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The thermal contraction between 293 K and 77 K of P505SO and UNS21904 grade stainless steel

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1. Introduction

In the cold sections of the Large Hadron Collider (LHC) a beam screen will be installed inside the cold bore, forming the beam vacuum envelope of the machine. For reasons of magnetic field quality this beam screen and its cooling tubes will probably be fabricated from a steel with a low magnetic permeability, a so-called high Mn grade, different to that of the surrounding cold bore, probably a seamless 304L or 316LN stainless steel. Of particular interest is the relative contraction of the beam screen with its cooling tubes and the cold bore since the cooling tubes pass through the cold bore at the interconnect. During cool down or warm-up a maximum temperature difference of 300 K could exist between the beam screen and the cold bore. It is therefore important to quantify the differential thermal contraction between these different grades of stainless steel.

The results of previous measurements of the thermal contraction between 293 K and 77 K for different grades of stainless steel are described in [1] and summarised in Table 1. The quoted error in the measured values is the 3σ error. This error is obtained from the standard deviation σ multiplied by 3 ($\pm 3\sigma$ contains 99.7% of the data in the case of a Gaussian distribution).

The values in the third column are scaled from the measured values in the second column by adding 8.1%, see ref. [1].

Table 1

Material	Measured $\Delta L/L$ (293 K and 77 K) [mm/m $\pm$ 3σ]	Scaled $\Delta L/L$ (293 K and $\leq$ 4.2 K) [mm/m]
304L	2.82±0.06	3.05
316LN	2.75±0.02	2.97
UNS21904	2.43±0.02	2.63

Recently, a new grade of high Mn stainless steel, P506, has been included in the beam screen development program. The new P506 grade will, however, not become available before February 1998. We therefore performed thermal contraction measurements on an available sample of the very similar P505SO grade. A UNS21904 sample was included in this series of measurements for verification purposes.

Table 2 gives the chemical compositions of P506, P505SO and UNS21904.

Table 2: Chemical composition in weight-%.

	C	Cr	Mo	Ni	Mn	Si	N
P506*	<0.03	19.3	0.9	11.0	12.1	<0.5	0.32
P505SO	0.03	19.3	0.85	10.9	12.0	0.4	0.31
UNS21904	0.03	20.1	0.01	6.8	9.1	0.22	0.35

*) Target specification.

2. Measurement Details

The 10 x 10 mm L-shaped P505SO sample was machined from 10 mm thick flat bar. The wall thickness of the sample was 2 mm. The 16 x 16 mm L-shaped UNS21904 sample was formed from 1 mm sheet, co-laminated with 0.05 mm of OFE copper.

The measurements were performed as described in ref. [1] but with a shorter sample length (300 versus 550 mm) for reasons of availability of the test material.

The samples were measured once at ambient temperature, twice at boiling liquid nitrogen temperature and twice again at ambient temperature. The average of the three "warm" measurements is considered as the length at ambient temperature (293 K). The average of the two "cold" measurements is considered as the length at boiling liquid nitrogen temperature (77 K).

3. Results

The mean of the thermal contractions $\Delta L/L$ of the two steel grades, between 293 K and 77 K taken at the three slightly different separations, and the 3σ error from this mean for both steels are shown in Table 3.

Table 3

Material	Measured $\Delta L/L$ (293 K and 77 K) [mm/m $\pm$ 3σ]	Scaled $\Delta L/L$ (293 K and $\leq$ 4.2 K) [mm/m]
UNS21904	2.48±0.05	2.68
P505SO	2.53±0.05	2.73

The standard deviations of the measured values are larger than for the previous measurements, probably partly due to the shorter sample length.

The measured thermal contraction of P505SO is not significantly different from the value for UNS21904 (values are within $\pm 3\sigma$).

Using the scaling factor of 8.1% [1], the deduced values from 293 K to $\leq$ 4.2 K are shown in Table 3. Errors on these values are not indicated since the error in the scaling factor is unknown.

4. Conclusions

The measured thermal contractions, between 293 K and 77 K, of UNS21904 and P505SO grade stainless steels with their 3σ errors are: (2.48±0.05) mm/m and (2.53±0.05) mm/m respectively. The deduced values between 293 K and ≤4.2 K, by increasing the values at 77 K by 8.1% are 2.68 mm/m and 2.73 mm/m respectively. The value for the UNS21904 grade is consistent with that found in ref. [1].

The value quoted by Nohari [2], for stainless steel similar to UNS21904, of 2.6 mm/m between 300 and 4 K is in good agreement with our (scaled) value of 2.68 mm/m. No error margins are quoted in ref. [2].

For more reliable values of the thermal contraction between 293 K and ≤4.2 K it will be necessary to perform experiments at these temperatures since the scaling procedure used here might not be accurate.

Acknowledgements

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References

[1] I.R. Collins, N. Kos and A.G. Mathewson, CERN, LHC-VAC/TN-96-20, October 1996.

[2] K. Nohara, Kawasaki Steel, Japan, private communication, September 1996.