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"Excellence in Metallurgical Engineering"

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Case Study: Laser-cut Steel

By

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Subject

Examination of a preproduction part laser-cut from 1084 steel to determine if there were any detrimental effects to the steel resulting from the laser cutting process. When any high carbon or readily heat-treatable steels are cut by flame cutting, plasma cutting, or laser cutting, there is a very high likelihood that an untempered martensitic layer will occur in the heat affected zone; based on this knowledge, this examination concentrated on the heat affected zone. This sample was examined by hardness testing and metallographic examination.

Hardness Testing

Hardness testing was done according to ASTM E384, using a Knoop indenter and a 500 gram load. The results of the testing are given in the table that follows. The values were an average of five readings.

Hardness Test Data (Rockwell C Scale)					
Location	Knoop	STD DEV	MAX VALUE	MIN VALUE	HARDNESS
Surface	429.00	43.12	476.00	362.00	41.96 RC
White Martensite	757.00	22.14	773.00	721.00	61.08 RC
HAZ	372.00	11.76	392.00	362.00	37.12 RC
Core	302.00	9.04	311.00	287.00	28.64 RC

The layer that was of greatest concern was the white martensite layer that had a hardness of 61 on the Rockwell C Scale. This layer would be very brittle, and would likely result in premature failure of the part.

Metallographic Examination

Figure 1 shows the microstructure affected by the laser cutting. There was a layer at the surface which consisted of bainite and bands of white martensite, Figure 2. This layer was between 0.002 and 0.003 inch thick, and was likely very brittle, even though the hardness was in the low 40's on the Rockwell C Scale. Figure 1 shows a layer of very fine grained bainite. The thickness of the combined layers was 0.025 to 0.030 inches.

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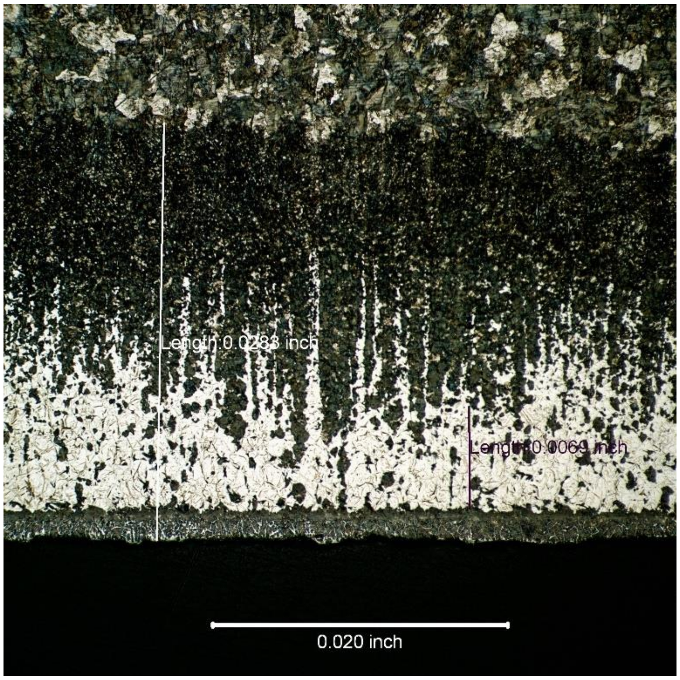

Figure 1 – 100X Layers Caused by Cutting

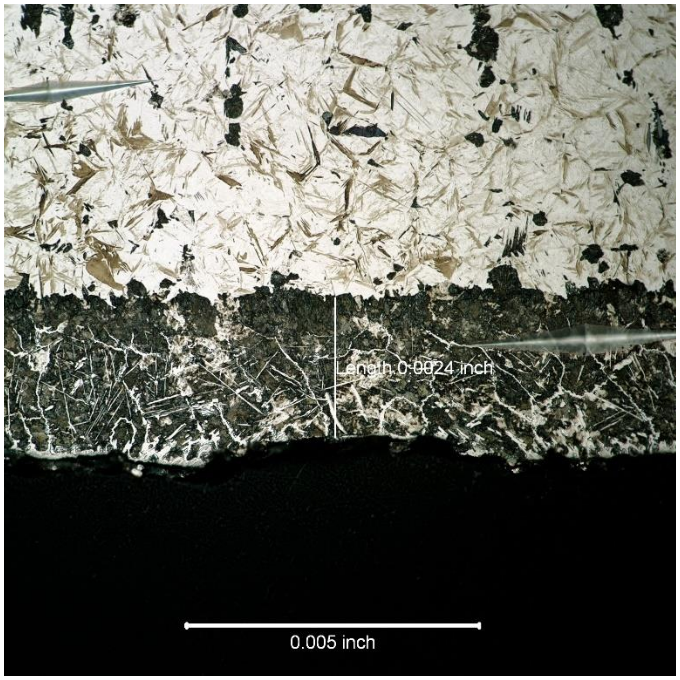

Figure 2 – 400X Surface Layer

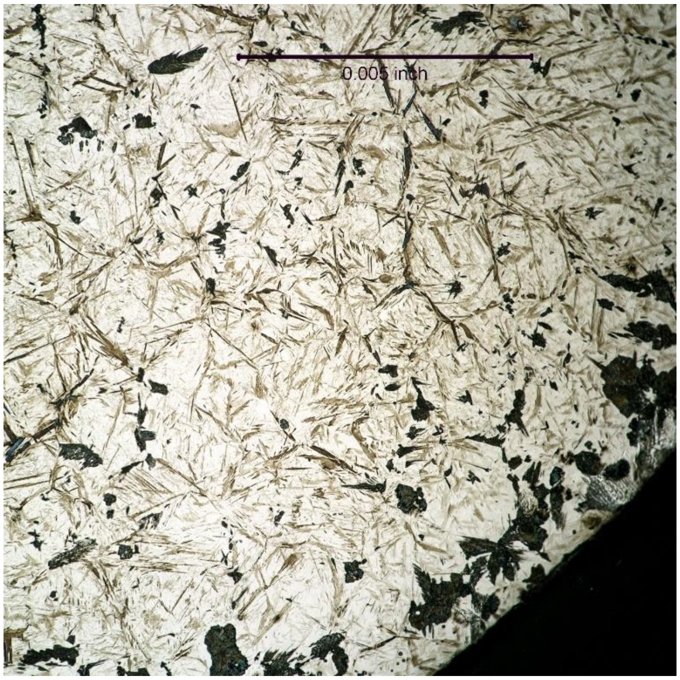

Figure 3 – 400X White Martensite at Corner

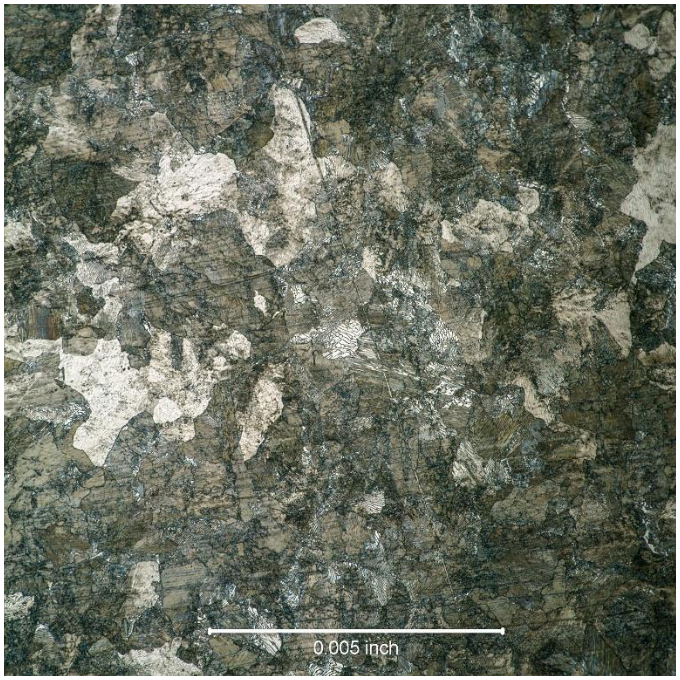

Figure 4 – 400X Core Microstructure

The white or untempered martensite layer was thickest at the corners of the part, and made up most of the heat affected zone, Figure 3. Untempered martensite has very poor fracture toughness and was not an acceptable microstructure for this application. The black areas are Bainite. The 1084 material core of the part is shown in Figure 4. The core consisted of fine grained bainite and pearlite.

Discussion

Thermal cutting of steels, such as 1084 often requires pre-heating of the steel prior to cutting to prevent the formation of a brittle layer of untempered martensite in the heat affected zone. This is similar to the heat affected zone developed during welding. In both cases, untempered martensite in the heat affected zone can lead to premature part failure. In many cases pre-heating to 200º F. is sufficient; in extreme cases, both pre-heating and post-heating are required to prevent formation of untempered martensite.

Conclusion

1) Without pre-heating, laser cutting is not suitable for this part because it leaves a very brittle layer of untempered martensite.

2) Pre-heating to 200º F. would eliminate the formation of untempered martensite in this part.

This client followed good business practice in being proactive in identifying possible causes of failure before putting a new manufacturing process into production.