Research on the fractured reasons of aluminum piston for air braking system

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Abstract. The test and analysis of sample elements, sample factures, metallographic structures and mechanical characteristics are described in this document. There are many reasons for the fracture of aluminum piston, which involves many factors, such as the smelting, pressing, heat treatment of raw materials and the subsequent machining, service conditions of products. Referring to the analysis of the returned products, there is only a piece of fractured product in the serial supplying. Raw material: a sample stick, several samples without fracture from different batches. The bad consistency leads to hard analysis. Considering that there are many factors involved in the analysis of fracture, it is necessary to analyze and study the relevant factors from the raw materials, the fractured samples and the intact samples as far as possible. Therefore, we test and analyze the elements, factures, metallographic structures and mechanical characteristic of relevant samples, referring to relevant domestic and foreign literatures and national standards.

1. Analysis of elements

According to national standard GBT 3190-2008《Wrought aluminum and aluminum alloy-chemical composition》, the elements of fractured samples should meet the requirement in 7003 aluminum alloy national standard. Table 1 is the test results of fractured sample.

1.1 elements of fractured samples

Table 1 is the test results of fractured sample, it can meet the requirements of 7003 aluminum alloy national standard.

| Element | Cr  | Mn  | Fe   | Ni  | Cu  | Ga  | Zr  | Mg  |
|---------|-----|-----|------|-----|-----|-----|-----|-----|
| Content(%) | 0.037 | 0.017 | 0.226 | 0.006 | 0.035 | 0.078 | 0.078 | 0.597 |

| Element | Al  | Si  | S    | Ti  | V   | Zn  | P   |
|---------|-----|-----|------|-----|-----|-----|-----|
| Content(%) | 92.306 | 0.303 | 0.016 | 0.043 | 0.012 | 6.240 | 0.006 |

2. Analysis of fractured samples

Figure 1 shows the fracture of fractured samples under scanning electron microscope. Figure 1(a) and (c) shows that partial factures are transgranular facture mode, which means that the strength in the
internal of crystal is bigger than crystal. Figure 1(b) and (d) are the selected energy spectrum from figure1(a) and (c), which means that the smooth parts are pure aluminum while the boundary of crystal are mixing with many impurities. It meets the test results in table 1 that Si element excesses the limitation. Figure 1(e) and (f) shows that partial fractures are intergranular fracture mode. Generally, the strength of crystal boundary is bigger than the internal of crystal, the prolongations of fractures is transgranular fracture. Normally, 7003 aluminum alloy doesn’t occur intergranular fractures. But the smooth parts of the fractures should not be judged as transgranular fracture, maybe it occurs because of the not well preserved of fractures. The rest parts of the fractures are intergranular fracture.

Figure 1 The micro characteristics of the fractures of No.1 sample: (a)(c)(e)(f) are microscopic structures; (b)(d) are selected energy spectrums
3. Analysis of metallographic structures
According to GB/T 3246.1-2012《 Inspection method for structure of wrought aluminum and aluminum alloy products Part 1: Inspection method for microstructure 》， over burning is the phenomenon that eutectic or the crystal boundary of solid and solution remelt when the metallic temperature reaches or excesses to the melting point or solidus curve of the low eutectic in alloy. It can be defined as over burning when the remelting of eutectic ball or the local melting and broadening of the crystal boundary or the formation of the remelting triangle at the junction of the three crystal boundaries occurs in the microscopic structure.

3.1 Metallographic structures of fractured samples
The metallographic structures of fractured samples are shown as figure 2-5, the test results of fractured samples are shown as following. According to the following figures, there are few remelting of eutectic ball, local melting and broadening of crystal boundary, remelting triangle phenomenon occurs in the fractured samples, so it can be defined as a slight over burning phenomenon.

Figure 2  Metallographic structures of the central parts of No.1 fractured samples(horizontal)

Figure 3  Metallographic structures of the partial parts of No.1 fractured samples(horizontal)
4. Analysis of mechanical characteristics

According to national standard GBT 3191-2010 «Aluminum and aluminum alloy extruded bars, rods», we did stretch test for original extruded rods, normal components, fractured samples in ambient temperature to determine whether the strength and elongation met the national standard.

| Code | Supply status | Sample status | Diameter (it means the inner circle of square rod and hexagonal rod )/mm | Tension resistance Rm/MPa | Specified non proportional extension strength $R_{p0.2}$/MPa | elongation /% |
|------|---------------|---------------|-------------------------------------------------|--------------------------|-------------------------------------------------|--------------|
|      |               |               |                                                |                          |                                                 | $A$           |
|      |               |               |                                                |                          |                                                 | $A_{50mm}$   |

Figure 4  Metallographic structures of the central parts of No.1 fractured samples (vertical)

Figure 5  Metallographic structures of the surface parts of No.1 fractured samples (vertical)
4.1 The stretching characteristics of fractured samples

Figure 7 is the stress-strain curve of two fractured sample, table 3 is the mechanical performance of fractured samples. The plasticity of non-fractured components is better than the fractured samples, the elongation of three samples are 11.05%, 10.88%, 11.02%. While the yield strength and tension strength of those three samples is significantly bigger than normal samples. The results fit with the influence of over burning.

| 7003 | T5  | T5  | ≤250.00 | 310 | 260 | 10 | 8 |
|------|-----|-----|---------|-----|-----|----|---|
| T6   | T6  | ≤50.00 | 350 | 290 | 10 | 8 |
|      |     | >50.00~150.00 | 340 | 280 | 10 | 8 |

Figure 6 Stress-strain curve of fractured samples

Table 3  Mechanical characteristics of fractured samples

|     | Elasticity modulus (MPa) | elongation (%) | Tensile strength (MPa) | Yield strength (MPa) |
|-----|--------------------------|---------------|------------------------|----------------------|
| B1-1 | 70167.08017               | 11.04778      | 377.02                 | 327.68234            |
| B1-2 | 74669.77764               | 10.8829       | 378.42                 | 327.62046            |
| B2   | 68356.86014               | 11.01654      | 387.75                 | 332.77027            |

5. Conclusion

Through the analysis of elements, the scan of fractures, the inspections of metallographic structures and the test of mechanical characteristics, the conclusion are as follows:

From the metallographic structure of fractured samples, we found that there are few remelting triangles at the junction of the crystal boundaries, partial crystal boundaries widened, slight over burning happened. It could be defined as intergranular fracture mode according to the scan of fractures of fractured samples. Natural 7003 aluminum alloy shouldn’t contain this kind of fractured mode, it was caused by over burning. Comparing the mechanical characteristics of the two fractured samples with normal components, the plasticity of fractured samples is lower than normal one, and the strength is increased. It met the influences of over burning, but the decrease of plasticity is not obvious.

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