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The influence of process on automobile front muffler high-temperature salt corrosion resistance

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ABSTRACT: In recent years, automobile corrosion problems begin to concern more and more automobile companies and users, and the reports about the cases of automobile exhaust pipe muffler corrosion are not uncommon. Most corrosion-prone areas focus on the molding technique position of automobile front muffler. This paper analyzes automobile front muffler high-temperature salt corrosion resistance with a different process by the high-temperature salt corrosion experiment. This study shows that the corrosion rate of the flapping, crimping, welding and no molding process position of automobile front muffler increases with the number of corrosion cycles, and the corrosion rate of bending position first increases then decreases, the high-temperature corrosion resistance of crimping position is more apt to corrosive than the bending position, the welding position corrodes more easily.

1 INTRODUCTION

With the rapid development of urbanization and automotive in industry, cars are increasingly affecting our lives, and the corrosion failure of car attracts more and more public attention. As an important part of a car, the corrosion of automobile exhaust pipe is frequently reported in the reports. Throughout the exhaust system, the muffler has the highest failure rate, which will be easily corroded in a very short mileage (Ruan 2011).

The main components of an automotive exhaust system are hot manifold, low tail pipe and so on. Exhaust manifold and head tube which near the engine, work under the temperature of 700~900°C, required material to have high temperature strength, high temperature oxidation resistance, thermal fatigue properties, oxidation resistance and good resistance to salt corrosion. The muffler and tail pipe which are relatively far away from the engine, have the service temperature of 600~100°C, required material which has good resistance to salt corrosion and condensate corrosion (Bi 2010). The front muffler which locates between the head tube and the middle pipe, is mainly influenced by the high temperature salt corrosion.

On the corrosion of car front muffler, most current studies focus on aspects of the material properties. However, studies show that the front muffler corrosion occurs mainly determined by the location of various processing and local structures. Therefore, it is necessary to discuss the process of each part of front muffler and investigate the front muffler's process to corrosion resistance.

2 EXPERIMENTAL MATERIALS AND EXPERIMENTAL METHODS

2.1 *Experimental materials*

The raw experimental materials are two different front mufflers A and B on the current market. As shown in figures 1 and 2, using JY/T 016-1996 wavelength dispersive X-ray fluorescence to test the samples size of 34 mm × 34 mm, the chemical compositions of the two front mufflers are shown in table 1.

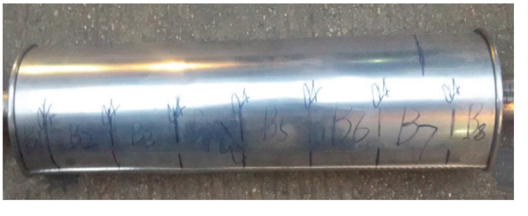

Figure 1. Front muffler A.

Figure 2. Front muffler B.

Table 1. Chemical composition of front muffler(%).

	Composition								
Name	Si	Al	Fe	Ca	S	P	n	Zn	Cl
A	0.18	0.50	35.61	0.048	0.008	0.003	0.072	63.55	0.018
B	0.20	2.12	66.07	0.036	0.017	0.011	0.25	31.26	0.031

The two different exhaust pipes are cut into difference experimental parts, we took out the middle part and the end part of the front muffler as the samples of high-temperature salt corrosion experiment as shown in figures 3, 4, 5 and 6.

As shown in figures 3 and 5, the main process in the middle part of the front muffler is only hem. Flanging process is mainly to make the edges of the double front muffler bent into a certain angle, which is close to the front muffler surface. Flanging has a long curved line and a small bending radius, after folding, it can greatly improve the strength and stiffness of the structure.

As shown in figures 4 and 6, compared to the middle of front muffler, the process and the structure of the end is more complex, such as, crimping, welding, bending, etc. Bending process is mainly on the angle of the bend at the front muffler side cover. Welding process is mainly the muffler welding between the front muffler side cover and the front muffler tube. Crimping process is mainly close overlapping process by compaction of the front muffler cylinder and the front muffler end cover (Zhang 2014).

Figure 3. The middle part of the front muffler A.

Figure 4. The end part of the front muffler A.

Figure 5. The middle part of the front muffler B.

Figure 6. The end part of the front muffler B.

2.2 *Experimental methods*

To evaluate the high-temperature salt corrosion resistance (Nobuhiro 1996), the samples are incubated at 600°C for insulation of 2h and cooled in the air for 5 min, then the samples are immersed in a saturated sodium chloride solution for 5 min as one cycle, generally 40 cycles are required.

The following is the specific experimental procedure, prepared samples as shown in figures 3, 4, 5, 6 for three each one, progressively polished with SiC water sandpaper to 1000#, then cleaned with water and alcohol. Put the 12 experimental samples into the box-type resistance furnace which had been heated to 600°C for insulation of 2h, then cooled in the air for 5 min, after that, immerse the samples in the saturated NaCl solution for 5 min. Finally dry the surface of samples and remove the corrosion products in the surface. The above process as one cycle, 40 cycles totally are experimented.

We tested the thickness of the various technique and structure position in the different samples every five cycles, then study the effect of high-temperature salt corrosion on the thickness

Table 2. The box-type resistance furnace specific model and parameters.

Type	Rated voltage (V)	Rated current (A)	Rated power (Kw)	Commonly temperature (°C)	Maximum temperature (°C)	Size (mm)
SX-1 2–10	380	20	12	900	1000	500 × 30 0 × 200

of samples and analyze the impact of various process and structure on corrosion resistance. The box-type resistance furnace specific model and parameters are shown in table 2.

3 THE EXPERIMENTAL RESULTS AND ANALYSIS

In order to eliminate the influence of the original thickness value in the experimental data, we dealt with experiment values through the simple mathematics method.

$$\Delta d_{5i} = d_{5i} - d_{5(i-1)} \tag{1}$$

where Δd_{5i} are the $5i$ periodic variation value in thickness, d_{5i}, $d_{5(i-1)}$ are the $5i$ cycle values in thickness and the $5(i-1)$ cycle values in thickness; $5i(i = 1, 2, \dots, 8)$ are the number of cycles.

Plugged the average thickness of every 5, 10, 15, 20, 25, 30, 35, 40 cycle s into the formula (1), calculated variation value in thickness of each cycle in different process location.

3.1 *High temperature salt corrosion in the middle of the front muffler*

The main process in the middle part of the front muffler is only hem, by formula (1) processing, we can got the change thickness of the flanging process and no flanging process in the front muffler of A and B made as shown in figure 7. As shown in figure, in the first 20 cycles of front muffler A and B, thickness change value of the flanging process position was greater than no flanging process position, but after 20 cycles instead. The key circumstance factor was the surface tensile stress in the process of forming, at the beginning of the corrosion, the tensile stress of flanging position in saturated salt and stress caused the stress corrosion. Therefore, the change of erosion thickness was bigger. Since the 20 cycles, the position of no flanging position preferred happen electrochemical corrosion, and removed corrosion products in every 5 cycle, new electrochemical corrosion was going on, the corrosion process was as follows:

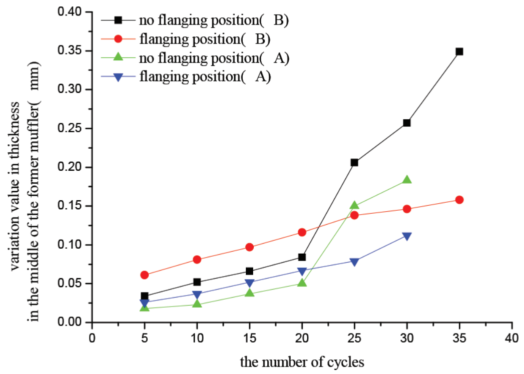

Figure 7. Middle part of front muffler corrosion thickness change curve.

The anode: $Al \rightarrow Al^{3+} + 3e$

$Zn \rightarrow Zn^{2+} + 2e$

$Fe \rightarrow Fe^{2+} + 2e$

The cathode: $O_2 + 2H_2O + 4e \rightarrow 4OH^-$

As shown in figure 7, whether no flanging position or flanging position, the change thickness of B is bigger than A in the middle place of front muffler.

Based on analysis of X-ray fluorescence spectrometer test results, the Zn, Fe content had a great influence on corrosion thickness change value.

3.2 *High temperature salt corrosion in the end of the front muffler*

Compared to the middle part of front muffler, the process and the structure of the end is more complex, such as, crimping, welding, bending, etc. Figures 8, 9 is the diagram of thickness of corrosion rate and the corrosion cycle count in the end part of the front muffler.

According to the analysis for figure 8: with the number of cycles increasing, thickness change value of the welding process position and no molding process position was increases in the end part of the front muffler A and B; the change corrosion value of welding process position was significantly higher than no molding process position. The posi-

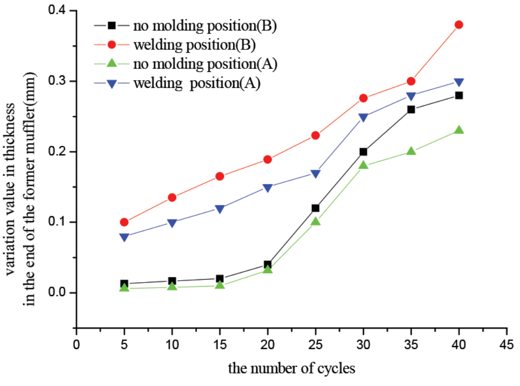

Figure 8. End part of front muffler no process and welding process thickness change curve.

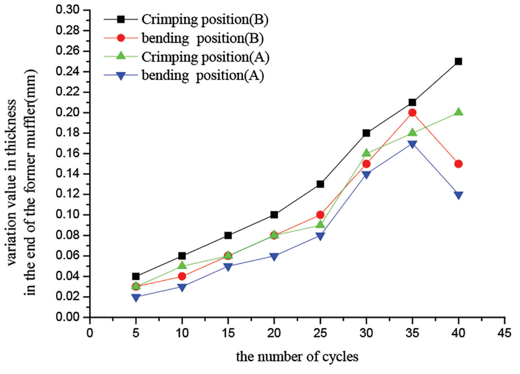

Figure 9. End part of front muffler bending process and crimping process thickness change curve.

tion of welding process happened electrochemical corrosion with the process of soaking in saturated salt solution, it existed not only electrochemical reaction between different metal, but also electrochemical reaction between based material and welding material, thus corrosion change value is big.

Analysis as figure 9: in 5 to 35 cycles, thickness change value of the bending process position was increases in the end part of the front muffler A and B, with the cycle number increasing, thickness change value has decreased after 35 cycles; thickness change value of the crimping process position was increased in the end part of the front muffler A and B, and the thickness change value of the Crimping position was greater than the bending position. In theory, the bending position was measured internal and external surface, There existed tensile stress outside and compressive stress inside, the crimping position of external diameter was measured, there were double tensile stress. Studies show that the tensile stress is not easy to make materials stress corrosion, and stress corrosion can effectively be controlled (Huang 2004), as a result, the thickness of the crimping position change value was greater than the bending position's.

4 CONCLUSION

In the first 20 cycles, the corrosion rate of flanging process position is bigger than no flanging process position in the middle part of front muffler, and corrosion is more likely to happen around the flanging process position, after 20 cycles, with the cycle number increasing, the corrosion rates of each process position are all accelerated.

For the end part of former muffler, with the cycle number increasing, corrosion rates of crimping, welding, no forming process position all exacerbate. But corrosion rate of bending process position first increase then decrease. Corrosion rate of crimping process position is bigger than bending process position; the high temperature salt corrosion resistance for bending process position is the worst.

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REFERENCES

Bi, H.Y., Wu, Y. & Li, X., 2010. the application of ferritic stainless steel and the evaluation of the corrosion failure in the system of Automotive exhaust. *Journal of bao steel technology*, 2, pp. 7–11.

Huang, J.Z., 2004. *Car corrosion and protection technology*. Beijing: Chemical Industry Press.

Nobuhiro Fujita. 1996. Development of ferritic stainless steel YUS450 with excellent heat resisitance for automotive exhaust system. *Nippon Steel Technical Report*, (361), pp.25–30.

Ruan, W.H., 2011. The review about muffler in the system of automobile exhaust. *Journal of Shanghai auto*, 2, pp. 47–49.

Zhang, J. & Bo, J., 2014. Mini car muffler manufacturing technology and process improvement. *Equiipment Manufacturing Technology*, 2, pp. 210–212.