Background

Artificial graphite materials are used for manufacturing industries, electric furnace steel manufacturing, silicon and SiC semiconductor manufacturing, and aluminum refining.
【熱ストレス抵抗（TSR）】

\[ TSR = \frac{TC \cdot FS}{CTE \cdot YM \cdot ER} \]

*TC*: Thermal Conductivity  
*FS*: Flexural strength  
*CTE*: Coefficient of thermal expansion  
*YM*: Young’s Modulus  
*ER*: Electrical Resistivity

**Fig. 9** Steps in raw material based graphite electrode quality expressed by thermal stress resistance

SGL-carbon presented in Carbon2007

**TRS**: one of the measure for graphite materials applied at high temperate.

High temperature *CTE* could not be measured in my Lab.
**TSR =** \( \frac{TC \cdot FS}{CTE \cdot YM \cdot ER} \)

- **TC**: Thermal Conductivity
- **FS**: Flexural strength
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- **YM**: Young’s Modulus
- **ER**: Electrical Resistivity

**Fig. 9** Steps in raw material based graphite electrode quality evaluation and its resistance

**TRS**: one of the measure for graphite materials applied at high temperate.

High temperature **CTE** could not be measured in my Lab.
Fig. 16  Coke CTE improvement over past 30 years
For measurement of thermal expansion of artificial graphite materials above 2000°C, special electric furnace with the device measuring specimen dimension has been developed on the basis on JIS R2207.

“Idea of development” of thermal expansion measurement device of graphite materials at high temperature
For the measurement at the temperature above 2000 degree-C, we used “isotropic graphite” as furnace heater and measurement jigs. And also as the reference materials for thermal expansion measurement with contact method, isotropic graphite was used.
Idea 1

**Measurement System**

From the front

- **Test piece**: 20 mmφ x 100 mm
- **Laser micro-gage**
- **Laser source**
- **Detector rod**
- **Differential transformer** (spring gage)
- **furnace**
- **extensometer**
- **thermocouple**
- **receiver**

**Perspective From the front**
Idea 1

Measurement System

Test piece
20 mmφ x 100 mm

Laser micro-gage
Laser sauce

heater

pyrometer

thermocouple

LMG receiver

Front door

Perspective
From top
ここに技ありhalberPunkt
External appearance of device

Spring gage

LMG

Front door

LMG: TOE D5-1505 II -HS
**Furnace inside**

- Pass slit for laser beam
- Detector rod
- Back heater
- Support tube
Furnace inside

Detector rod

Support tube

Test piece
(Φ20 mm x 100 mm)
Reference material: IGS743

- Heat Rate: 10°C/min

Data from spring gage

Reference data

1400°C
Reference material: IGS743

Data from spring gage

Contact method

Base line

Reference data
Idea 2

Laser beam & Support tube

- Laser beam
- Test piece
- Pass slit for laser beam in thermal insulator
- Pass slit for laser beam
Idea 2

Signal of LMG receiver

Laser beams reached to receiver
Laser source
@ 2400°C
Receiver
Elongation measurement by LMG

CIP: IGS743

Red: measured (heating)
Blue: measured (cooling)
Reference data

Elongation (mm) vs. Temperature (°C)
Good Job!
Gut gemacht!
CIP: IGS743

Thermal expansion (left scale)

Contact

Non-contact (LMG)

CTE (right scale)

Temperature / °C

Thermal Expansion / %

CTE / K⁻¹
CIP & Nipple

Thermal Expansion / %

CTE / K⁻¹

Temperature / °C

-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7

-1.0E-06
0.0E+00
1.0E-06
2.0E-06
3.0E-06
4.0E-06
5.0E-06
6.0E-06
7.0E-06

0
500
1000
1500
2000
2500

CTE (right scale)

TE (left scale)

CIP

nipple
CIP & Nipple

Thermal Expansion / %

Temperature / °C
Sample Dimension Change of “carbonized block”

Linear thermal expansion (%)

Temperature (°C)

heating
1100°C

cooling
1600°C

measured by LMG
The development the measurement device of thermal expansion of artificial graphite at high temperature can be succeeded using isotropic graphite, as heater, measurement jigs and the reference materials.

Not only contact method, but also non-contact method for the measurement of thermal expansion can be adapted in the device.

By introducing the non-contact method with LMG, accurate thermal expansion can be measured up to 2400 °C.
• CIP isotropic graphite has three times larger thermal expansion and CTE than Nipple electrode.

• In the case of Nipple electrode with strongly anisotropic orientation, negative thermal expansion at the temperature between 200~300 °C was observed with LMG.

• By the developed device, thermal shrinkage of carbonized block can be observed at high temperature above 1100 °C. Two steps of shrinkage behavior against temperature was observed.
Thank you very much for your attention
Good Job!

Gut gemacht!