ID: 3008

A MATERIAL DATABASE OF SS316L(N)-IG FOR ITER BLANKET SHIELD BLOCKS

S.W. KIM*, J.Y. JEONG, J.S. CHANG, T.H. KWON and D.H. KIM

Korea Institute of Fusion Energy

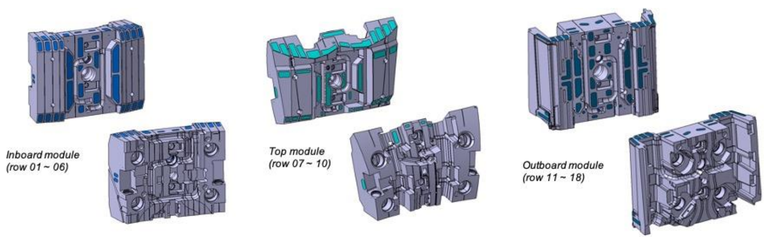
swkim12@kfe.re.kr

ABSTRACT

- The ITER project requires reliable structural materials capable of withstanding high neutron flux, thermal stresses, and irradiation conditions.
- SS316L(N)-IG, a nitrogen-controlled ITER-grade austenitic stainless steel, has been adopted as the primary material for the Blanket Shield Block (BSB).
- This study presents a comprehensive database of its chemical, physical, and mechanical properties based on procurement and fabrication of more than two hundred forged blocks.

BACKGROUND

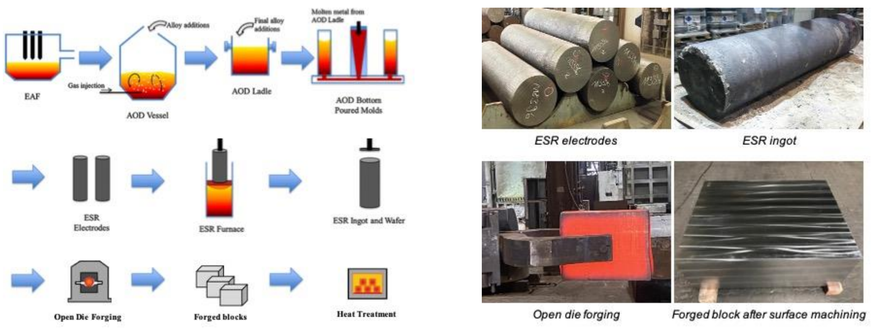
- SS316L(N)-IG (ITER Grade) was selected as the structural material for the BSB due to its balanced combination of corrosion and irradiation resistance, and mechanical strength as well.
- It is essentially a low-carbon 316L stainless steel with tightly specified alloying ranges and nitrogen control.
- Developing a validated materials database is essential for ITER designers, since predictive assessment of BSB performance requires reproducible and traceable input properties.



Typical configurations of the ITER Blanket Shield Blocks (inboard, top and outboard modules)

MATERIAL FABRICATION

Primary melting was applied in an Electric Arc Furnace (EAF), followed by Argon Oxygen Decarburization (AOD) for carbon and impurity control. The refined alloy undergoes Electro-Slag Remelting (ESR) to minimize inclusions and achieve uniformity. Large ESR ingots were subsequently shaped through open-die forging and then subjected to solution heat treatment at 1050–1150 °C with water quenching. Final machining (surface finishing), non-destructive examinations (ultrasonic and liquid penetrant testing), metallographic evaluation and mechanical testing were performed to validate quality.



Fabrication process and photos in each process for SS316L(N)-IG

CHAMICAL COMPOSITION

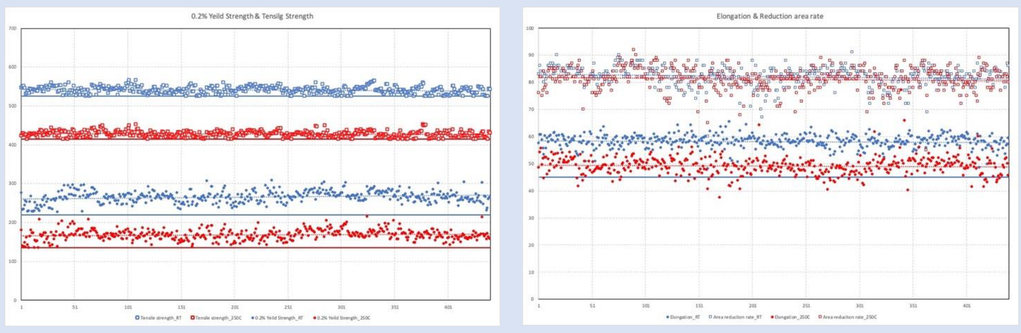
Chemical composition of SS316L(N)-IG (Heat No. 725051 as an example) both ladle and product analyses were confirmed that it is fully compliance with the ITER procurement specification. Trace elements such as Cu, Ti, Nb, Ta, and Co remained within strict limits, confirming the uniformity and quality control of SS316L(N)-IG mass production for ITER Blanket Shield Blocks.

Element		C	Mn	Si	P	S	Cr	Ni	Mo	N	Cu	Ti	Others
Content wt. % (Heat 725051)	ladle	0.021	1.79	0.38	0.017	0.0005	17.76	12.38	2.47	0.066	0.105	0.002	Nb: 0.004 Ta: 0.005 Co: 0.036
	product	0.023	1.70	0.35	0.015	<0.001	17.69	12.13	2.46	0.065	0.09	<0.01	Nb: 0.02 Ta: 0.002 Co: 0.04

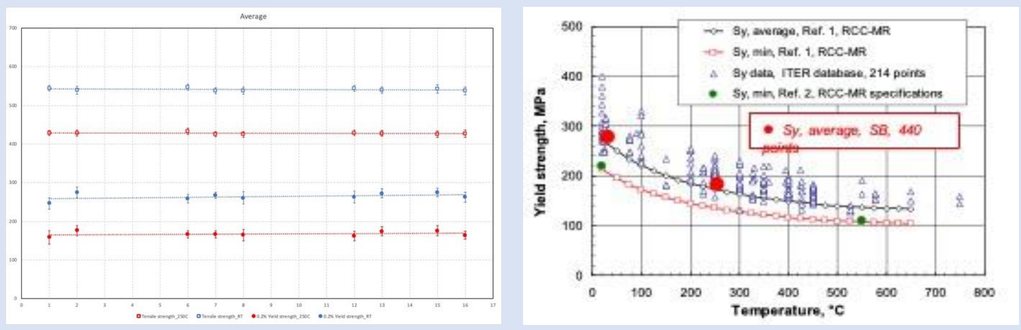
Example of chemical composition for SS316L(N)-IG (Heat No. 725051)

MATERIAS DATABASE

- 0.2% yield strength, tensile strength, elongation, and area reduction at both RT and 250 °C were characterized from 220 forged blocks.
- **Specification compliance**
  - All measured values at both test temperature satisfy ITER requirements
- **Statistical consistency**
  - Scatter of results limited to ±5% from average trend lines
  - Row-by-row analysis confirms uniformity across inboard, top and outboard modules
- **Microstructural & Chemical stability**
  - Controlled nitrogen and low carbon ensure reproducibility
  - Stable austenitic structure with suppressed delta-ferrite formation
- **Traceability**
  - Each block fully linked to manufacturing & inspection reports
  - Enables backtracking of properties to heat numbers and production batches
- **Significance**
  - Provides a validated database for ITER engineering design
  - Supports predictive modeling and structural integrity assessments
  - Establishes foundation for DEMO and future fusion reactor materials



Comprehensive evaluation of mechanical properties of SS316L(N)-IG compared with ITER requirements



Comparison of mechanical property averages (left) with ITER database values (right)

Statistical distribution of tensile strengeh deviations from the average at RT and 250 °C

CONCLUSION

- **Database established**: 220 ESR-forged blocks and 440 tensile specimens characterized
- **Specification satisfied**: All mechanical properties (tensile, yield, elongation, area reduction) meet ITER Technical Specification at RT and 250 °C
- **High reproducibility**: Very small scatter (±5%) across poloidal rows confirms stable fabrication and heat treatment
- **Traceability ensured**: Each block linked to manufacturing and inspection records
- **Broader impact**: Provides validated design data for ITER, and a foundation for DEMO and future fusion systems

ACKNOWLEDGEMENTS / REFERENCES

- This research was supported by an R&D Program “Manufacturing and Procurement of ITER Blanket Shield Block (2710000407)” through the Korea Institute of Fusion Energy (KFE) funded by government grants from the Republic of Korea.
- The views and opinions expressed herein do not necessarily reflect those of the ITER Organization and Korea Domestic Agency.