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ACCREDITED
TESTING CERT #0510-01

MSi Investigative Summary

BACKGROUND

Multiple samples from two (2) lots of stainless steel springs used in electric toothbrush switch assemblies were submitted to our laboratory for **Consumer Product Safety Testing**. A comparative metallurgical investigation was performed in accordance. Reportedly, the parts from lot "A" had a history of sticking in the "ON" position when the switch assemblies were actuated simultaneously at the opposite ends. The parts from lot "B" performed satisfactorily under the same actuation conditions. One of the submitted spring samples from lot "C" exhibited variegated surface discoloration.

It was also reported that the springs were fabricated from a 300-series austenitic stainless steel. However, the processing details and the target values for the metal properties were unavailable. We were requested: (a) to identify the likely metallurgical factors that could have caused the difference in the performance of the springs from the two lots; and (b) to perform qualitative analysis of the surface discoloration observed on one spring from lot "C".

SAMPLE IDENTIFICATION

Lot	Spring Material
Hi-P	300-series austenitic stainless steel
CIL	

PERFORMED TESTING

Visual and Stereoscopic Examination
Scanning Electron Microscopy (SEM)
Energy Dispersive Spectroscopy (EDS)
Metallographic (Microstructural) Examination
Microhardness Testing
Chemical Analysis

CONCLUSIONS

1. Based upon the performed tests and examinations, it is our opinion that the sticking of the springs from lot "A" resulted from lower hardness and, consequently, lower yield strength than those in the springs from lot "C".

2. Lower hardness levels in materials are indicative of lower tensile and yield strength levels. Therefore, components exhibiting lower strength are more likely to plastically deform (yield) and stick under the applied loads than the parts with higher hardness.

3. Metallographic examination of the springs from lots "A" and "C" revealed textured austenitic microstructures typical of work-hardened 300-series **austenitic stainless steels**. The observed microstructural features indicated that the level of the work-hardening in the spring from lot "CIL" was noticeably higher than that in the spring from lot "A".

4. The examined parts contained no evidence of pre-existing steel defects, excessive nonmetallic inclusions, or any other detrimental material conditions that could have contributed to the difference in the springs' behavior under the applied switch-actuating loads.

5. **SEM/EDS analysis** indicated that the variegated surface discoloration on one spring from lot "C" was caused by a thin layer of organic and inorganic substances (possibly, some type of detergent residue).

6. Chemical analysis identified the material of the parts from lot "A" as Type 304 stainless steel. The parts from lot "C" were identified as Type 301 stainless steel. ***Note:*** *Although both materials were confirmed as 300-series austenitic stainless steel and are expected to show comparable corrosion properties, Type 301 is known to exhibit a higher work-hardening rate and is commonly used in industrial applications where a combination of high strength and high ductility is required.*

7. Microhardness measurements revealed higher hardness values of the parts from lot "C", which indicated a higher level of work-hardening and supported the results of the preceding metallographic observations.

8. It is our opinion that the switch actuation at the two opposite ends of the assembly requires a higher level of mechanical properties in the springs than is exhibited by the parts from lot "A". Increasing the level of work-hardening will increase the strength of the springs and assure that the actuation stresses will be kept within the elastic deformation region on the stress-strain curve of the material. The original equipment manufacturer and/or designer should be consulted on the target hardness and strength levels suitable for the intended application.

SUMMARY of TEST RESULTS

Visual and Stereoscopic Examination

1. Visual and stereoscopic examination of the springs from lot "A" revealed a slight difference in curvature between the stuck and intact parts (see Photo 1). The surfaces of the springs from lot "A" showed a uniform silvery finish.

2. The springs from lot "C" showed no detectable difference in shape. Except for one part exhibiting variegated surface discoloration, the springs from lot "C" had a uniform silvery finish (see Photo 2).

3. Randomly-selected clean springs from both lots and the discolored part form lot "C" were used for further examinations described in the following sections of this report.

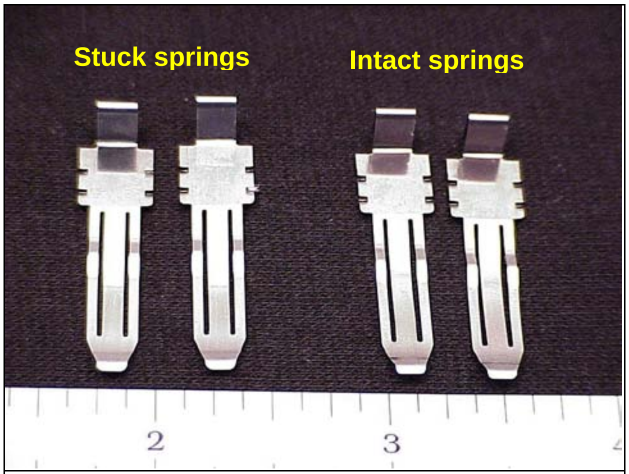

Photo 1: Representative parts from the lot "A".

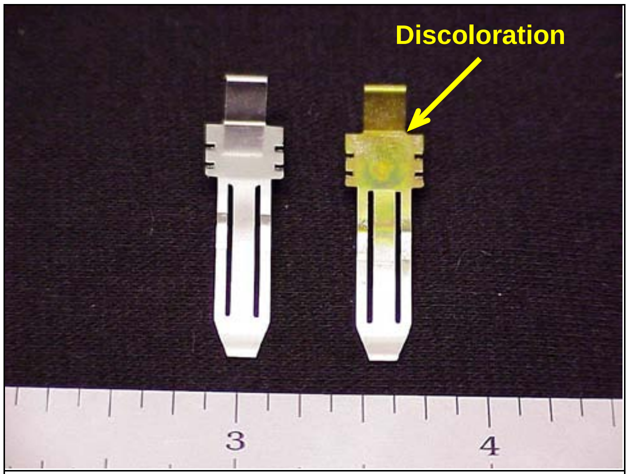

Photo 2: Representative parts from the lot "C".

Metallographic Examination

1. Longitudinal sections removed from the selected spring samples revealed textured austenitic microstructures typical of work-hardened 300-series **austenitic stainless steels** (see Photos 3 – 4 on the following page).

2. The spring from lot "C" exhibited heavier texturing and more pronounced grain elongation. The observed microstructural features indicated that the level of work-hardening in the spring from lot "C" was noticeably higher than that in the spring from lot "A".

3. The examined parts contained no evidence of pre-existing steel defects, excessive nonmetallic inclusions, or any other detrimental material conditions that could have contributed to the difference in the springs' behavior under the applied switch-actuating loads.

Metallographic Examination (cont.)

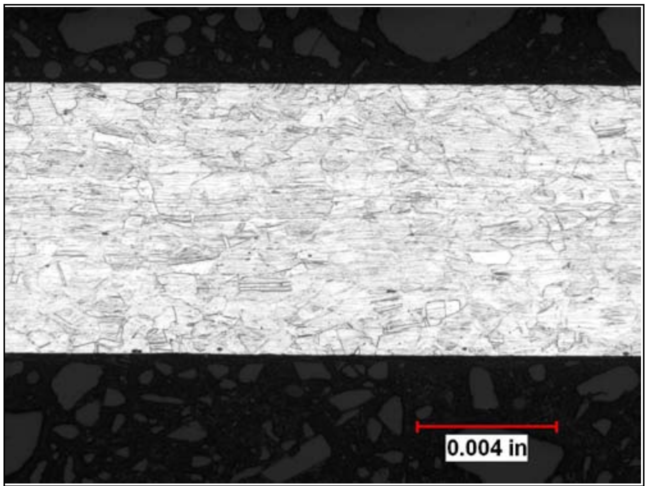

Photo 3: 100X Etchant: 10% oxalic (electrolytical)
Typical microstructure, lot “AP“.

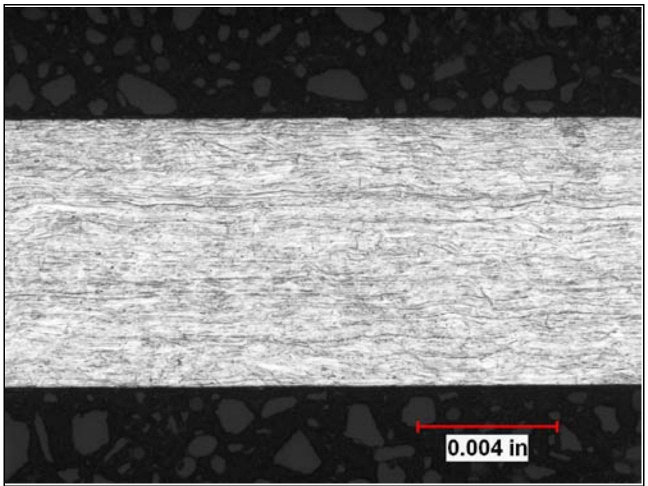

Photo 4: 100X Etchant: 10% oxalic (electrolytical)
Typical microstructure, lot “C“.

SEM/EDS Examination

1. SEM/EDS examination was performed on a clean surface and an isle of variegated discoloration on the selected parts from lot “C”. Major, medium, minor and trace elemental peaks were identified on each corresponding spectrum (see Figures 1 – 2 on the following page).

2. **EDS analysis** of the clean area detected major elemental peaks of iron (Fe) and chromium (Cr), a medium peak of nickel (Ni) and minor peaks of carbon (C) and silicon (Si). This elemental composition is typical of a 300-series austenitic stainless steel.

3. **EDS analysis** of the discolored area detected major elemental peaks of iron (Fe), chromium (Cr) and potassium (K), medium peaks of carbon (C), oxygen (O) and nickel (Ni), and minor peaks of silicon (Si), zinc (Zn) and possibly sodium (Na). Adjusting for the spectral contribution from the underlying base metal, the observed elemental composition identified the discolored substance as a thin layer of organic and inorganic compounds (possibly, some type of detergent residue).

4. Trace peaks on the EDS spectra were considered to be incidental.

SEM/EDS Examination (cont.)

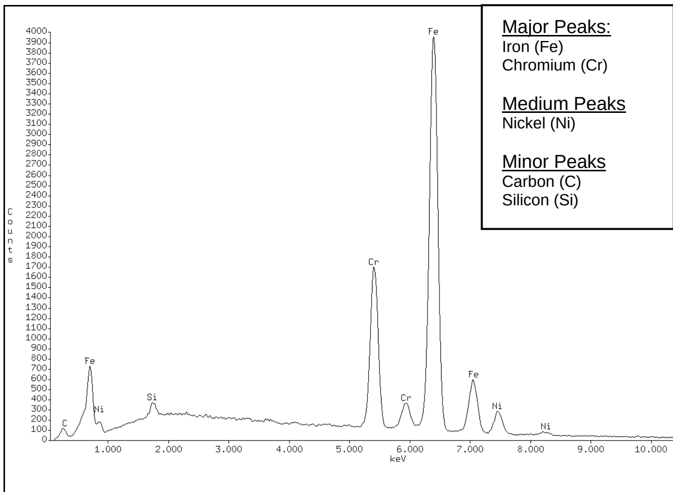

Figure 1: EDS spectrum of a clean spring (lot “C“).

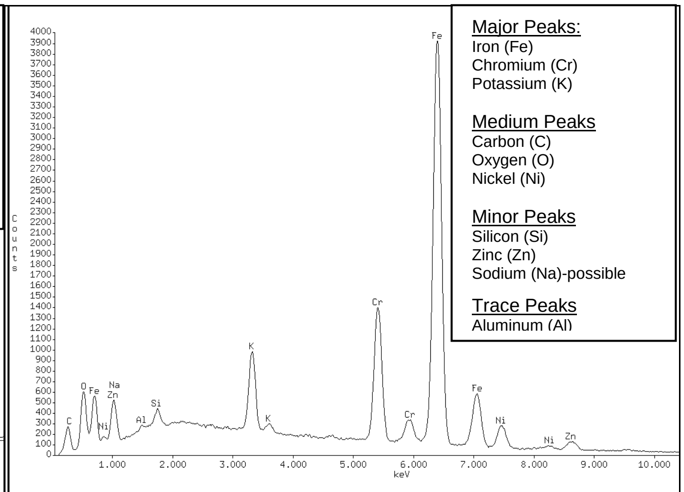

Figure 2: EDS spectrum of the discoloration area (lot “C“).

Microhardness Testing

1. **Microhardness testing** revealed that the spring from the lot “A” had lower hardness than spring from the lot “C”.
2. The results are shown in Table 1 attached.
3. Lower hardness levels are indicative of lower strength. Springs exhibiting lower strength are more likely to plastically deform (yield) and stick under the applied loads than the parts with higher hardness.

Chemical Testing

1. Chemical testing identified the spring samples from lot “A” as Type 304 austenitic stainless steel. The samples from lot “C” were identified as Type 301 austenitic stainless steel.
2. The results are shown in Table 2 attached.
3. ***Note**: Type 301 steel exhibits a higher work-hardening rate and is commonly used in industrial applications where a combination of high strength and high ductility is required.*

Table 1 – Microhardness Testing*

Lot	Hardness, HRC		
A	36	36	37
B	38	39	39

* **Microhardness testing** performed using a Knoop diamond indenter and 500 gram load per ASTM E384. $Knoop_{500}$ values converted to approximate HRC values.

Table 2 – Chemical Testing*

Element	A	B
Carbon	.05 %	.11 %
Manganese	1.23	1.00
Phosphorus	.017	.017
Sulfur	.006	<.005
Silicon	.36	.48
Nickel	8.25	7.22
Chromium	18.17	16.92
Molybdenum	.17	.27
Copper	.24	.30
Aluminum	<.01	<.01
Steel Grade	Type 304 SS	Type 301 SS

* Testing performed in accordance with ASTM E1086.

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