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METALLURGICAL ANALYSIS OF TWO POWDER METAL HUBS

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DESCRIPTION AND PURPOSE

Two powder metal hubs were received for metallurgical analysis. One hub was made in China for Masterdrive while the other was a competitor's hub that was provided for comparison. Material specifications were not provided for the hubs. It was requested that the chemistry, hardness, and microstructure of the Masterdrive hub be evaluated and compared to the benchmark competitive hub.

CONCLUSION

In general, the findings indicate that the competitive hub was superior to the MasterDrive hub in several aspects. Chemical analysis of the hubs revealed the Masterdrive sample met the requirements of MPIF Standard 35 Grade F-008 carbon steel powder metal while the competitive sample met the requirements of MPIF Standard 35 Grade FC-0205 copper steel powder metal. In general, copper is added to powder metal steel to increase strength, toughness, apparent hardness, and wear resistance. Therefore, the competitive hub would be expected to have superior strength, toughness, apparent hardness and wear resistance to the Masterdrive hub. The apparent and particle microhardness of the competitive hub was superior to the Masterdrive hub. Metallographic inspection of the samples revealed similar levels of porosity, but a higher amount of pearlite was present in the competitive sample. Higher levels of pearlite have been associated with higher tensile strength. A sharp radius, approximate 0.0042 inch, and crack were present at the flange of the Masterdrive hub. The radius of the competitive hub was 0.0578 inch. The small radius at the flange of the Masterdrive hub increases the stress concentration at the flange which makes the part much more susceptible to fatigue cracking than the competitive hub. The wall thickness of the competitive hub at mid-length was approximately 5/16 inch while the Masterdrive wall thickness at mid-length was approximately 1/4 inch. The greater wall thickness of the competitive hub should provide better strength.

TESTS AND RESULTS

Visual Inspection

The hubs are shown as-received in Figure 1, where the powder metal hub made in China for Masterdrive is on the left and the competitor's hub is on the right. The Masterdrive hub was identified as Sample A and the competitor's hub was identified as Sample B for the purposes of this study. Sections MA and MB were selected for metallographic examination. The wall thickness of Sample A at mid-length was approximately 1/4 inch while the wall thickness at mid-length of Sample B was approximately 5/16 inch. The bottom of the hubs is shown in Figure 2. The name "Browning" was stamped on the bottom of the Sample B.

Chemical Analysis Results

The chemical composition of the base metal of the hubs was determined using inductively coupled plasma/optical emission spectroscopy (ICP/OES) with the carbon and sulfur contents determined using a combustion/IR technique. The test results are presented in Table 1. The base metal composition of Sample A met the requirements for MPIF Standard 35 Grade F-008 steel powder metal. The base metal composition of Sample B met the requirements for MPIF Standard 35 Grade FC-0205 steel powder metal. In general, copper is added to powder metal steel to increase strength, toughness, apparent hardness, and wear resistance to the steel. Therefore, Sample B would be expected to have superior strength, toughness, apparent hardness and wear resistance to Sample A.

Table 1 - Chemical Analysis Results
(Weight Percent)

Element	Hub Sample A	MPIF Standard 35 Grade F-008 Requirements	Hub Sample B	MPIF Standard 35 Grade FC-0205 Requirements
Carbon	0.77	0.6 - 0.9	0.53	0.3 - 0.6
Manganese	0.17	N.S.	0.32	N.S.
Sulfur	0.13	N.S.	0.15	N.S.
Silicon	0.12	N.S.	0.04	N.S.
Nickel	0.01	N.S.	0.05	N.S.
Molybdenum	<0.01	N.S.	0.03	N.S.
Copper	0.02	N.S.	2.13	1.5 - 3.9
Iron	98.78	97.1 - 99.4	96.75	93.5 - 98.2

Carbon and sulfur contents determined using a Combustion/IR technique (CA-6, 01-06); remaining elements determined using ICP-OES (CS-3, 09-07).

N.S. = Not Specified.

Metallography

Metallographic cross sections were prepared through an area of the hubs 180° away from the keyway, as indicated by the black lines labeled MA and MB in Figures 1 and 2 in order to facilitate examination of the part profile and microstructure. The profile between the flange and the body of the hub of Sample A is presented in Figure 3, where the body of the hub is oriented horizontally at the top of the image and the flange is oriented vertically at the left and center of the image. The radius between the flange and the body of the hub was very small, 0.0042 inch. A higher magnification view of the top right portion of Figure 3 is presented in Figure 4 which shows a small crack that started at the radius. In general, the smaller the radius, the higher the stress concentration will be and the more prone the part will be to fatigue cracking. The profile between the flange and the body of the hub of Sample B is presented in Figure 5, where the body of the hub is oriented horizontally at the top of the image and the flange is oriented vertically at the left and center of the image. The radius between the flange and the body of the hub in Sample B was 0.0578 inch, which is much larger in comparison to the radius in Sample A. The larger radius makes Sample B less susceptible to fatigue cracking. A higher magnification view of the top right portion of Figure 5 is presented in Figure 6 which shows no obvious indications of cracking. The level of porosity of the hubs qualitatively appeared to be similar to in comparison to each other. Etching of Sample A revealed a microstructure of pearlite and ferrite, as shown in Figures 7 and 8. Etching of Sample B also revealed a microstructure of pearlite and ferrite, as shown in Figures 9 and 10. More pearlite appears to be present in Sample B which is often associated with higher strength.

Hardness Test Results

The apparent hardness of the hubs was tested with the results presented in Table 2. The apparent hardness for Sample A is typical of Grade F-008-25 powder metal. The apparent hardness for Sample B is typical of Grade FC-0205-45 powder metal.

Table 2 - Hub Apparent Hardness Test Results

Reading	Sample A, HRBW	Sample B, HRBW
1	51	76
2	52	75
3	52	77
4	52	77
5	51	76
Average	52	76

Tested in accordance with ASTM E 18-05.

The core microhardness of the hubs was tested with the results presented in Table 3. It should be noted that due to the small particle size and low hardness of the particles, microhardness testing was performed at a 50 gf load rather than a typical 500 gf load. Since microhardness testing at a 50 gf load is outside the scope of Stork Technimet's A2LA accreditation, the results are presented for reference only. The average particle microhardness of Sample B was higher in comparison to the particle microhardness of Sample A.

Table 3 - Hub Microhardness Test Results

Reading	Knoop Microhardness - Sample A, HK_{50}	Knoop Microhardness – Sample B, HK_{50}
1	180	235
2	192	192
3	181	223
4	197	214
5	196	204
Average	189	213
Approx. Equivalent Rockwell Hardness*, HRB	87	92

Tested in accordance with ASTM E 384-07.

*** Per Table 2 of ASTM E140-07.**

If you have any questions concerning the contents of this report, please contact me. It should be noted that it is our policy to retain components and sample remnants for 30 days from March 10, 2009, after which time they will be discarded. If you would like to make alternate arrangements for disposition of the material, please let me know. This project shall be governed exclusively by the General Terms and Conditions of Sale and Performance of Testing Services by Stork Technimet, Inc. a Wisconsin business corporation d.d. November 4, 2008. In no event shall Stork Technimet, Inc. be liable for any consequential, special or indirect loss or any damages above the cost of the work.

Respectfully submitted,

Electronic Original

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Fig. 1 - **The hubs are shown as-received, where the Masterdrive hub is shown on the left and the competitive hub is shown on the right. The Masterdrive hub was identified as Sample A and the competitive hub was identified as Sample B for the purposes of this study. Sections MA and MB were selected for further analysis.**

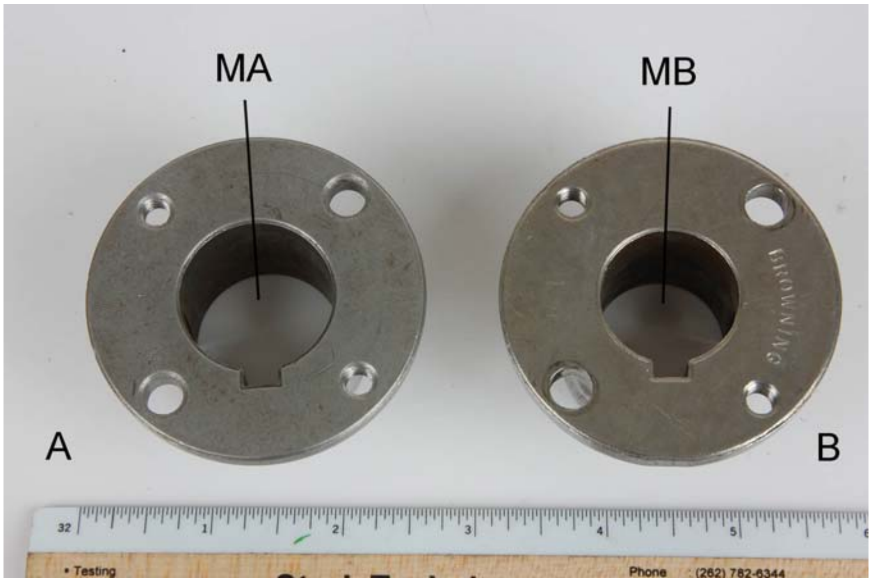

Fig. 2 - **The opposite side of the hubs shown in Figure 1 is presented. The name, “Browning”, is stamped on the flange of Sample B.**

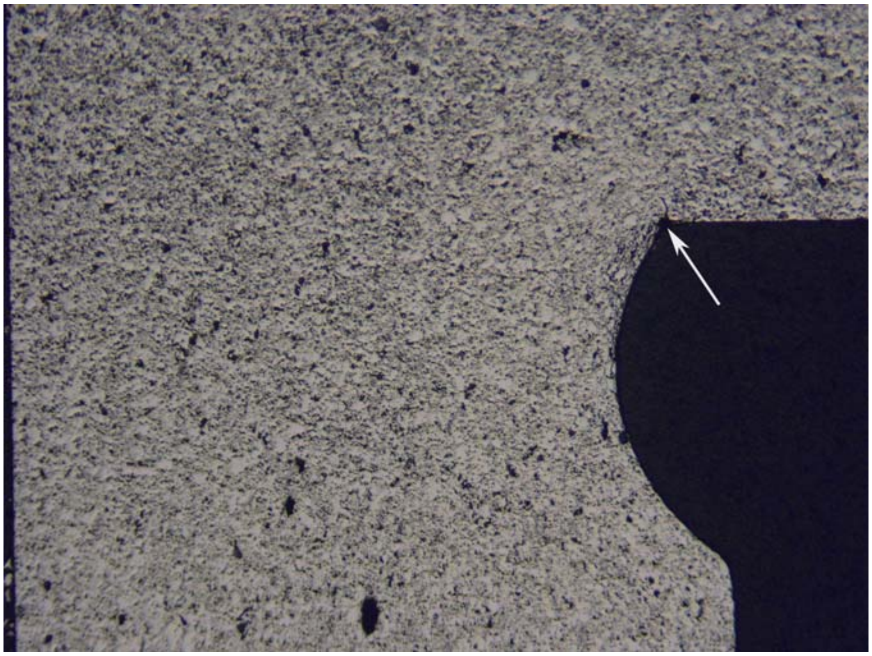

Fig. 3 - A metallographic cross section through Sample A at the area that is indicated by the black line labeled MA in Figures 1 and 2 is presented. The arrow indicates a sharp radius and crack. As polished. (15X)

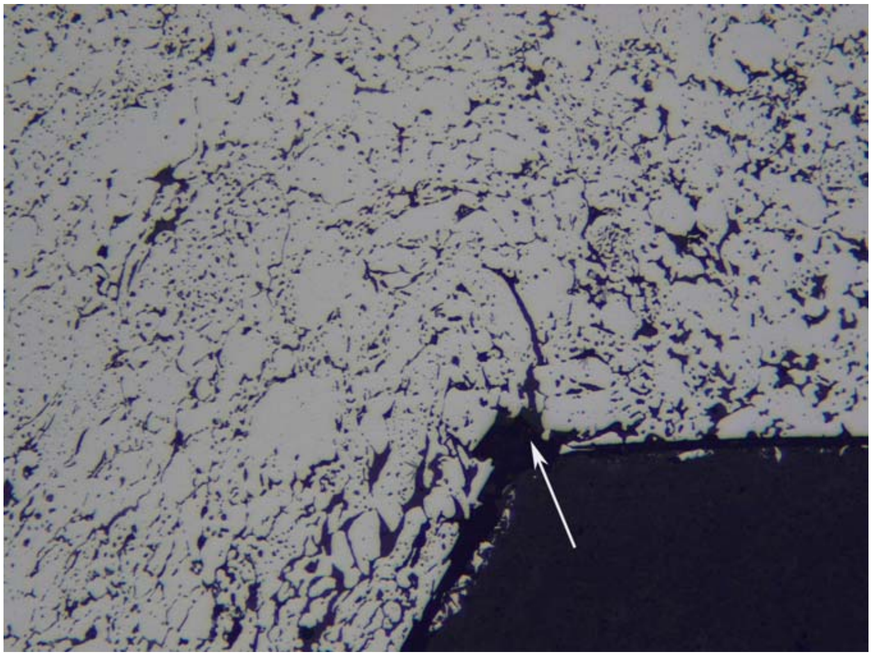

Fig. 4 - A higher magnification view of the top right portion of Figure 3 showing the sharp radius is presented. As polished. (100X)

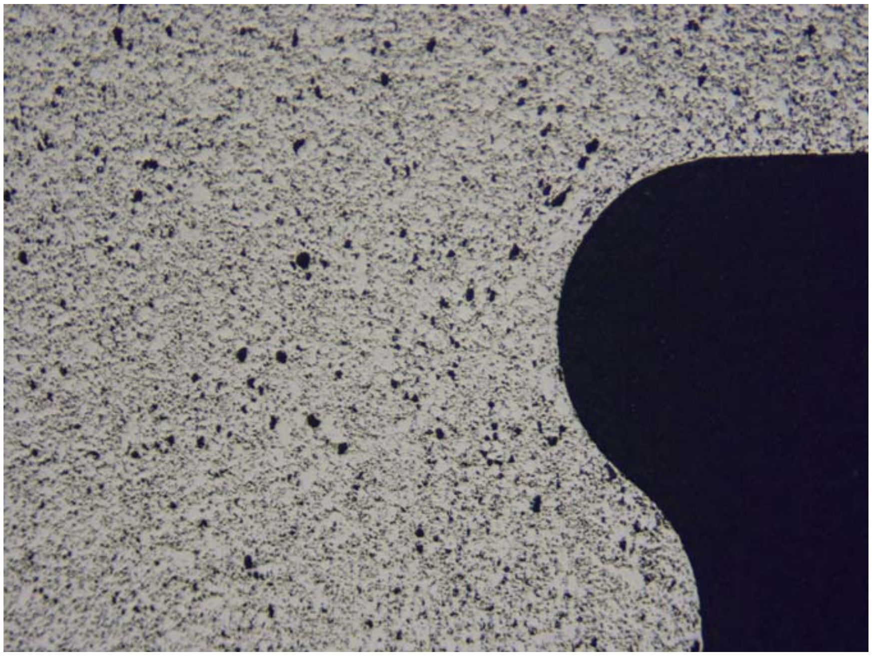

Fig. 5 - A metallographic cross section through Sample B at the area that is indicated by the black line labeled MB in Figures 1 and 2 is presented. As polished. (15X)

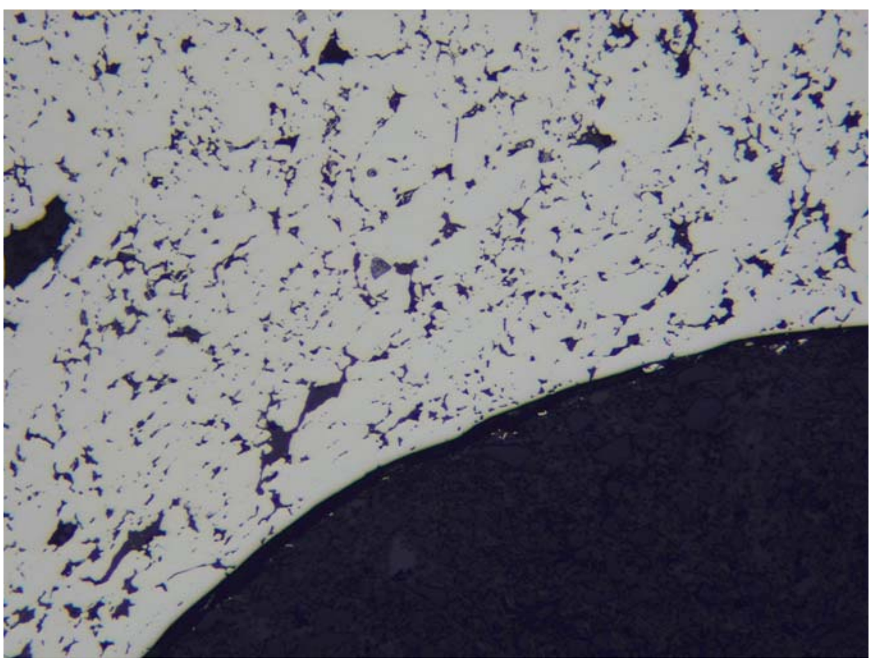

Fig. 6 - A higher magnification view of the top right portion of Figure 5 showing a much larger radius in comparison to Sample A is presented. As polished. (100X)

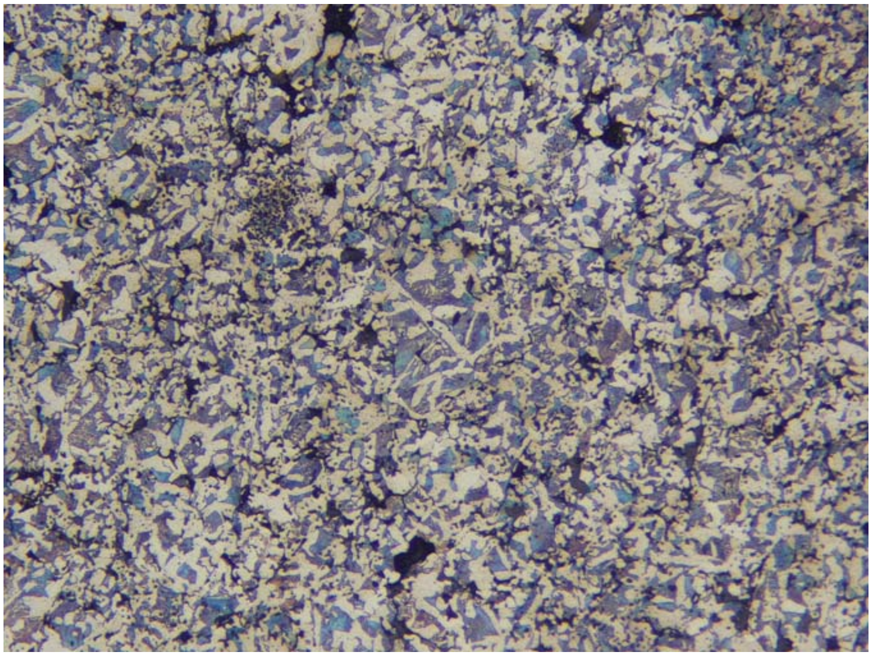

Fig. 7 - The area shown in the left portion of Figure 3 is presented after etching. 2% Nital. (100X)

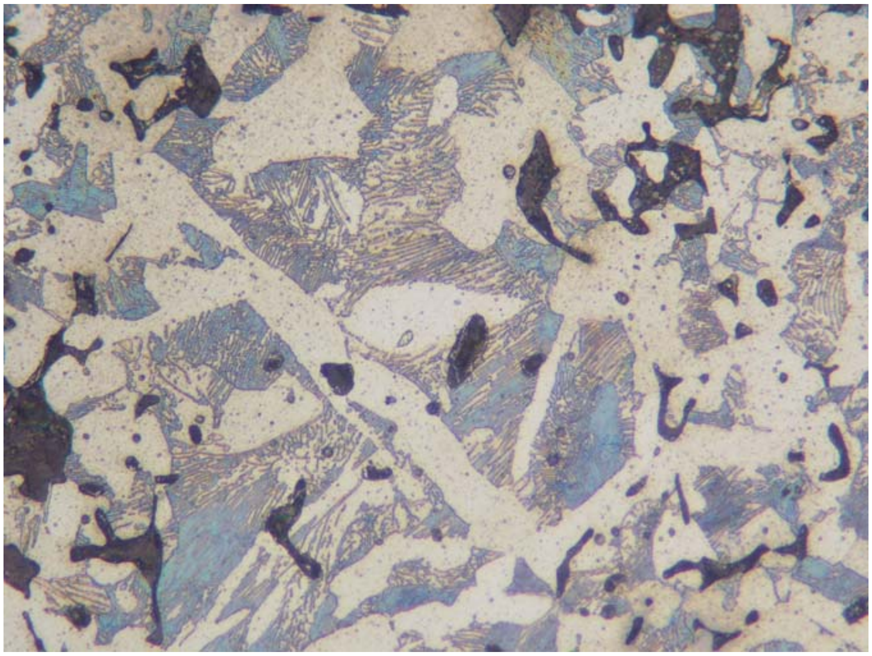

Fig. 8 - A higher magnification view of the center of Figure 7 is presented. The microstructure consists of ferrite and pearlite. 2% Nital. (500X)

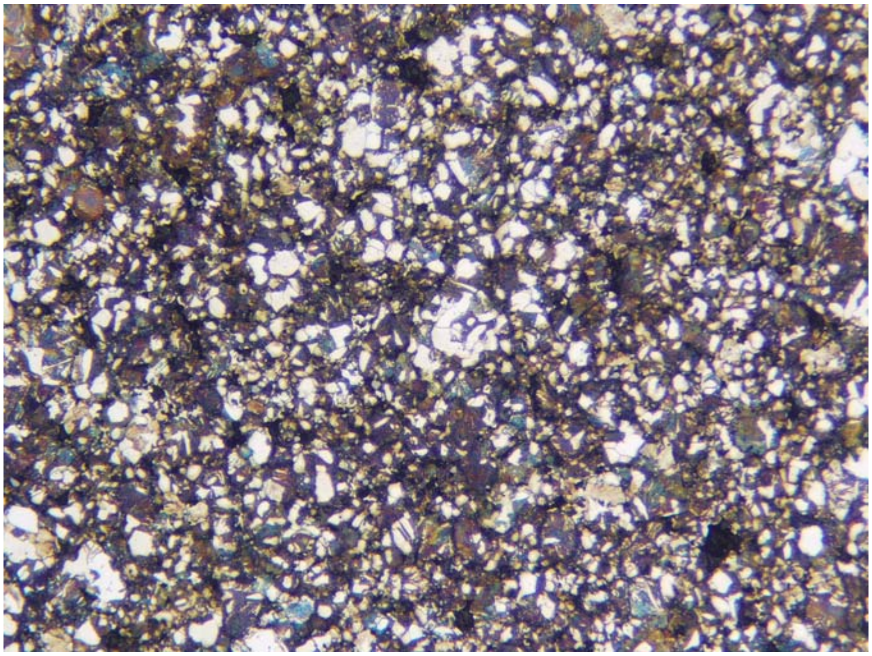

Fig. 9 - The area shown in the left portion of Figure 5 is presented after etching. 2% Nital. (100X)

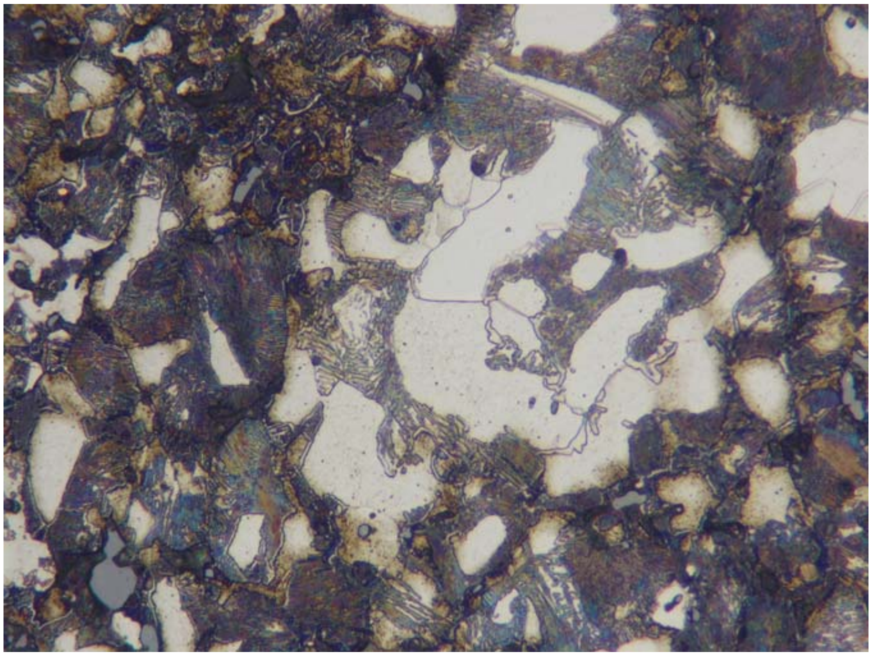

Fig. 10 - A higher magnification view of the center of Figure 9 is presented. The microstructure consists of ferrite and pearlite. 2% Nital. (500X)