M. E. Williams and Associates, Inc.

"Excellence in Metallurgical Engineering"

12825 385th Avenue
Waseca, MN 56093

Welding Nightmare II – Case Study

By

Merlin E. Williams, P.E.

Introduction

This case study is an examination of a Rotary Hydraulic Valve to determine cause of leaks associated with fillet welds. The valve housing was fabricated from 1215 Free Machining Steel, and welded to carbon steel hydraulic tubing using an austenitic stainless steel filler metal. After welding, the assembled valve was ferric nitrocarburized to increase the wear resistance of the bearing faces. The valve was examined by visual examination, hardness testing, and metallographic examination. The examination primarily focused on the interface between the Rotary Hydraulic Valve housing, and the weld metal.

Visual Examination

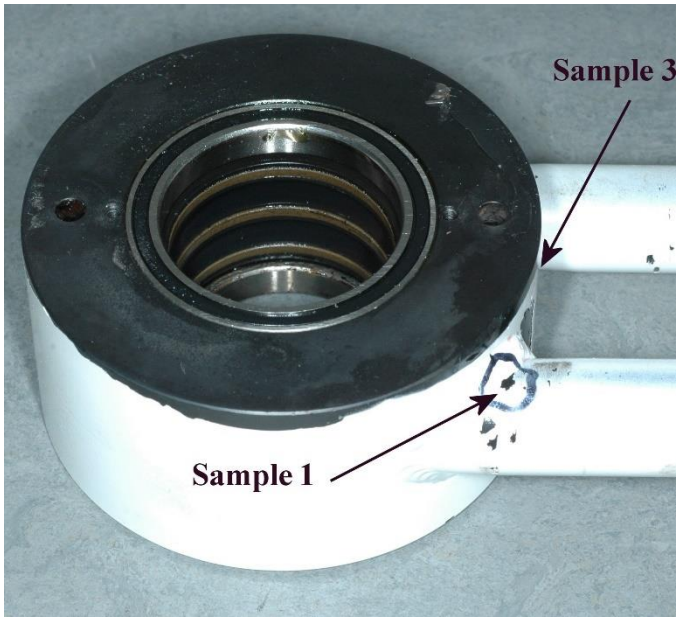

Figure 1 – Rotary Coupling

Figure 2 – Location of Sample 1

Figure 1 shows the Rotary Coupling. The locations of Samples 1 and 3 are indicated. Figure 2 shows a close-up of the Sample 1 location.

Phone (507) 835-2344 • FAX (507) 835-3412 • Twin Cities & Cell (612) 750-5578 • Toll Free (800) 854-6078

Email merlin@mewai.com – Web Site www.mewai.com

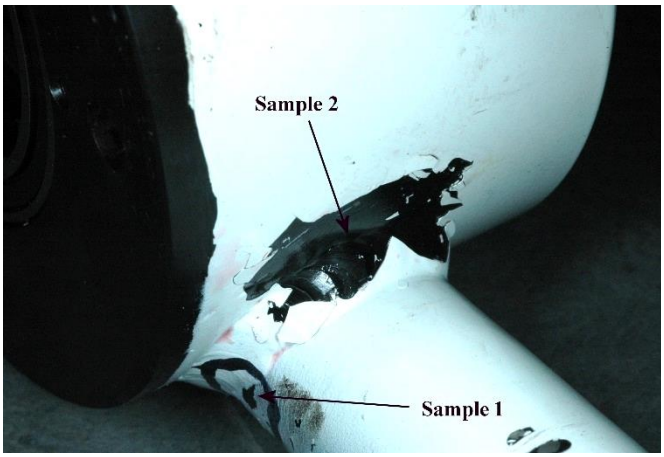

Figure 3 – Locations of Samples 1 and 2

Figure 4 – Location of Sample 3

The locations of Samples 1 and 2 are shown in Figure 3. These locations had been identified as places where hydraulic fluid had leaked.

Sample 3 was chosen at a location where there was no leakage of hydraulic fluid, to be used as an exemplar, Figure 4.

Hardness Testing

The hardness testing was done according to ASTM E384, using a Vickers indenter and a 500 gram load. The Vickers indenter and a 100 gram load was used for hardness testing of the intermix zone because of the narrow width of the zone. The results of the testing are given in the table that follows.

Hardness Test Data

Sample	Vickers	Std. Dev.	Maximum	Minimum	Hardness
Housing 1	148	5.17	153	141	79.24 RB
Housing 2	154	2.24	157	151	81.30 RB
Housing 3	169	4.45	174	163	85.94 RB
Weld 1	278	7.37	288	270	26.84 RC
Weld 2	282	11.8	294	265	27.26 RC
Weld 3	253	12.3	265	234	22.62 RC
Intermix 1	443	53.96	512	385	44.34 RC
Intermix 2	374	100.41	481	260	38.88 RC
Intermix 3	292	26.09	323	256	28.54 RC

The hardness of the intermix zones 1 and 2, indicates that the steel is very brittle. The reason for this is pick-up of carbon by the austenitic stainless steel from the valve housing steel.

Metallographic Examination

The magnification shown for the photos is the magnification at which the photos were taken. The photos shown in this report may be smaller or larger in size than the originals.

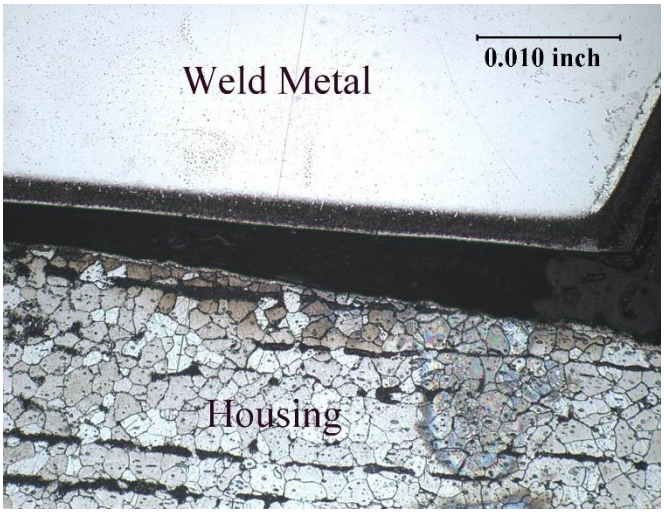

Figure 5 – 100X Weld Root

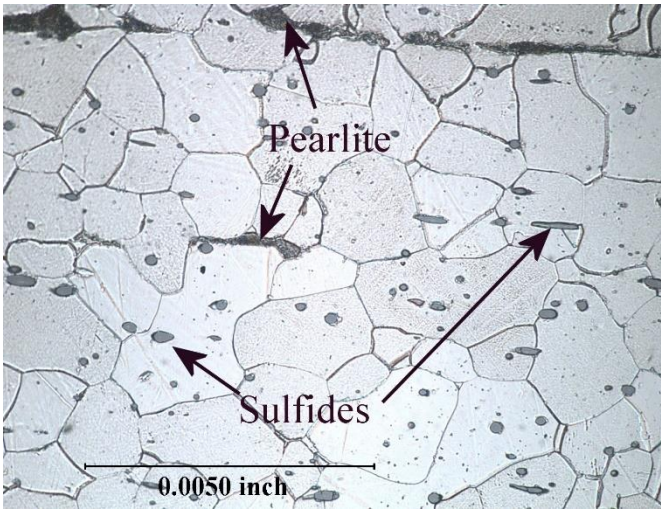

Figure 6 – 400X Microstructure of Housing

Figure 5 shows a significant lack of fusion in the weld root on the housing side of the weld. The lack of fusion extended for about 50% of the leg length on the housing side of the weld, indicating the weld operator was not qualified for these welds. The lack of fusion was the primary cause of leakage at this location. The weld metal was an austenitic stainless steel. The weld filler metal did not etch, the ferritic nitro-carburized layer did etch, and was found at any location where the weld metal had not bonded to the housing steel.

The microstructure of the housing steel was predominantly ferrite with small amounts of pearlite and manganese sulfides, Figure 6. The microstructure is typical of 1215. This grade of steel is not suitable for welding because of the high sulfur and phosphorous contents.

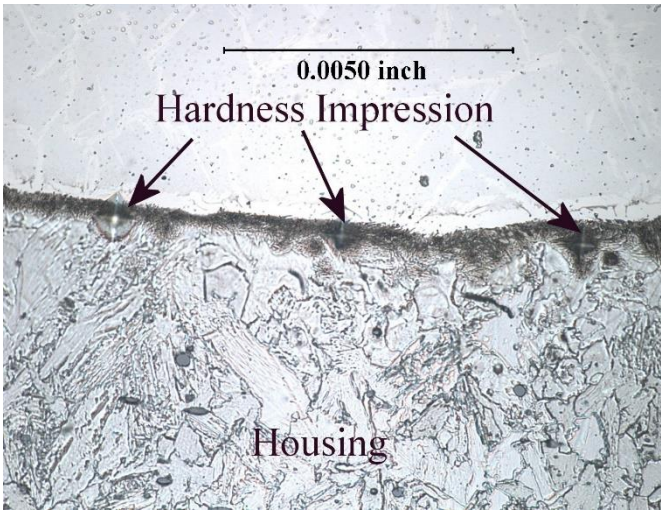

Figure 7 – 400X Interface between Housing and Weld Metal

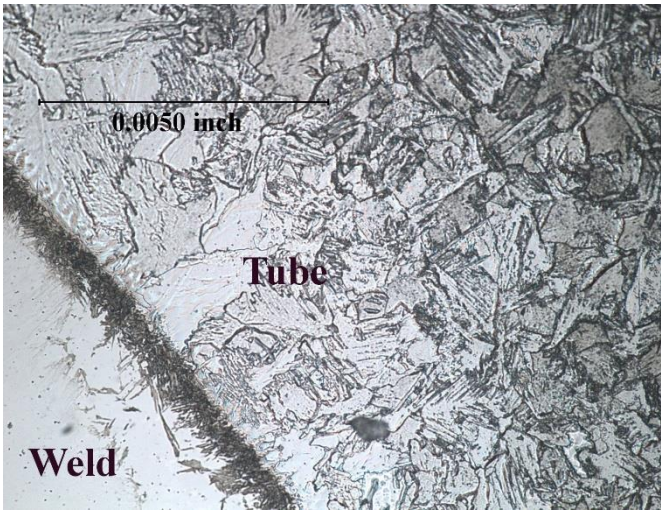

Figure 8 – 400X Intermix Zone between Tube and Weld Metal

Figures 7 and 8 show the interfaces between the housing steel, hydraulic tubing, and the weld metal. Bands of tempered martensite were formed due to carbon being picked up by the weld metal. Martensitic intermix zones occur when carbon steels are welded with austenitic stainless steel. These zones are often quite brittle and are the weak location in the weld joint.

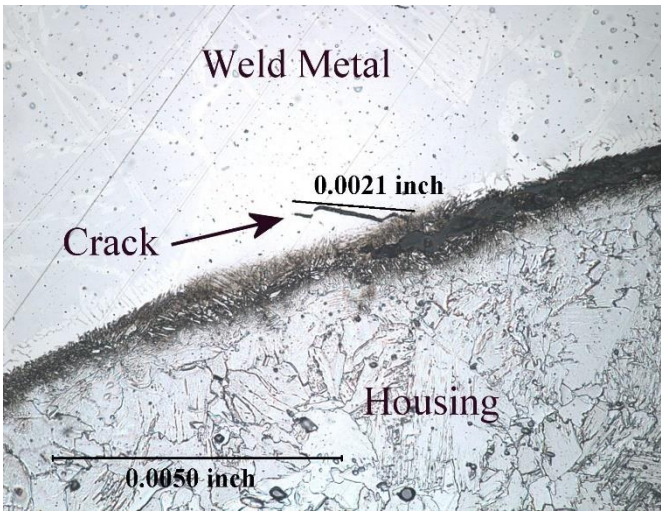

Figure 9 – 400X Crack in Weld Metal

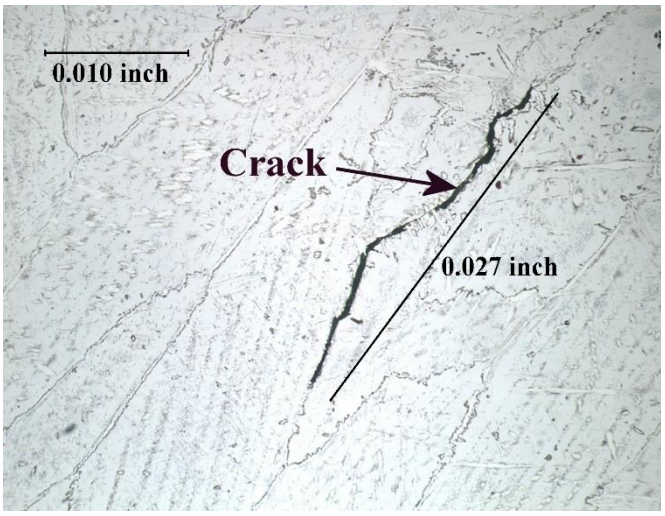

Figure 10 – 100X Crack in Weld Metal

Figures 9 and 10 show cracks in the weld metal. Both of these cracks were hot cracks caused by phosphorous and sulfur pick-up from the housing steel. The etched microstructure of the weld metal, shown in Figure 10, indicates the weld metal was austenitic stainless steel.

Conclusions

There were three major welding defects found with the Rotary Hydraulic Valve assembly: 1) The leaks were the result of lack of fusion between the 1215 steel valve body and the weld filler metal. This is strictly operator error and a clear indication that the weld operator was not qualified for this procedure. The other two major errors were design errors: 2) the valve body was machined from re-sulfurized and re-phosphatized 1215 steel, which is not weldable; and 3) austenitic stainless steel filler metal was used. These two errors would have eventually caused the valve to fail, even if the welding had been done correctly. 1215 Free Machining Steel has one purpose and that is high machinability and should never be considered as part of a welded assembly. The high machinability of 1215 is the result of the inherent brittleness caused by re-sulfurizing and re-phosphatizing of the steel to improve chip breakage during machining. Welding increases this brittleness in both the intermix and heat affected zones. The use of austenitic stainless steel filler metal with carbon or alloy steel requires a full metallographic evaluation of the procedure to determine the pre- and post-heating requirements. In some cases, the post-heating will be a full heat treatment prior to the welded assembly cooling to room temperature.

The Rotary Hydraulic Valve assembly should have been designed for copper brazing instead of welding.