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The Effect of Cataphoresis Coating on Fatigue Behaviour of Control Arms under Corrosion Environment

Cem UCAN
Teknorot Steering&Suspension Parts

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Abstract: In this paper, the effect of the cataphoresis coating on fatigue life of control arms was evaluated under corrosion environment. The used sheet metals were manufactured by Erdemir as a technical code of S355MC grade steel according to EN 10149-2:2013 quality standard. The sheet metals were shaped at the Teknorot Automotive manufacturing processes. The shaped metals were coated with cataphoresis at the Teknorot Automotive coating facility. In order to determine the corrosion environment of the parts salt spray test was performed according to TS EN ISO 9227:2012 quality standard. Salt spray test was implemented to both cataphoresis coated and uncoated control arm bodies during 30 days. Ascott S450s brand salt spray corrosion test chamber was used for the salt spray test. After the corrosion applications, fatigue life tests were applied to the both control arm bodies, which were cataphoresis coated and uncoated, by fatigue life test machine produced by CAE Solutions for Teknorot Automotive. From test results, it was determined that cataphoresis coating was necessary for a better fatigue life performance on automobile control arms. Damage analysis was also applied to determine the damages which were occured in the coated and uncoated parts.

Keywords: Fatigue, Cataphoresis coating, Corrosion, Control arms

Introduction

The system that reduces road loads, road vibrations and ensures the connection of the wheels to the chassis is called suspension system [1,2]. Suspension systems provide more comfortable journey for passengers in the vehicles. Most of the suspension components are safety part for safe driving. The most important component is the control arms that directly connects the wheel and the chassis. In the automotive manufacturing industry, all the suspension system components are designed for infinite life and must not be damaged during the service conditions. Control arms are usually tested for fatigue life before the final assembly of the vehicle, to ensure the technical specifications of the customers and to avoid unexpected failure and accidents with vehicles [3]. The stress results of working load on the control arms should be less than the related material's endurance limit. The component would be expected to withstand these stress levels without failure during fatigue life tests and then real performance.

Material fatigue is a natural event where the structures fail when subjected to a cyclic load. Fatigue failure is one of most common source behind issues of mechanical structures. The most important parameter for the fatigue failure is the stress amplitude [4]. The fatigue failure is the greatest danger on suspension control arms during service life of a vehicle. The engineers who work at the automotive industry design the components for infinite life by reason of the fact that suspension components are under dynamic loads which cause the fatigue failure [5]. However, various parameters affect the fatigue life of the suspension control arms such as material grade, component shape, material properties and corrosion. Corrosion is one of the most dangerous issue for the component working life. Although there are different alternatives, high strength low alloy (HSLA) steels are

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commonly used for control arms and as known that these type of steels have good corrosion behaviour. Corrosion fatigue is a form of material failure caused by crack growth under cyclic loading in a corrosive environment and generally corrosion has an accelerating effect on fatigue failure, and crack growth rates are substantially higher under corrosion fatigue [6]. Fisher et al. [7] claimed that the fatigue life of the steel components affected by corrosion by reason of the fact that corrosion supports the crack growth and propagation. Kim and Kim [8] investigated that corrosion evidences were intensively observed on crack initiation region, indicating that crack initiation and propagation affected by corrosion and also the result indicated that the corrosion could be an important factor of the fatigue life of suspension control arms in automotive industry.

Coating processes are an important solution against corrosion. Coating applications provide some advantages such as superior control of application conditions to ensure superior performance, corrosion prevention, ease of damage repair, as well as superior waste and pollution control. Price and Figueira [9] claimed that organic based coating systems or metallic coatings such as electroplating, diffusion, hot-dipping and thermal spraying commonly could be used to avoid the corrosion. In the automotive industry, cataphoresis coating is commonly preferred since 1970's to avoid the corrosion on the suspension components [10]. The cataphoresis coating provides the same corrosion resistance on the inner and outer surfaces independent from the component geometry [11]. The cataphoresis coating extends the life of the component and ensures its quality against corrosion. However, corrosion can be occurred on the components by reason of the fact that some problems such as coating process problems, surface damage after production, service conditions. The components under corrosion risk although coating application. For this reason, it is necessary to investigate the fatigue behaviour of the coated samples and corroded samples.

In this study, the effect of the cataphoresis coating on the fatigue life of S355MC grade steel control arms was evaluated under corrosion environment. The control arms were coated with cataphoresis technique. In order to determine the corrosion environment of the parts, salt spray test was performed according to TS EN ISO 9227:2012. After the corrosion applications, fatigue life tests were applied to the both control arm bodies which were cataphoresis coated and uncoated by fatigue life test machine. In addition, damage analysis was also applied to determine the damages which were occurred in the coated and uncoated parts.

Materials and Method

Material

The control arm bodies were produced from S355MC grade steel sheet metals which were manufactured by Erdemir according to EN 10149-2:2013 quality standard. The steel metal thickness is 4 mm. The chemical composition and the mechanical properties of the used sheet metal are shown in Table 1 and Table 2.

Table 1. The chemical composition of S355MC grade steel

Standard	Quality	%C max.	%Mn max.	%P max.	%S max.	%Si max.	%Al max.	%Nb max.	%Ti max.	%V max.
EN 10149-2	S355MC	0,12	1,40	0,025	0,020	0,50	0,02	0,09	0,15	0,20

Table 2. The mechanical properties of S355MC grade steel

Standard	Quality	R_e N/mm^2 min.	R_m N/mm^2 min.	%A		Impact KV_c (Longitudinally, d>6) Temparature: -20 °C min.	Bend (Transverse, 180°) mdb d: thickness
				d<3 A_{80} min.	d ≥3 A_5 min.		
EN 10149-2	S355MC	355	430-550	19	23	40 J	0,5 d

Where Re refers to yield strength, Rm refers to tensile strength, A refers to elongation, A5 refers to elongation (L0 = 5.65x√S0), A80 refers to elongation (L0 = 80 mm), S0 refers to cross-sectional area of the specimen (mm²), L0 refers to original gauge length of the specimen , d refers to nominal thickness (mm), mdb refers to mandrel diameter for bending, KVc refers to impact energy (J).

Method

Production

The control arm bodies were produced by applying template cutting sheet forming operations on hydraulic presses to the steel at Teknorot Co. The used hydraulic presses are shown in Fig. 1.

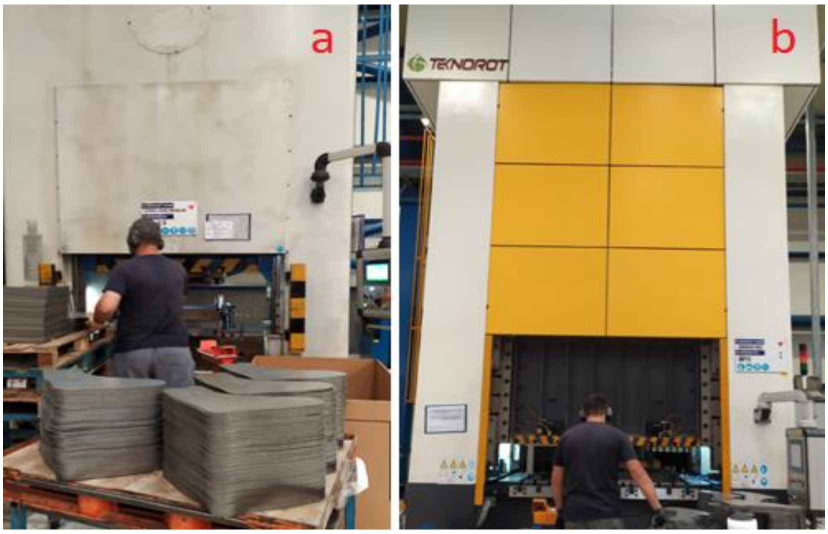


Figure 1. a) Template cutting press, b) Sheet forming press

Coating

The cataphoresis coating of control arm bodies was applied to the formed bodies at Teknorot Co. after sheet forming operations. The cataphoresis coating process has four steps respectively; (a) surface cleaning, (b) surface preparation, (c) coating and (d) flash-off and oven as shown in Fig. 2. Application thickness of the cataphoresis coating was approximately 20µm.

Figure 2. a) Surface cleaning, b) Surface preparation, c) Coating, d) Flash-off and oven

In order to bond the coating with product, surface cleaning must be done perfectly. Surface cleaning process (Fig.2-a) consisted of oil-removal and rinse tanks where negative structures such as oil film, welding powders, dust on the piece were removed. Process time of surface cleaning was approximately 15 minutes. Surface preparation process (Fig.2-b) existed in cataphoresis coating by the reason of fact that held on to ZnPO4 crystals to metal surface and to provide bonding of coating and product. Activation tanks were consisted of ZnPO4 tanks and water rinse tanks on surface preparation process. Process time was approximately 5 minutes. Coating step (Fig.2-c) was applied to metal surfaces after surface preparation step. This step had application of water-based coating structure. It consisted of painting tanks and UF tanks. Process time was approximately 5 minutes. The liquid build-up in the coating was made possible by the removal of the coating from the coating as a gas and the solidification of the paint after curing was provided by this group (Fig.4-d). Process time was approximately one hour.

Salt Spray Test

The corrosion resistance of both cataphoresis coated and uncoated control arm bodies were determined by using salt spray test according to TS EN ISO 9227 quality standard. The neutral salt spray test was applied at 5 wt.% sodium chloride solution in the pH range from 6,5 to 7,2 at 25°C ± 2ºC. In the saturation tower of the testing machine, the water temperature was 45°C and the pressure value was 70 kPa. The temperature of the testing machine was 35°C. The coating specification of Teknorot Co. describes the test time as minimum 720 hours for cataphoresis coating. In this study, salt spray test applied to both cataphoresis coated and uncoated control arm bodies during 720 hours (30 days). Testing machine is also shown in Fig. 3.

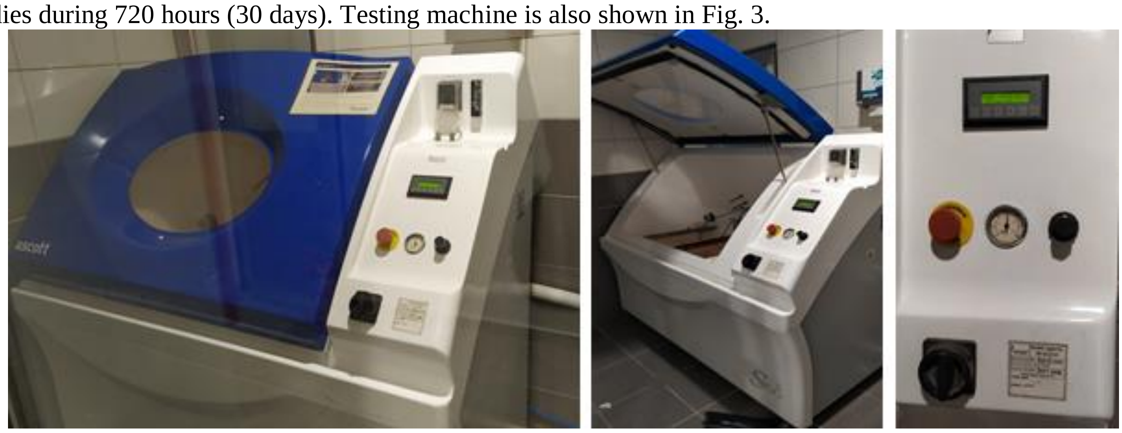


Figure 3.Ascott S450s brand salt spray corrosion test chamber

Weight lose that occurs due to corrosion phenomenon was checked after salt spray tests. Table 3 shows the weight lose differences between coated and uncoated control arms. Control arms are shown in Fig. 4. after salt spray test.

Table 3. Weight lose difference after 720 hours corrosion test

	After Production (gram)	After Coating (gram)	After Salt Spray Test (gram)
Coated Sample	2400	2450	2442
Uncoated Sample	2400	-	2298

Figure 4. a,b) Cataphoresis coated control arm after 720 hours salt spray test, c,d) Uncoated control arm after 720 hours salt spray test

Fatigue Test & Damage Evaluation

Fatigue tests were applied to both control arms which coated and uncoated according to related technical specification of Teknorot Co. Test parameters are 4 Hz frequency and 45° angle. The cycle load was calculated by the technical specification of Teknorot Co. as ±560 kgf. The fatigue tests carried out on 3 replications for each coated and uncoated control arm groups. Tests were finished when crack formation is detected. Damage and fracture surfaces of control arms were evaluated by visual inspection. Test apparatus was shown in Fig.5.

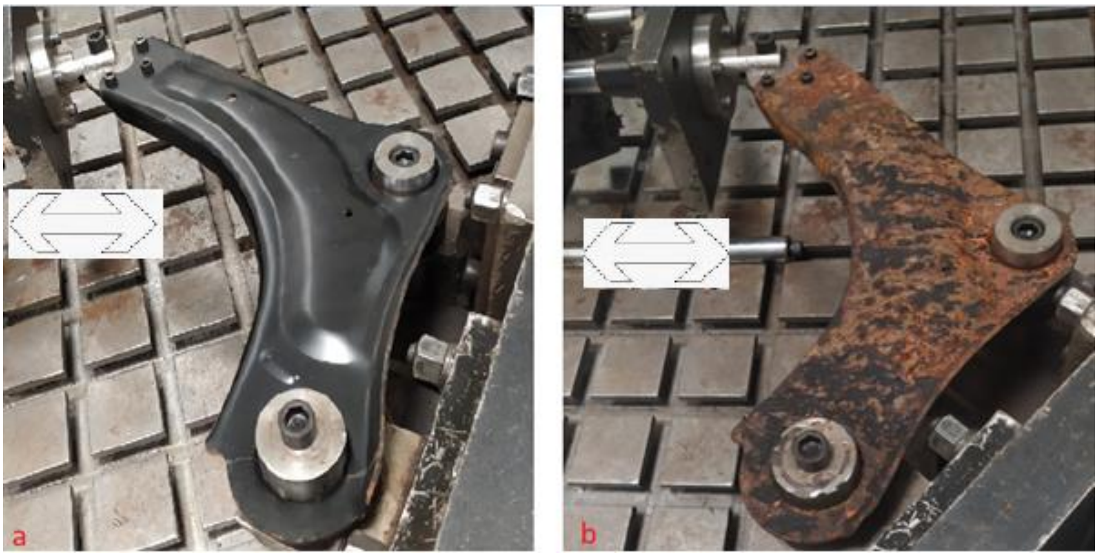


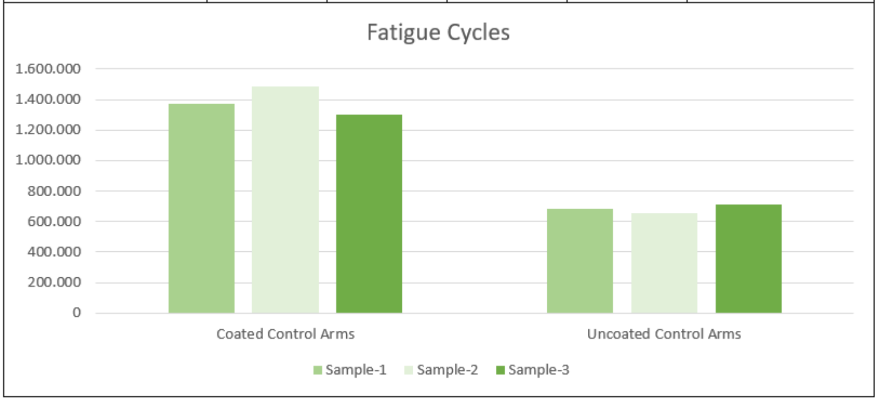
Figure 5. a) Cataphoresis coated part during fatigue test, b) Uncoated part during fatigue test

Results and Discussion

The results which were obtained from fatigue life tests were shown in Table 4.

Table 4. Fatigue life test results for coated and uncoated control arms

	Sample-1	Sample-2	Sample-3	Average	Standard Deviation (±)
Coated Control Arms	1.375.635	1.482.697	1.302.364	1.386.899	90.693
Uncoated Control Arms	681.236	653.687	709.873	681.599	28.095



The performed control arm samples were successfully completed the fatigue tests for infinite life according to Teknorot’s technical specification. However there was a significant difference between cataphoresis coated and uncoated control arms. Although all the control arms were successfully completed the fatigue tests, uncoated control arms were close to the lower limit which was described as 500.000 cycle. It was clearly shown that corrosion decreased the fatigue life of the control arms significantly. According to Table 4, the fatigue life of uncoated control arms were approximately 50% less than the fatigue life of the cataphoresis coated control arms. The reason for this was predicted that the microcracks grew earlier than they should be due to corrosion. It evaluated that the coating application provided the corrosion resistance and improved fatigue life of the control arms. As stated in ref [7,8], corrosion supported the crack growth and it affected the fatigue life of the steel components. The result indicated that the corrosion could be an important factor of the fatigue life of lower arm in automotive.

During the fatigue tests, crack formation was observed on the samples. Crack initiation regions were detected on the big bushing assembly hole for all the samples. But uncoated control arms were also damaged on different regions by the effect of the corrosion. Crack regions of coated and uncoated control arms were shown on Fig.6 and Fig.7, respectively.

Figure 6. Crack regions on the cataphoresis coated parts after fatigue test

Figure 7. Crack regions on the uncoated parts after fatigue test

Conclusion

In this study, the effect of the cataphoresis coating on the fatigue life of control arms was evaluated under corrosion environment. The obtained results are given below.

- Fatigue life was found 1,3 million cycle at cataphoresis coated control arms. However this value was fallen to 50% for the uncoated control arms compared to the fatigue life of cataphoresis coated control arms.
- The crack initiation was observed on the bushing assembly hole for cataphoresis coated control arms. However it was changeable for uncoated control arms and crack initiation was observed on anywhere according to corrosion damage.
- Cataphoresis coating application provided corrosion resistance perfectly and increased the fatigue life of the control arms that made from steel.

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