# Corrosion resistance and adhesion evaluation of press hardened steel 22MnB5 coated with AlSi and ZnNi in cyclic corrosion testing

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***Abstract***

AlSi coating has been the most applied on press hardening steels - PHS. However, alternative coatings such as Zn-based alloys are under investigation. This paper has the objective of evaluating the corrosion resistance of the 22MnB5 steel, coated either with hot-dip AlSi or electroplated ZnNi, by means of cyclic corrosion test. Automotive parts of ZnNi coated PHS steel were tested in two different conditions: after hot stamping, and after hot stamping plus sandblasting. Other parts coated with AlSi were evaluated just in the after hot stamping condition. The cyclic corrosion test results showed that all metallic coated samples had excellent corrosion performance. However, the ZnNi coated in the as hot stamped condition, presented the best corrosion performance during testing. Surface coating cracks were found in all parts. Moreover, the adhesion was evaluated after 28 and 68 cycles in creepback area and the results showed that there was no loss of adhesion after the cyclic corrosion tests. The corrosion resistance results pointed that the electroplated ZnNi is a potential alternative to AlSi coating.

**Keywords:** adhesion, AlSi coating, cyclic corrosion test, PHS, ZnNi coating

## Introduction

The ultra high strength boron-manganese steels, known as press hardening steels (PHS), are usually employed in the hot stamping process (1) which consists in heating up a steel blank to complete austenitization at a furnace and then transferring it from the furnace into the forming die, where the steel blank is shaped and quenched at the same time (2-4).

During the hot stamping process, in the transfer step, the heated-up steel and the air atmosphere are in contact for a few seconds which causes deleterious oxidation. To avoid this, the steel is usually coated with either aluminium or zinc-based alloys (2; 3; 5; 6).

Hot-dip aluminium-silicon (AlSi) has been widely applied onto PHS. The coating composition comprises about 10 % of silicon and 90 % of aluminium (2; 3; 5). Due to the

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high demand of PHS, new coatings are under investigation. One of them is the electroplate zinc-nickel which comprises 15 % of nickel and zinc balance (6).

Both metallic coatings, AlSi and ZnNi, have their corrosion behaviour well established (7; 8), however, little is known about the corrosion resistance of these metallic coatings after hot stamping. Considering the few numbers of published works discussing the corrosion resistance of AlSi and ZnNi after hot stamping, this work has the aim of evaluating the corrosion resistance and the coating adhesion by means of cyclic corrosion test, one of the most important tests carried out at carmakers to approve or reprove materials.

## Methodology

Samples of 22MnB5 steel coated with either hot-dip AlSi or ZnNi were removed from the commercial side impact beam, and then the corrosion resistance and the adhesion were evaluated by means of cyclic corrosion test according to GMW14872 (9) and GMW15272 (10) standards. Samples of the ZnNi coated steel were tested in two different conditions: after hot stamping and after hot stamping followed by sandblasting. Samples coated with AlSi were evaluated just in the after hot stamping condition.

After the cyclic corrosion test, the adhesion was evaluated after 28 and 68 cycles in creepback area by scotch tape.

## Results and discussion

Photographic images were taken after 28 and 68 cycles which represent the minimum and maximum number of cycles, considering the automotive parts as external panel. According with the standard GMW14872, the samples are rated as shown in Table 1.

**Table 1- Corrosion evaluation according sample rating after GMW14872 (9)**

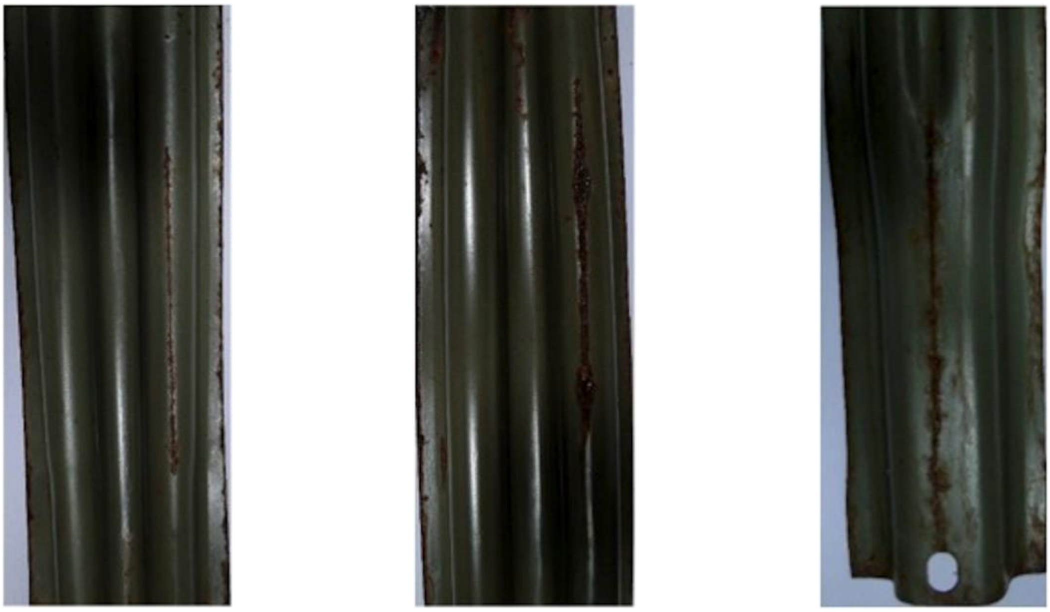
| Rating | Description |
|---|---|
| 10 | No visible corrosion |
| 9 | Trace of corrosion |
| 8 | Slight corrosion |
| 7 | Light corrosion |
| 6 | Moderate corrosion |
| 5 | Medium corrosion |
| 4 | Mostly corroded |
| 3 | Totally corroded |
| 2 | Severe corrosion |
| 1 | Perforation |

Figure 1 shows the results for the samples coated with ZnNi, ZnNi sandblasted and AlSi, respectively, after 28 cycles.

A B C

**Figure 1 - PHS corrosion images after 28 cycles according to GMW14872. A) electroplated ZnNi, B) electroplated ZnNi plus sandblasting, C) hot-dip AlSi.**

The GMW14872 specifies that the 28 cycles are the minimum number of testing cycles for material evaluation. From Figure 1, it is seen that the corrosion was more intense for the samples ZnNi sandblasted and AlSi than ZnNi as received. According to Table 1, ZnNi as received showed slight corrosion (rating 8), whereas the two other sample conditions showed light corrosion (rating 7). Figure 2 shows the samples surfaces after 68 cycle testing.



A B C

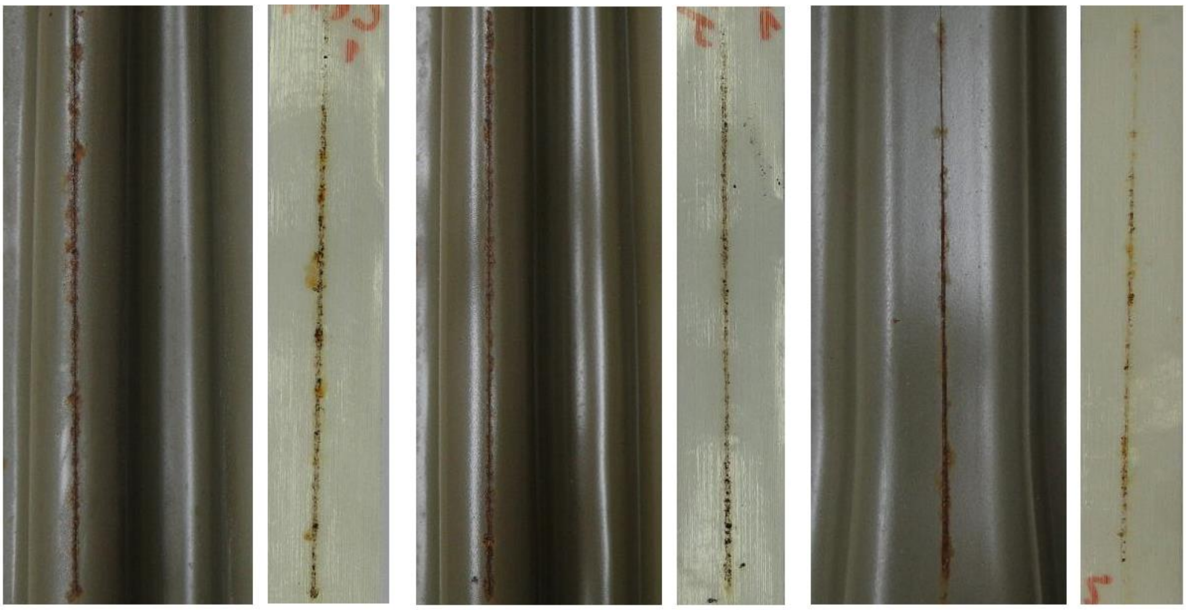
**Figure 2 - PHS corrosion images after 68 cycles according to GMW14872. A) electroplated ZnNi, B) electroplated ZnNi and sandblasted, C) hot-dip AlSi.**

According to the GMW14872 standard, 68 cycles are the maximum number of cycles necessary to evaluate the material cosmetic corrosion. Figure 2 shows that the corrosion was more intense; nevertheless, the corrosion can be classified as moderate (rating 6) according to Table 1, since the predominant area in the samples was preserved. Again, the average rating of ZnNi as received was slightly better than the two other conditions of samples, in this way, the ZnNi as received can be classified with a light corrosion grade (rating 7).

The reason for the ZnNi as received condition showed performance slightly better than the two other sample conditions could be due to the predominant zinc oxide layer formation on the surface.

The protection mechanism against corrosion of AlSi is by barrier (11), on the other hand, the ZnNi provides cathodic protection (12). The barrier mechanism is very efficient against corrosion; however, it is impaired due to the presence of cracks, which probably leads to localized corrosion. Thus, in this case, the cathodic protection is more efficient, because the zinc plays a role of sacrifice anode corroding preferably in relation to the steel (6; 8). Possibly, the sandblasting process might remove the superficial oxide layer, exposing the coating layer which comprises regions of intermetallic phases of Zn-Fe, Zn-Ni or Zn-Ni-Fe.

Besides the corrosion resistance evaluation, the adhesion of the coating onto the steel or for painting situations is also evaluated to validate the material. Figures 3 and 4 show the results of adhesion test after 28 and 68 cycles, respectively.



A B C

**Figure 3 - Adhesion test after 28 cycles for PHS samples (the left picture is the tested automotive part and the right picture is the scotch tape). A) electroplated ZnNi; B) electroplated ZnNi and sandblasting; C) hot-dip AlSi.**

From figures 3 and 4, a loss of adhesion is not observed. This means that there is a good adhesion between the metallic coating and the steel substrate.

Finally, all evaluated samples were approved according to the standard; however ZnNi in the as received condition showed a slight better ratting than the other samples.

It is known that general accelerated tests did not provide a good correlation with field tests (13; 14). However, a study showed that there is a good correlation between the present cyclic accelerated testing and field tests (14), because the cycling consists in exposure to salt solution, humid and dry stage, as a field condition (13; 14).

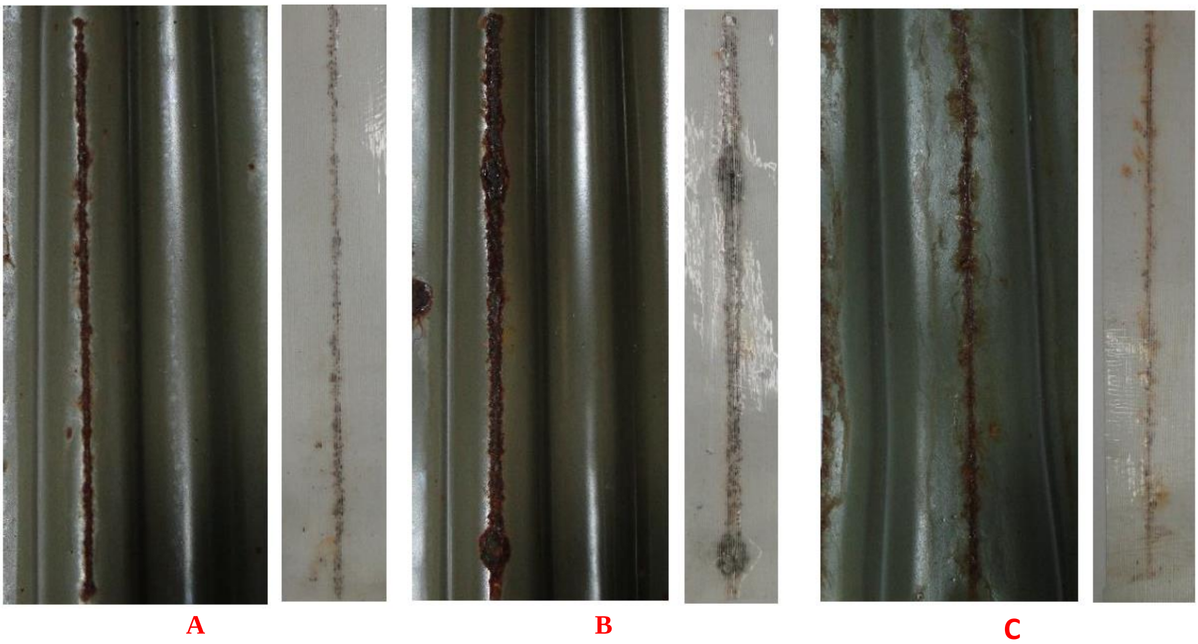



**Figure 4 - Adhesion test after 68 cycles for PHS samples (the left picture is the tested automotive part and the right picture is the scotch tape). A) electroplated ZnNi; B) electroplated ZnNi and sandblasting; C) hot-dip AlSi.**

## Conclusion

All tested samples evaluated were approved according to the standard GMW14872, however ZnNi as received had a slightly better ratting than the other sample conditions. In addition, they showed a good coating adhesion onto the steel substrate.

The ZnNi sample in the as received condition showed better rating than other samples in all cycles. This means that the ZnNi is a potential coating for AlSi replacement. Moreover, the sandblasting process did not show to be necessary, neither for corrosion resistance nor for adhesion.

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