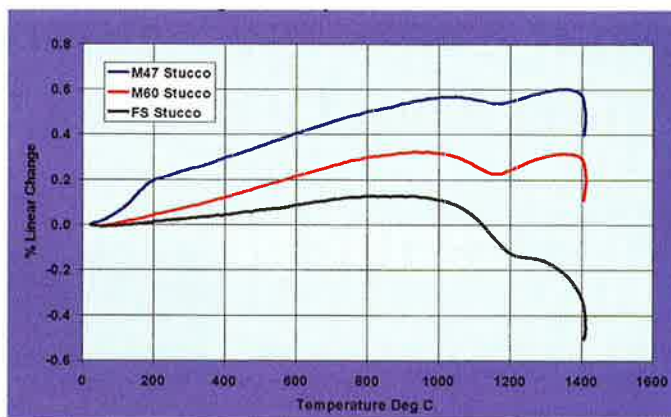


Figure 6. Thermal expansion of shells made with Mulgrain 60 slurry and various stuccoes.

used with fused silica slurry. If stucco is changed, the difference in casting size can easily be estimated

"It is possible to use this same phenomenon to correct dimensional issues."

from these curves. Assuming the shell temperature at the time the casting becomes solid is about 1200°C, the Mulgrain 60 casting would be about 0.4% larger and the Mulgrain 47 casting would be about 0.7% larger. For a 10" diameter casting, this is a difference of 0.040" and 0.070" respectively. These differences may or may not be important depending on casting dimension tolerance and the actual casting dimension being produced. For example, if the current casting is near the maximum for this diameter, changing from fused silica stucco may result in the casting being out of specification.

It is possible to use this same phenomenon to correct dimensional issues. If you normally use fused silica stucco and your dimensions are too small, a simple change to a different type of stucco may solve this problem.

Now, look at what happens when the stucco remains fused silica and the slurry is changed (Figure 4).

Two things are noticeably different from the previous chart. First, the magnitude of the difference is much less. That is to

say, changing stucco has a larger impact than changing slurry. The other difference is that at or above

1300°C, the Mulgrain slurries shrink dramatically. This indicates that for large castings and high pour temperatures, shell integrity may be compromised.

When using Mulgrain 47 slurry and stucco, changing to Mulgrain 60 stucco will reduce dimensions, but it appears that changing to fused silica stucco may present dimensional stability issues above about 1100°C (Figure 5). Caution needs to be used in making this change. The use of Mulgrain 60 slurry mirrors what happens with Mulgrain 47 slurry (Figure 6). In fact, it appears that using Mulgrain 47 slurry with fused silica stucco yields less shrinkage in the 1200-1400°C temperature range.

The issue of dimensional stability of the shell at high temperature is more of a concern when making directionally solidified and single crystal castings. This is because the shell temperatures are higher. If a particular shell is shrinking at high temperature, there is a good chance it will not have adequate stability to produce consistent castings dimensionally.

Grace Davison

LUDOX®
Colloidal Silica for Precision Investment Casting

LUDOX® SK Colloidal silica gives you **MORE**

M • Maintenance requirements are reduced
O • Outstanding slurry stability
R • Rapid processing
E • Easy slurry mixing and monitoring

The only binder that extends Zircon pot life!

Contact your local Grace Davison representative or call 800-795-6437 www.grace.com

GRACE®, GRACE DAVISON® and LUDOX® are trademarks, registered in the United States and/or other countries, of W. R. Grace & Co., Conn. This trademark list has been compiled using available published information as of the publication date and may not accurately reflect current trademark ownership. © 2010 W. R. Grace & Co., Conn. All rights reserved.

GRACE

**Shell Burnout & Firing:
Metal Melting & Casting**
NEW training CD for your foundry from...

Investment Casting Institute
136 Summit Ave.
Montvale, NJ 07645-1720
Phone 201-573-9770 Fax 201-573-9771
www.investmentcasting.org

\$69 for members, \$98 for nonmembers
(Plus shipping) VISA, American Express, Mastercard accepted.

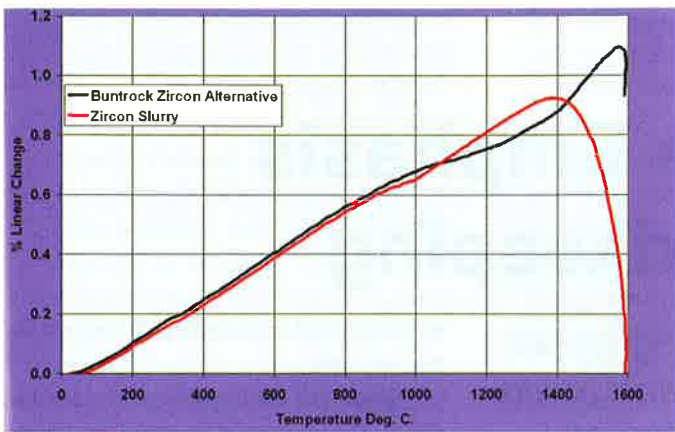


Figure 7. Thermal expansion of a typical zircon slurry, alumina stucco DS shell. A zircon flour alternative is also shown.

A common shell system used for this type of casting is a zircon slurry with tabular or fused alumina stucco (Figure 7). The expansion of the zircon slurry shell shows good linear behavior up to 1400°C and dimensional stability is good in general. Another test was completed with a hold for 1 hour at 1400°C. The zircon slurry shrank some, but the alternative shell did not.

The slurry presented as a zircon alternative has better high temperature performance than the zircon shell. However, for next generation very high temperature alloys being considered for directionally solidified and single crystal castings, there is some concern about the shrinkage at 1600°C (Figure 7).

Additional work has resulted in materials that apparently overcome this issue. In Figure 8, a shell system is used that is very stable at 1600 C. Different stuccoes were investigated and White Fused Alumina performed the best.

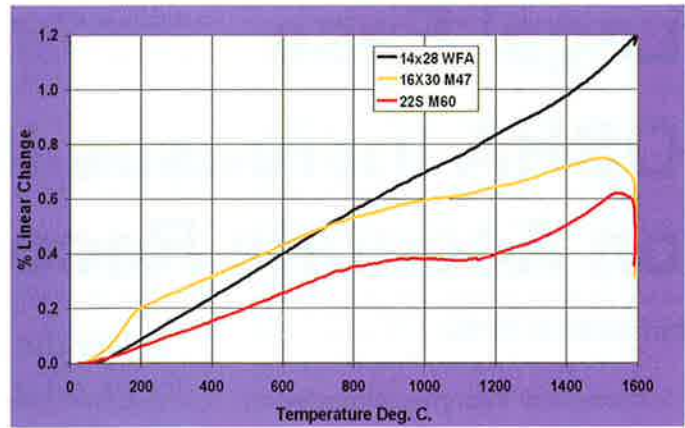


Figure 8. Thermal expansion of very high temperature shell with various stuccoes.

Conclusions

1. Thermal Expansion is a good tool for determining the effect a stucco or slurry change may have on dimensions of castings.
2. Be very cautious about using Fused Silica stucco with alumino-silicate slurries.

3. When using fused silica slurry, changing to alumino-silicate stucco appears fine, but casting dimensions will increase.
4. There are materials that appear to match and even improve upon the zircon backup slurries in use.
5. Materials for ultra high temperature shells perform well at 1600°C.

AVIGNON CERAMIC

Ceramic cores at the heart of investment casting



Independent coremaker since 20 years.

Simple and complex cores for Aero, IGT, medical, ...


DS - EQX - SX

Also ceramic rods and plugs.

EICF Krakow Booth #16


AVIGNON CERAMIC SAS - Route de Noirlac - 18200 Bruère-Alichamps - France
Tel. +33 (0)2 48 62 03 70 - Fax +33 (0)2 48 61 02 22 - contact@avignonceramic.com
Visit us on our website www.avignonceramic.com !

Black Hole



YOUR Production?

Integration & Clarity



Specific Manufacturing Control Software for the Cast Metal Industry

SYNCHRO³²
www.synchro32.com

- USA +1 800 323 2808
- UK +44 845 370 3232
- EU +44 845 370 3232
- BRAZIL +55 31 3581 1516

WEB: www.synchro32.com
EMAIL: sales@synchro32.com

CastExpo'10
Orlando, Florida March 20-22, 2010
Visit us at Booth # 2101