FAILURE ANALYSIS OF TAPPING SCREWS FRACTURE FOR ENGINEERING APPLICATION

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Abstract: Self-drilling screw of Φ10mm broken off after assemblage, and there were also a few screw fractured during embrittlement test for this lot products. In this paper metallograph, fracture and microhardness were tested and analyzed. The examination results showed that the fracture character were mainly brittle fracture with intergranular fracture form. The carburization penetrated the section between head and shank, and the microhardness test proved that the strength in the fracture area exceeded that of 10.9 bolt as the micrhardness exceeded 40HRC, which directly resulted in increasing greatly fracture sensitive hydrogen induced. According above, the fracture was caused by hydrogen embrittlement in conjunction with higher microhardness of fracture area and lower toughness resulted from carburization . Finally the improving suggestions were put forward and applied.

Keywords: self-drilling screw, fracture, hydrogen embrittlement

INTRODUCTION

Bolt and screw fasteners were widely used in machinery, electronic, astronaut & aerospace and telecom communication engineering, etc. In recent years the failures of fasteners had taken place frequently, which resulted in many significant accidents and economical loss. In this paper the tapping screws fracture failure was analyzed by metallographic examination, SEM fracture analysis and contrast experiments. The processing information about screws was as following: material type WCH22A（1022）, Surface cleaning→pulling wire and polishing→header made→rub thread→carbonization→heat treatment (preheat to 900℃, 30min then quenching into oil and temperature 395℃ 60min)→electroplating→passiration→hydrogen removing→finish, case hardness HRC40~50， core hardness HRC28～38. However, a few screws fractured after assemblage. And in fact, before that, 13 screws had already been used for hydrogen brittleness test in which torque 0.28Nｍ(85% of designing failure torque 0.32Nm)，and keeping 24h while seating then unloaded and after that reloaded again. But, of which there always had 1-3 screws fractured in a lot while retighten. It was worth doubting whether caused by hydrogen?

FRACTURE AND METALLOGRAPHIC EXAMINATION

Fig.1 was failure screws macrograph, heads were separated from their shanks. the cross-slot had formed a throughout hole. And scarabs were observed in fracture. Some

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intergranular brittleness in inner of fracture and dimples in local area were also found (fig.2 to fig.4).

Metallographic test were showed in fig.5 to fig.7. That carbonization through the whole section between head and shank. Core microstructure was tempered sorbite with keeping martensite shape and carbonization layer was tempered troosite.(see also fig.6 to fig.7）.

The microhardness in fracture area and shank were examined and the test data were shown in tab.1 and tab.2.

TABLE 1- grads microhardness in case depth of thread root

Distance from surface /mm	0.03	0.08	0.11	0.18	0.30	40	0.50
HV0.3	495	452	370	360	330	330	332
HRC	48.7	45.4	39.8	36.6	33.3	33.3	33.6

TABLE 2- grads microhardness of section between head and shank

Distance from surface /mm	0.05	0.08	0.15	0.18
HV0.3	475	466	429	417
HRC	47.3	46.6	43.5	42.4

The micrhardness shown that case depth was less than 0.2mm, core hardness and case hardness confirmed to the technology requirements.

ANALYSIS AND DISCUSSION

Generally intergranular fracture might caused by hydrogen brittleness or carbonization. But which one was possible? In order to explain this, 3 screws of same lot were used to test the content of hydrogen, and the content was 0.00085％, 0.00055% and 0.0014％, respectively. It was evident that the hydrogen level was much high. It was well known that case hardness was HRC32 for 8.8 bolts, HRC37 for 9.8, HRC39 for 10.9, therefore the strength in core had already exceeded 800MPa (for 8.8), and in the fracture 1040MPa (for 10.9)〔1〕. In other wards, the screws reached high level strength and as result it was inevitable for screws broke off caused by hydrogen（Lihelin 〔2〕）during assemblage or hydrogen brittleness test.

Next the overload test was made according fig.8, in this experiment the screws were exserted a overload torque until fracture. The average fracture torque was 0.58Nm, which was 2 times that of hydrogen test (left side in fig.9，fig.10). Observing the fractures with shearing dimples〔fig.11〕, fracture happened in the first tooth root other than above that (fig.9 and fig.10). However the screws were clamped at head and twisted till fracture, the average torque was 0.32Nm which reached the designed torque and the fracture site were as same as overload test (0.58Nm, middle in fig.9).

According above experiments, the danger area should be that of thread root other than intersect, from this point of view the strength in transect area between head and shank was better than that in thread root. It was be sure that former fractures were caused by hydrogen. However delay fracture of lots of screws were not observed which was the main judgment of hydrogen brittleness. It was considered that the washer (170HB) and the test plate (73HV) were very soft which played a cushioning effect on stress caused by torque on great extent, only if in the condition of very small section area, large scales fracture might happened. Subsequently, hydrogen embrittleness evidence was finally hidden. The failure torque was different from each other in above test, this might be explained by different stress condition.

CONCLUSION AND SUGGESTIONS

The fracture of screws were caused by hydrogen embrittleness. In which the prerequisitions were consisted of two factors, one was high hardness and low toughness resulted from carbonization; the other was high hydrogen content caused by acid cleaning and electroplating.

A suggestion was put forward and adopted, i.e. declining suitably hardness and decreasing case depth, and the application showed that the fracture might be fully avoided.

References：

（1） ISO 898.1-2000, fastner mechanicals –bolts, studs and screws.

（2） Lihelin, failure examples proceeding for oil pipes, Oil industrial press, Beijing, China, 2006.

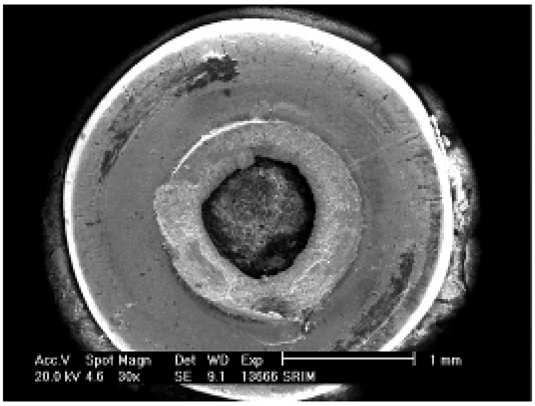

FIGURE: 1 -SEM fractograph of fracture

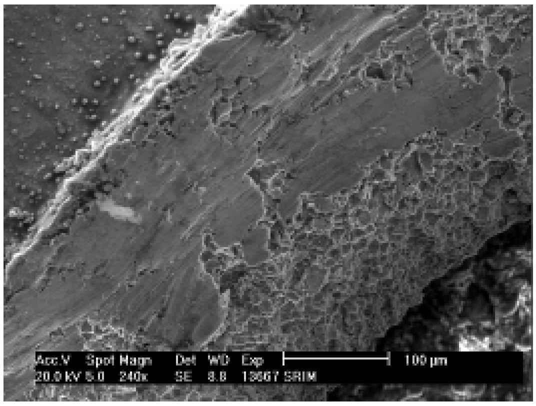

FIGURE: 2 -Scratch in the fracture

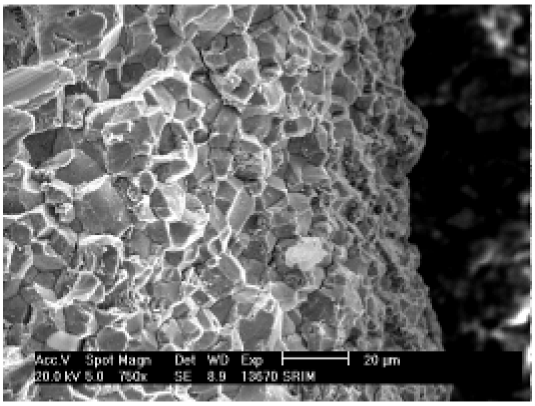

FIGURE: 3 - Intergranular fracture

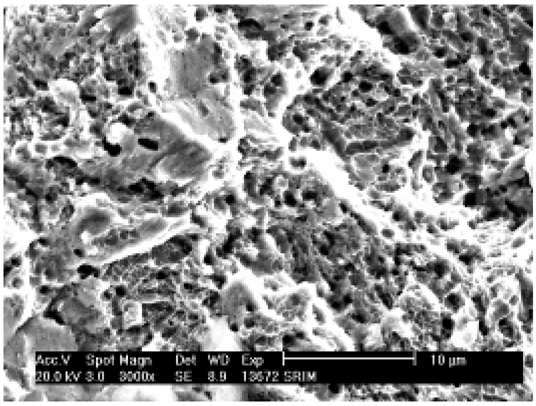

FIGURE:4 - Dimples in local area

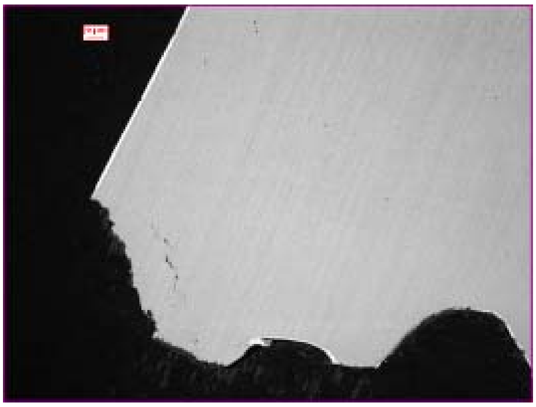

FIGURE: 5 – Polished state of fracture

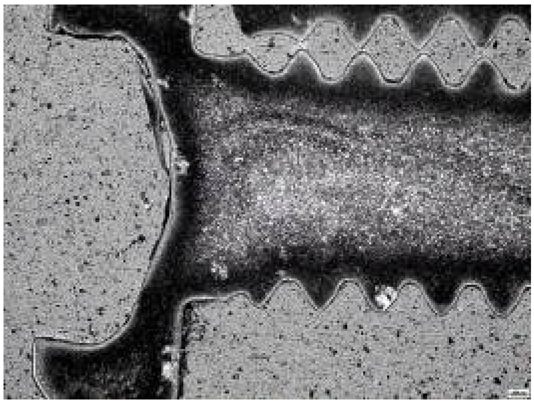

FIGURE:6 – Section plane through center

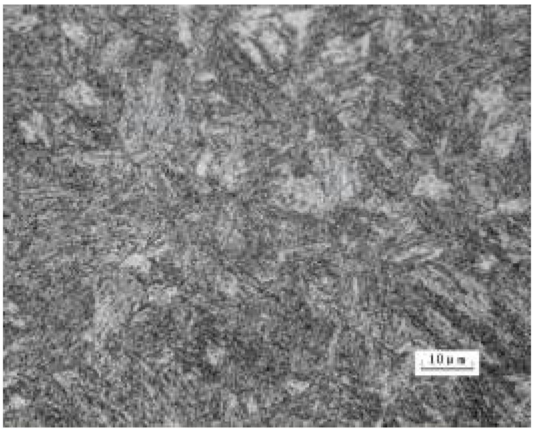

FIGURE:7 -Microstructure in the center of screw

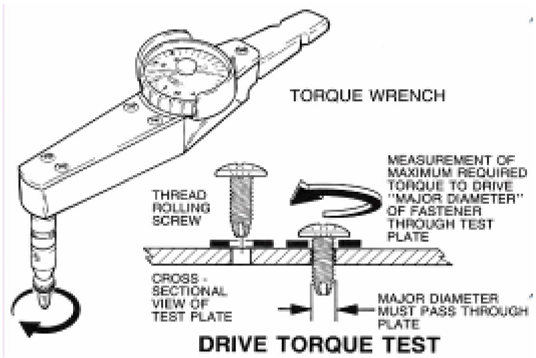

FIGURE: 8- Hydrogen embrittlement test sketch

FIGURE: 9- Overload fracture

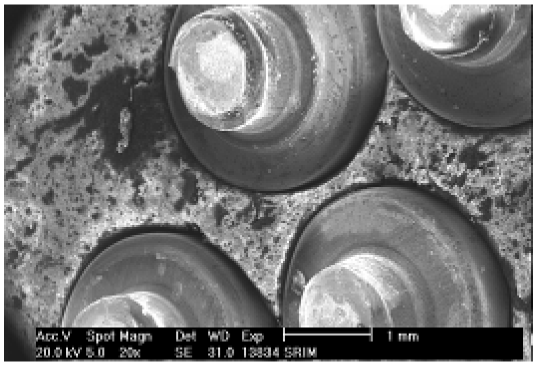

FIGURE: 10 Overload fracture

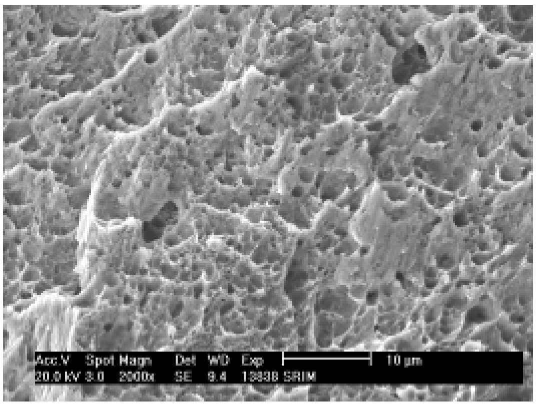

FIGURE:11 - Shear dimples in fracture