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Verifying the Strength of a Shrink Fit Joint for the RHIC Post Leg

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RHIC Technical Note

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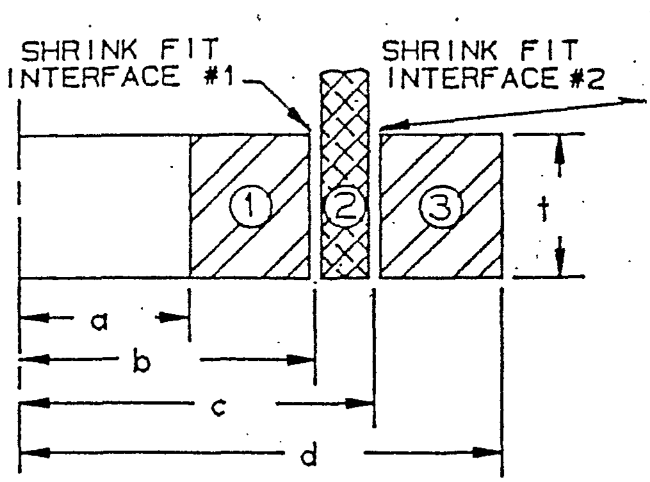
ABSTRACT

The strength of a shrink fit joint for the RHIC magnet support post leg has always been difficult to verify. Primarily this is due to small clearences used between the metal rings and the G-11 tubes, and the difficulties in testing a partially assembled leg. Although the strength of an assembled leg, consisting of series of joints, can be checked on a tensile test machine, it is desirable that an individual joint can be verified independently during assembly without using the tensile testing machine. A measurable quantity has been found as an useful means to determine the strength of the joint. The measurement can be performed on each joint during assembly. This procedure is suitable for quality control purposes.

SHRINK FIT JOINT

The sectional view of a typical joint consisting of the G-11 tube and the metal rings is shown in Fig. 1. The contact pressures between the inner ring and the G-11 tube, and between the outer ring and the G-11 tube are obtained through the interferences among the surfaces. The strength of a shrink fit joint is then obtained from these contact pressures and the friction coefficient between the metal and the G-11 surfaces. Primaray concerns of this technical note are the contact pressures.



MATERIAL PROPERTIES

Elastic Modulus: E_1, E_2, E_3

Poisson's Ratio: v_1, v_2, v_3

INTERFACE PROPERTIES

Contact Pressure: P_1, P_2

Radial Interference: Δ_1, Δ_2

Coefficient of Friction: μ_1, μ_2

Fig. 1. Sectional View and Nomenclature of a Shrink Fit joint

Equation 1 to 4 relate the contact pressures with interferences, forces, and bending moments required to cause a joint to slip as given by T. H. Nicol[1] in a study for SSC.

$$P_1 = \frac{P_2(K_4 + K_5) - \Delta_2}{K_6} \; ; \quad P_2 = \frac{\Delta_1 K_6 + \Delta_2(K_1 + K_2)}{(K_4 + K_5)(K_1 + K_2) - K_3 K_6} \tag{1}$$

where

$$K_1 = \frac{b}{E_1}\left[\frac{b^2 + a^2}{b^2 - a^2} - \nu_1\right] ; \; K_2 = \frac{b}{E_2}\left[\frac{c^2 + b^2}{c^2 - b^2} + \nu_2\right] ; \; K_3 = \frac{b}{E_2}\left[\frac{2c^2}{c^2 - b^2}\right]$$

$$K_4 = \frac{c}{E_3}\left[\frac{d^2 + c^2}{d^2 - c^2} + \nu_3\right] ; \; K_5 = \frac{c}{E_2}\left[\frac{c^2 + b^2}{c^2 - b^2} - \nu_2\right] ; \; K_6 = \frac{c}{E_2}\left[\frac{2b^2}{c^2 - b^2}\right] \tag{2}$$

$$F_1 = P_1 \,(2\pi b t \mu_1) \; ; \; F_2 = P_2 \,(2\pi c t \mu_2) \tag{3}$$

$$M_1 = 4P_1\mu_1 b^2 t \quad ; \; M_2 = 4P_2\mu_2 c^2 t \tag{4}$$

Equation 1 through 4 provide straightforward calculations for designing a shrink fit joint. When a joint is formed, equation 1 through 4 can not be used to determine the pressures built in the joint and tension or compression test must be performed on test machine to verify the strength of the joint. It becomes impractical to test every joint.

VERIFICATION PROCEDURE

The procedure presented here employs the relationship of the metal ring displacement U at position d and a to the contact pressures P_2 and P_1 as given in equation 5 and 6.

$$U_d = \frac{P_2}{E_3} \, \frac{2c^2 d}{(d^2 - c^2)} \tag{5}$$

$$U_a = \frac{P_1}{E_1} \, \frac{(-2ab^2)}{(b^2 - a^2)} \tag{6}$$

The minimum design requirement for P_1 and P_2 suggests a minimum set of values for U_a and U_d. By measuring the diameter displacements of the rings before and after the shrink fit, the displacements U_a and U_d are obtained and the contact pressures can be determined. In practice it is not necessary to measure both U_a and U_d for each joint, because both the thickness and the elastic modulus of the G-11 tube are quite small compared to the outer and the inner metal rings. The difference in contact pressure between the inner surface and the outer surface are small. The sum of U_a and U_d are slightly less than the sum of the radial interferences of the joint. Therefore by measuring either the displacement of the outer ring or the inner ring whichever is more convenient, the contact pressures of the shrink fit joint can be verified.

Nominal values for the outer ring diameter displacement 2 U_d and for the inner ring diameter displacement 2 U_a are given in Table 1. The maximum values for 2 U_a and U_d shown in Table 1 are the displacements resulting if the parts are produced such that the maximum interference possible results. A measured value for the outer ring displacement is also shown in Table 1.

Table 1

Outer Ring and Inner Ring Displacements

	7" Tube Bottom Outer Ring	7" Tube Top Outer Ring	5" Tube Bottom Outer Ring	5" Tube Top Outer Ring
Minimum: Inch	0.0024	0.0080	0.0074	0.0029
Maximum: Inch	0.0028	0.0090	0.0085	0.0036
Measured: Inch				0.003
	Inner Ring	Inner Ring	Inner Ring	Inner Ring
Minimum: Inch	-0.0053	-0.0081	-0.0047	-0.0013
Maximum: Inch	-0.0061	-0.0091	-0.0054	-0.0017

CONCLUSION

The technique of measuring either the outer ring or the inner ring displacement for each shrink fit joint following assembly is a useful tool to verify the design contact pressure and avoid lengthy mechanical tests of each joint for design verification.

REFERENCE

1. T. H. Nicol, R. C. Niemann and J. D. Gonczy. "A Suspension System for Superconducting Super Collider Magnets," SSC-N-196.