LPD Lab Services

Consultant Metallurgical Investigation of a Failed Wood Drill Bit

Report Number: T1234

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23 April 2020

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1 Introduction

LPD Lab Services received a failed 3 mm wood drill bit from the client for examination and metallurgical failure investigation. The part was representative of a series of similar field failures and customer returns associated with complaints. The drill bit was said to have bent whilst being used to drill into relatively soft wood and other manufactured parts had suffered similar symptoms.

This report discusses the results of light optical microscopy (LOM), scanning electron microscopy (SEM), energy dispersive X-ray (EDX) analysis and metallographic assessment performed on the drill bit. The purpose of this work was to understand why the drill bit failed as well as offer options for process improvement and optimisation to minimise the chance of reoccurrence of the failures.

2 Sample Preparation/Method Details

Visual examination and low magnification optical examination, using a Leica MX12 binocular zoom microscope, were performed on the failed tool. This aids the study of macro features that can help to identify the type of failure and contributing factors.

A cross section was taken from both ends of the drill bit, using a junior hacksaw. The sections were encapsulated in phenolic resin and then metallographically prepared and etched in 3% nital. Examination of the microstructure was done at magnifications up to 500x using a Zeiss Axioskop-40 metallurgical microscope and up to 5000x magnification in a Philips XL30 scanning electron microscope (SEM) equipped for energy dispersive X-ray (EDX) analysis, using a tungsten filament.

The SEM examination was carried out in secondary electron (SE) which gives good topographical contrast. The composition of the drill bit material was determined by EDX using a beam acceleration voltage of 20 keV.

EDX analysis is a semi-quantitative technique based on the detection of X-rays emitted from the top few micrometers of the sample surface after interaction with the electron beam. X-rays are characteristic for each element present.

Vickers hardness measurements were performed on the cross sections from both ends of the drill bit using a Vickers-Armstrong B59153 hardness tester. Testing was performed according to BS EN ISO 6507 using a 10 kg load.

The analyses were performed on the 22nd of April 2020 and relate to the supplied drill bit after suitable sample preparation.

3 Results and Comments

3.1 Visual Examination

The failed drill bit is shown in Figure 1. It had bent nearly 90° at a location three quarters up the body. For a drill bit to have bent like this indicated that it did not possess sufficient yield strength to serve its intended function.

Figure 1. The failed drill bit.

Whilst sectioning the drill bit to prepare cross sections for metallographic examination it was noted that the material was relatively easy to cut. This would not be expected for a cutting tool.

3.2 Light Optical Microscopy

Low magnification examination was performed on the failed drill. There was evidence of wear along the margin and in a number of places a burr had formed behind the margin and it was overhanging onto the land, as shown in Figure 2. This could have been an indication that the material had insufficient wear resistance to perform its designed task, or it could have suffered careless grinding practice during manufacture depending on the extent of use before failure.

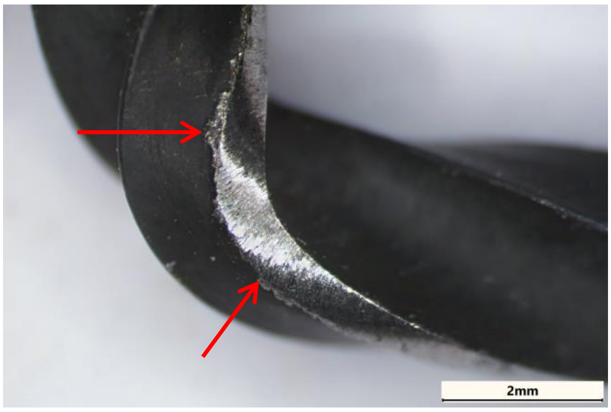


Figure 2. Burr forming behind the margin and overhanging onto the land.

The tip of the centre point was twisted and this indicated that the material probably had insufficient strength to perform its intended duty. This is shown in Figure 3 and at higher magnification in Figure 4.

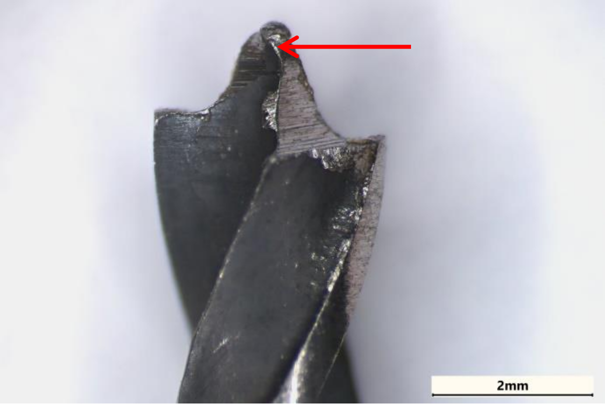


Figure 3. Deformed centre point.

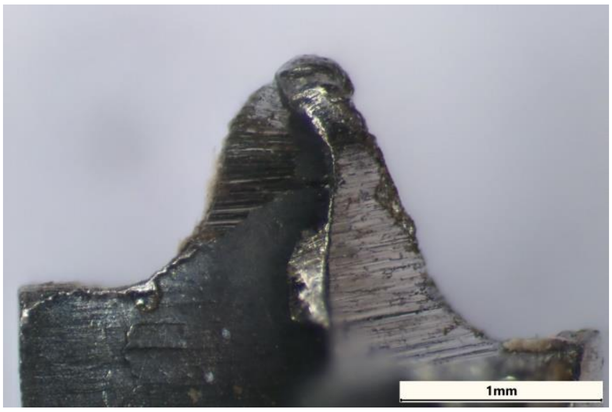


Figure 4. Higher magnification of the twisted centre point.

3.3 Metallographic Examination

Examination of the metallographically prepared sections from both ends of the drill bit indicated the material to have very fine grains. The microstructure was in the tempered condition and comprised a mixture of ferrite, martensite, pearlite and perhaps bainite. The microstructure was the same at the tip as it was at the shank. A mixed microstructure is not suitable for any tool and it indicated that the heat treatment performed on the drill bit was incorrect. It is crucial that tool materials are heat treated to obtain a fine tempered martensitic microstructure.

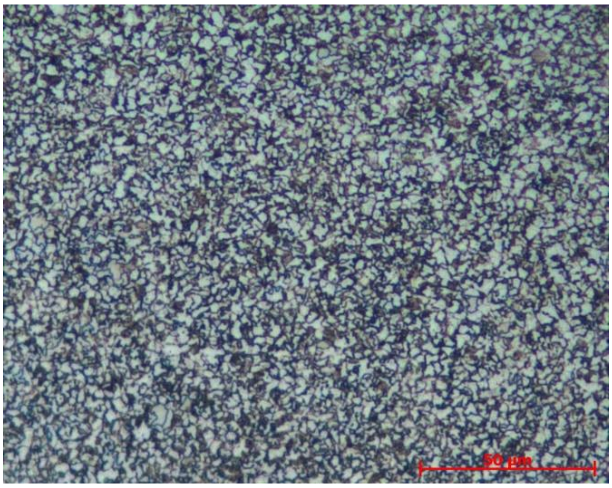


Figure 5. Microstructure of the tip, consisting of ferrite, martensite, pearlite and perhaps bainite.

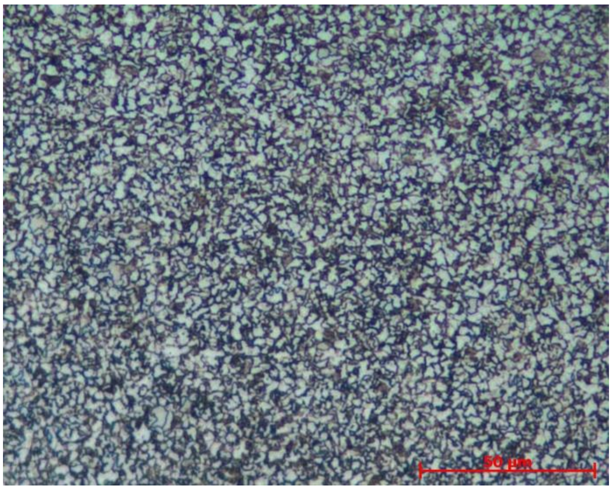


Figure 6. Microstructure of the shank, also consisting of ferrite, martensite, pearlite and perhaps bainite.

3.4 SEM Examination

In order to resolve the very fine microstructure of the drill bit it was examined at higher magnification in the SEM. Figure 7 shows the microstructure at the tip and Figure 8 shows the microstructure at the shank. At this high magnification there appeared to be subtle differences with the shank seemingly having larger martensitic grains and a more bainitic than pearlitic phase.

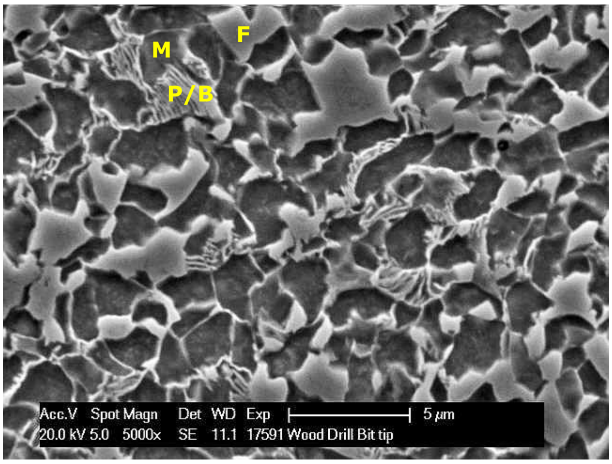


Figure 7. SE image showing the microstructure at the tip, consisting of ferrite (F), martensite (M), pearlite (P) and/or bainite (B).

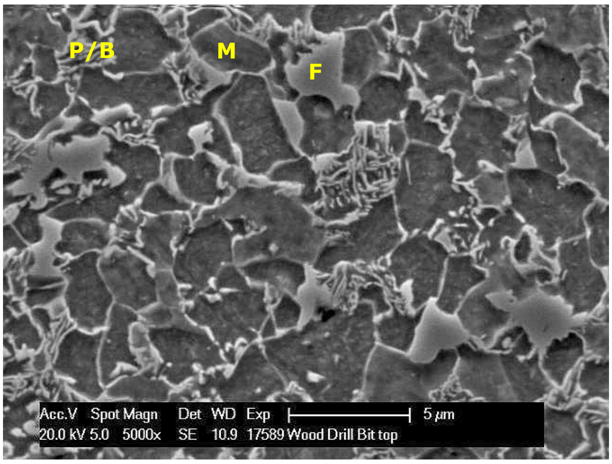
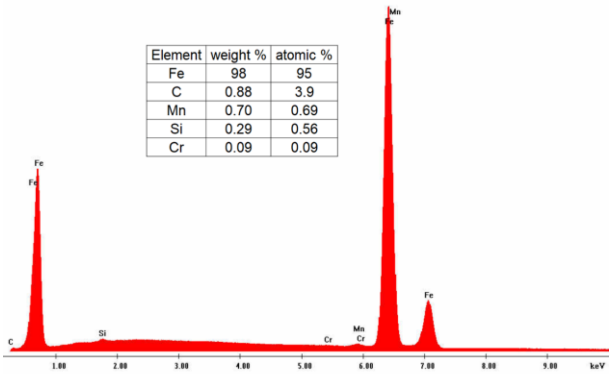


Figure 8. SE image showing the microstructure at the shank, consisting of ferrite (F), martensite (M), pearlite (P) and/or bainite (B).

3.5 EDX Analysis

The EDX spectrum and semi quantitative composition of the drill bit material is shown in Figure 9. The composition indicated the material to be medium carbon steel. Note that the carbon result produced by EDX is typically higher than the actual value. A separate carbon analysis is required to get a more reliable figure, but this was deemed unnecessary based on the wider findings in this report.



Element	weight %	atomic %
Fe	98	95
C	0.88	3.9
Mn	0.70	0.69
Si	0.29	0.56
Cr	0.09	0.09

Figure 9. EDX spectrum and composition of the drill bit material.

3.6 Hardness Testing

Table 1 presents the results of the hardness tests. The recorded hardness values were in agreement with what could be expected for the given microstructure and composition of this drill bit. The measured hardness values were, however, too low for this material to function appropriately as a cutting tool.

Table 1. Results of the hardness test (Vickers 10 kg).

Hardness values (HV10)	Tip	Shank
Test 1	249	222
Test 2	253	221
Test 3	251	218
Average	251	220

4 Conclusions

From the results obtained during this metallographic examination, it was concluded that the drill bit did not have the optimum microstructure that would be expected for a tool. It did not consist of fine tempered martensite, but rather of a mixture of ferrite, martensite, pearlite and bainite. If the drill had been heat treated correctly it would also have had a higher yield strength and it would not have bent so easily.

This undesirable microstructure would have been the results of an improper heat treatment. It is likely that the material was not fully austenitised before quenching, but it could also be that the quench rate was slower than the critical rate required to fully transform to martensite. The latter could occur if the drill bits were packed tightly into relatively large bundles to help maintain straightness during heat treatment. Steels with no alloy addition have limited hardenability and cannot transform fully to martensite if the ruling section is not sufficiently small (a larger mass cools significantly slower than a smaller mass and the slower it cools the less likely it is to transform to martensite).

The composition of the drill bit material (with lower carbon) was similar to that of AISI 1060 steel. This material would be expected to obtain a hardness in the order of 300 to 400 HV10 if suitably quenched and tempered, depending on the size of the component and the tempering temperature (smaller diameter and lower temper temperatures would be expected to attain higher hardness values and vice versa). Figure 10 shows a continuous cooling transformation (CCT) diagram for AISI 1060 steel with the as quenched hardness indicated at the end of each indicated cooling rate (subsequent tempering will lower the final hardness). It is observed that this type of material can obtain the desired microstructure and mechanical properties if quenched fast enough. If in manufacture the drills are grouped tightly together during heat treatment, to maintain straightness, then it is advisable to use an alloyed steel that possesses the desired hardenability.

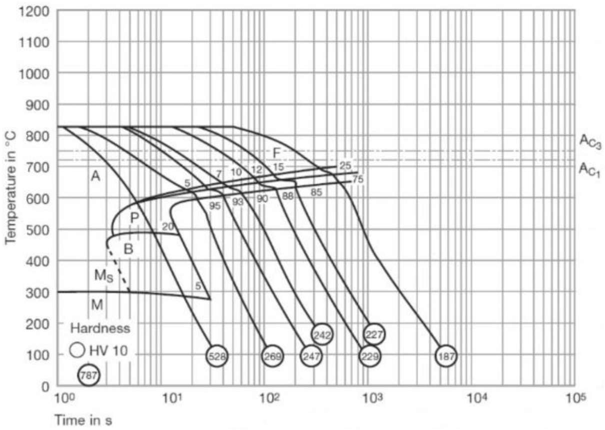


Figure 10. Continuous cooling transformation (CCT) diagram for AISI 1060 steel.

The drill bit was not of a high quality so in its wood application it would not be expected to last long but may be sufficient if it is intended for a low-end DIY market with limited use and for drilling into relatively soft wood. For that purpose, the drill bit would have been adequate provided it was kept sharp and used with light pressure applied along the axis of the drill bit (i.e. not at an angle). However, proper heat treatment would have turned this drill bit into a far more durable tool capable of withstanding moderate abuse and maintaining a keen cutting edge for much longer, at little or no extra cost.

In summary, hardened and tempered medium carbon steel is an acceptable material for cutting wood, even hard wood. This drill bit, however, did not possess the correct metallurgical microstructure and mechanical properties (hardness and yield strength to be precise) to perform its duty well enough and was, therefore, not fit for purpose.

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End of report