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S.A.F.E
METALLURGY - FORGING - HEAT TREATMENT - MACHINING

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Procedure used to shorten steering shaft:

Hollow steering shaft hardness-tested at 85 Rockwell B, cross-referencing to an indicated Ultimate Tensile Strength (UTS) of 530 MPa. Shaft cross-sectional area of 139mm2 indicates a tensile load-carrying capacity of approx 73kN (7.5 tons).

A 40mm section was cut from middle of shaft and analysed on an Optical Emission Spectrometer, with results showing a chemical analysis of: Carbon 0.1%, Manganese 0.34% This material is a low carbon-manganese 'mild steel' having a Carbon Equivalent (CEq) of 0.16.

Cut faces of steering shaft tube were prepared for welding by machining a 2mm x 45degree chamfer on each. The center hole was reamed to ensure consistent sizing, and 4 longitudinal weld slots of 20mm long x 7mm wide were milled in each. Slots were placed opposite each other (180deg apart), with the 2nd two slots in each half of the shaft being 90deg rotated from 1st pair, which were in urn 15mm back from the butt-joint.

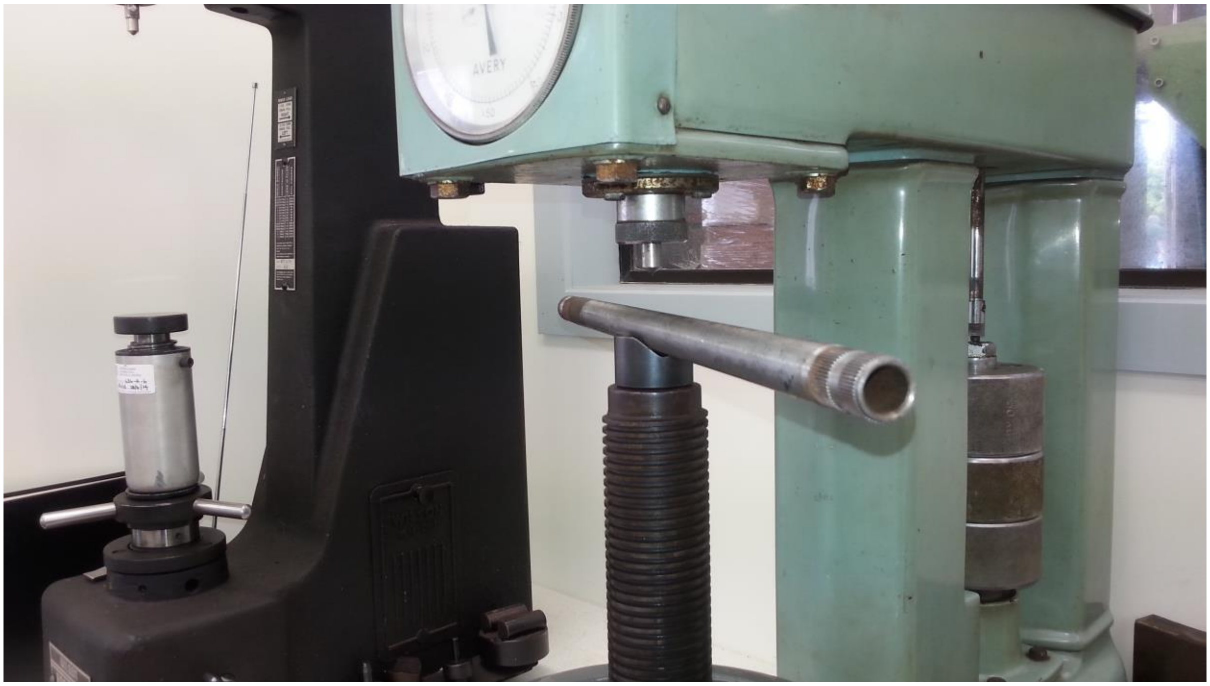
A 110mm-long high-tensile spigot was prepared for insertion across the joint. Material is AISI 4140 Cr-Mo alloy steel, with Carbon Equivalent (CEq) of 0.7. Spigot material hardness was measured at 25 Rockwell C, cross-referencing to an indicated Ultimate Tensile Strength (UTS) of 865 MPa. Spigot cross-sectional area of 109mm2 indicates a tensile load-carrying capacity of approx 94kN (9.6 tons). Spigot strength alone exceeds that of the steering shaft.
Spigot was machined to be a 'drive' fit into the steering shaft, and included a 4mm hole in one end for the insertion of a type K thermocouple for accurate temperature measurement. The 3 pieces were fitted together ready for welding.

Assembly was gently preheated to 300 degrees Centigrade and held at this temp while the butt joint was TIG welded. The intent of this joint was to join the original steering shaft together without weld-root penetration into the high-tensile spigot (which would create a stress-raiser). The preheat ensured that any un-intended penetration did not result in brittle martensite cracks in the spigot material.
Whilst held at 300 degrees Centigrade the 8 slots were filled using MIG weld, with high-tensile wire, to fully fuse the steering shaft to the spigot.

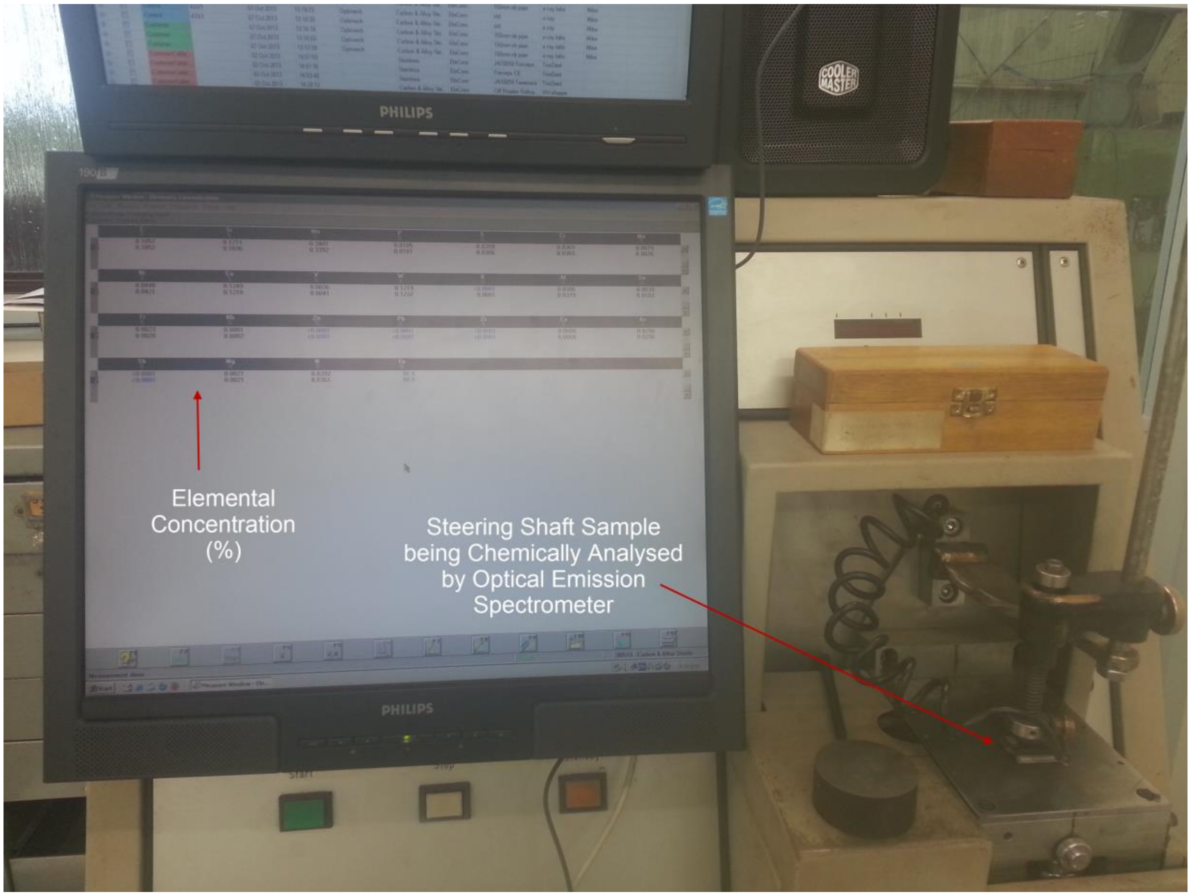
After welding the assembly was allowed to cool before being re-heated to a Post-Weld Heat-Treatment (PWHT) temperature of 550 degrees Centigrade and held for 20 minutes.

NOTE that thorough PREHEAT is required to avoid sub-surface brittle martensite cracks in material with a carbon equivalent of 0.3 or greater, and that PWHT is essential to do the following 3 things:

1. Change hard brittle martensite to tough tempered martensite
2. Reduce any high hardness to a more acceptable lower hardness
3. Relieve the massive contraction stresses created as weld-metal cools



Hardness Test shaft to determine strength of material. Hardness measured at Rockwell B translates to indicated UTS of MPa



Chemical Analysis

Machine weld prep slots and butt joint

Ream Hole for Spigot

PWHT in progress, with thermocouple inserted in centre of spigot.