



# MATERIALS ENGINEERING LABORATORY REPORT

[Redacted]

Supplement [Redacted]

Report No. [Redacted]

## BACKGROUND:

Process parameters validation [Redacted] of CV joint [Redacted] heat treatment. Six monoblock shaft samples were submitted for metallurgical analysis.

S/N 1-2: Hardened at Inductotherm (Brazil)

S/N 3-4: Hardened at Inductotherm then tempered for 1 hour at 167 °C in-house. [Redacted]

S/N 5-6: Hardened at Inductotherm then tempered for 20 minutes at 167 °C at Pyromaitre.

**SUMMARY:** All samples meet hardness and depth of hardening requirements. S/N 3 and S/N 5 exhibit evidence of tempering while S/N 1 does not. Hardness profiles indicate that tempering affected the surface hardness. No notable differences in surface characteristics were noted between the two tempering methods (S/N 3 and S/N 5). See Data Summary.

COMPLETED BY: [Redacted]	[Redacted]	[Redacted]
TITLE: <u>Associate Materials Engineer</u>	TITLE: <u>Manager, Materials Engineering</u>	
DATE: <u>10 September 2007</u>	DATE: <u>10 September 2007</u>	

CC: S. Cook, C. Calixto, Chad Johnson

[Redacted] REV. 3/29/06

## DATA SUMMARY

### VISUAL OBSERVATIONS:

Six CV joint monoblock shafts were submitted to the CML in the non-tested condition shown in Figure 1. The splines were not rolled and the ball tracks were neither machined nor heat treated. Weld spatter was noted on S/N 6. The origin of this spatter is unknown. S/N 1, S/N 3, and S/N 5 were evaluated as representative samples. See Figures 2-3.

### HARDNESS EVALUATION:

Surface hardness and core hardness measurements were obtained using the HRC and HRA scale respectively, in accordance with ASTM E18. Surface hardness measurements were taken on the body and core hardness measurements were obtained on mounted cross-sections. Conversions to HRC were performed per ASTM E140. Hardness results are presented in Table 1.

Sample	Surface Hardness (HRC)	Core Hardness (HRC)
S/N 1	62	<20 HRC
S/N 3	60	<20 HRC
S/N 5	59	<20 HRC
<i>Specification</i>	<i>58-62 HRC</i>	<i>35 HRC max.</i>

*Table 1- Hardness results.*

### INDUCTION HARDENING EVALUATION:

Longitudinal sections were removed from the examined samples and etched with 2% nital to view the pattern. The pattern on all samples looked typical except for the lack of heating in the fillet region. See Figures 4 for a representative image. Effective case depths (to 50 HRC) were obtained from the body location using a Vickers microhardness indenter and a 500g load in accordance with ASTM E384. These results are listed in Table 2. Profiles and their corresponding values are shown in Figures 5-8 and Tables A-C respectively.

Sample	Effective Depth to 50 HRC (mm)	Total Heat Affect (mm)
S/N 1	4.7	5.5
S/N 3	4.7	6.0
S/N 5	4.9	6.0
<i>Specification</i>	<i>2.5-5.0 mm</i>	<i>---</i>

*Table 2- Depth of hardening results at body location.*

### METALLOGRAPHIC EVALUATION:

Transverse cross-sections from the body of each representative sample were removed and prepared for metallographic evaluation in accordance with ASTM E3. The samples were etched with 2% nital to observe the microstructure. S/N 3 and S/N 5 exhibited a surface microstructure of tempered martensite while S/N 1 exhibited a surface microstructure of untempered martensite. All samples exhibited a core of pearlite and ferrite. See Figures 9-12.



Figure 1- S/N 1-2 (left), S/N 3-4 (center), and S/N 5-6 in as-received condition. (0.3X)



Figure 2- Visible heat pattern on all samples. (0.75X)



Figure 3- Weld spatter noted on S/N 6. (1X)



Figure 4- Representative induction pattern noted on all samples. (0.85X)

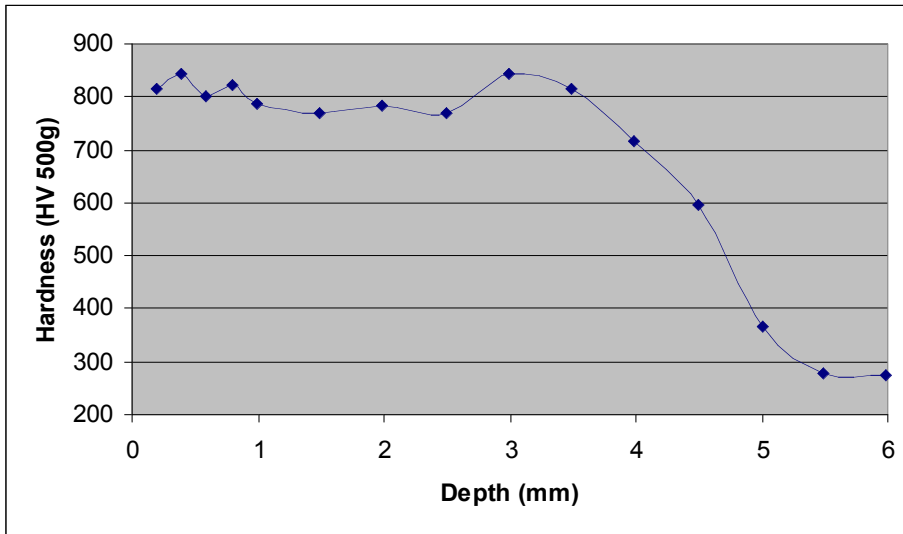


Figure 5- S/N 1 microhardness profile.

Table A- S/N 1 profile values.

Hardness	Distance	HRC
815	0.193	64.5
842	0.392	65.3
801	0.592	64
821	0.792	64.7
788	0.992	63.6
769	1.49	62.9
782	1.99	63.3
769	2.49	62.9
843	2.99	65.3
814	3.49	64.4
715	3.99	60.8
596	4.49	55.1
367	5	37.5
278	5.49	26.9
273	5.99	26.1

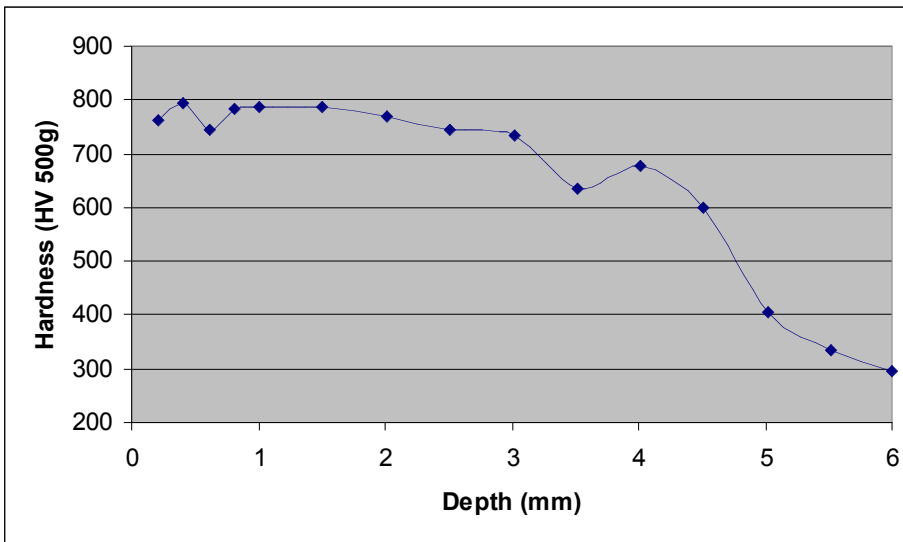


Figure 6- S/N 3 microhardness profile.

Table B- S/N 3 profile values.

Hardness	Distance	HRC
763	0.21	62.6
794	0.412	63.8
744	0.613	61.9
782	0.813	63.3
788	1.01	63.6
788	1.51	63.6
769	2.01	62.9
744	2.51	61.9
733	3.02	61.5
634	3.52	57.1
678	4.02	59.2
600	4.51	55.3
404	5.02	41.2
334	5.52	33.8
296	6.00	29.2

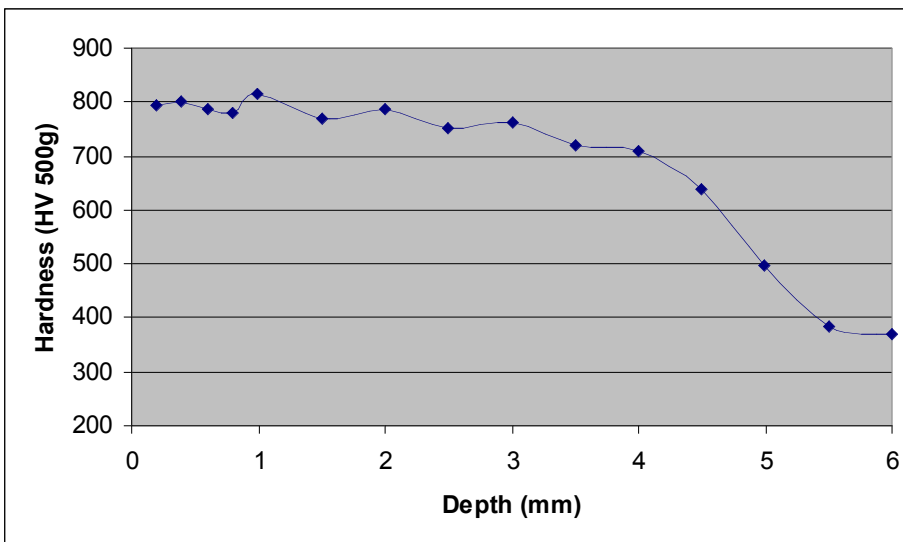


Figure 7- S/N 5 microhardness profile.

Hardness	Distance	HRC
795	0.196	63.8
801	0.396	64
788	0.596	63.6
781	0.796	63.3
815	0.997	64.5
769	1.5	62.9
788	2	63.6
751	2.5	62.2
763	3	62.6
721	3.5	61
710	4	60.6
638	4.5	57.3
497	4.99	48.9
384	5.5	39.2
368	6	37.5



Table C- S/N 5 profile values.

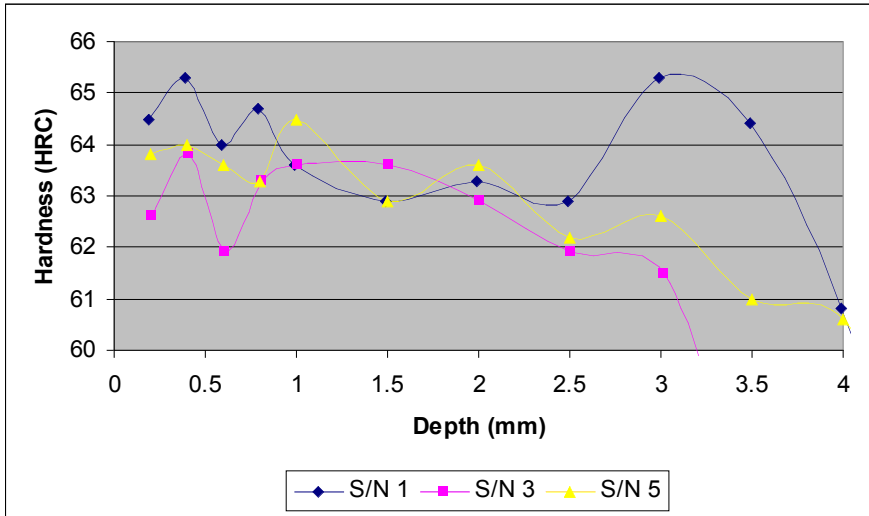


Figure 8- Microhardness profiles showing difference in temper.

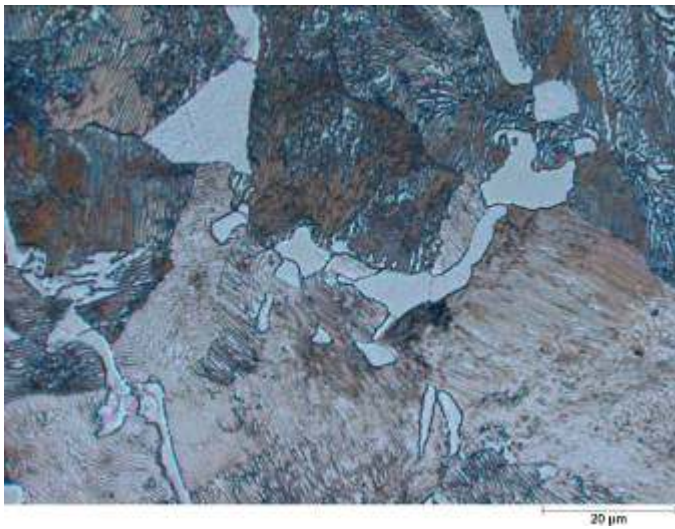


Figure 9- Representative core microstructure. 2% nital. (1000X)



Figure 10- Surface microstructure of S/N 1 as-quenched. 2% nital. (1000X)

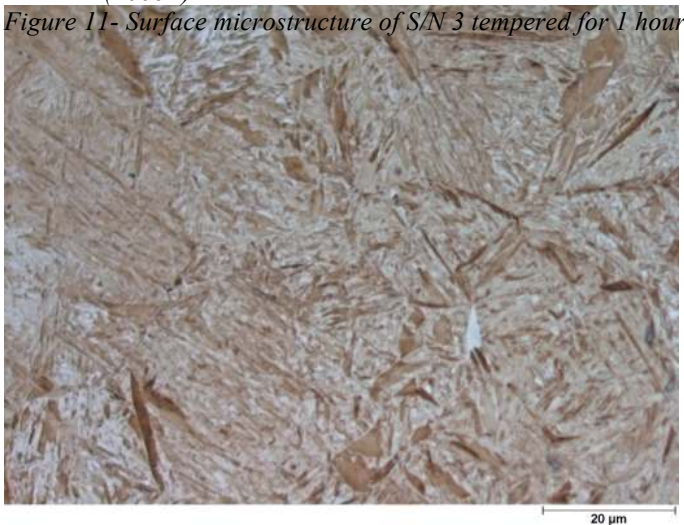


Figure 11- Surface microstructure of S/N 3 tempered for 1 hour

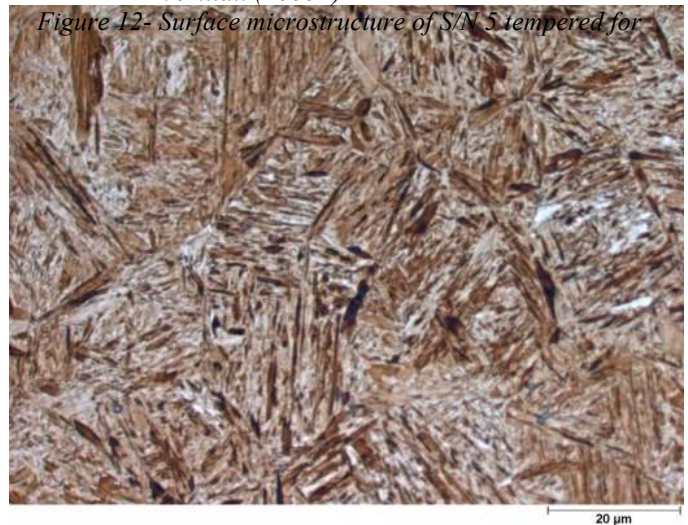


Figure 12- Surface microstructure of S/N 5 tempered for 1 hour

*At 167°C. 2% nital. (1000X)*

*20 min. at 167°C. 2% nital. (1000X)*