Application News

Microfocus X-Ray CT System inspeXio™ SMX™-225CT FPD HR Plus

Observation of Joined Metal and Rubber Parts Using a Microfocus X-Ray CT System

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User Benefits

- The progression of rubber deterioration, where rubber is in contact with metal, can be evaluated non-destructively.
- Even locations with no visible abnormalities can be inspected non-destructively to help improve or maintain quality.

■ Introduction

Because metal and rubber materials have different properties, using them together can achieve high strength, vibration-damping effects, lighter weight, tight seals, and various other characteristics that cannot be achieved with only one or the other. Therefore, mechanical parts with rubber joined to metal are widely used in automotive, industrial machinery, and other fields. However, joining parts with dissimilar properties can cause defects from heat, vibration, or other factors present during manufacturing processes or product use. In particular, rubber can potentially deteriorate at metal contact surfaces due to high metal temperatures without showing any symptoms significant enough for the deterioration to be discovered. Consequently, non-destructive inspections are required to evaluate deterioration and defects before they appear.

X-ray CT systems offer one type of non-destructive inspection. They can visually show the internal status of joined metal-rubber parts in order to assess the position and shape of internal defects without damaging the part. This article describes using an inspeXio SMX-225CT FPD HR Plus microfocus X-ray CT system (Fig. 1) to observe rollers made with rubber joined to metal.

Fig. 1 inspeXio™ SMX™-225CT FPD HR Plus

■ Target of Analysis

In this example, the rollers were composed of a combination of heavy metal, light metal, and rubber. As shown in Fig. 2, an aluminum part is attached around the mostly steel bearing, and rubber is joined to the aluminum around its perimeter.

Three types of workpieces were involved, the product that was actually being used (workpiece A) and two types of test samples (workpieces B and C). The rubber material and load test parameter settings for each workpiece are indicated in Table 1. Each workpiece had bulges (Fig. 3).

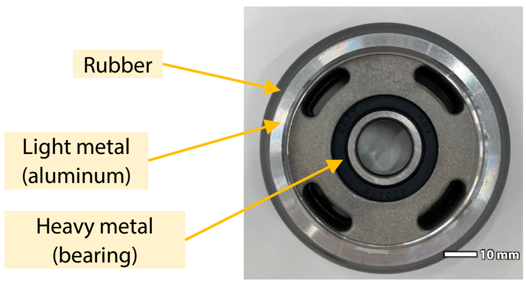

Fig. 2 Roller

Table 1 Testing Parameters

Workpiece	A: Actual Part Used	B: Workpiece 1	C: Workpiece 2
Rubber Material	Natural rubber	Nitrile rubber	Nitrile rubber
Temperature	Unknown*1	70 °C	60 °C
Test Force	Unknown*1	900 N	700 N
Travel Distance	Unknown*1	1000 km	2600 km

*1: Due to normal use, not all parameters were measured.

Fig. 3 Workpiece Bulges (Left: 2 Locations on Workpiece A, Center: 1 Location on Workpiece B, and Right: 2 Locations on Workpiece C)

■ Imaging Parameter Settings

CT scan settings for each workpiece are indicated in Table 2. Overview images of the entire workpiece and magnified images of the bulges were acquired using two different sets of CT scan settings. For workpiece C, which had two bulges visible from a distance, the exposure field was adjusted to include the area around both bulges.

Table 2 Workpiece CT Scan Settings

Workpiece	A: Actual Part Used		B: Workpiece 1		C: Workpiece 2	
Exposure Range	Overview	Magnified	Overview	Magnified	Overview	Magnified
Tube Voltage	225 kV	225 kV	225 kV	225 kV	225 kV	225 kV
Tube Current	300 µA	300 µA	300 µA	300 µA	300 µA	300 µA
Number of Views	2400	2400	2400	2400	2400	2400
Average Count	3	3	3	3	3	3
Voxel Size	0.090 mm	0.037 mm	0.096 mm	0.034 mm	0.096 mm	0.071 mm

■ Observations of Areas with Bulge

Cross-sectional images of the bulges and the position of cross-sections are shown in Fig. 4. However, only one of the two bulges is shown for workpieces A and C. In both workpieces, the areas on the interior sides of the bulges (indicated with red arrows in Fig. 4) are a darker gray than the rest of the rubber. In the cross-sectional images, the lower the density, the darker the color generally is. That indicates the area with bulges may have lower densities than the rest of the rubber.

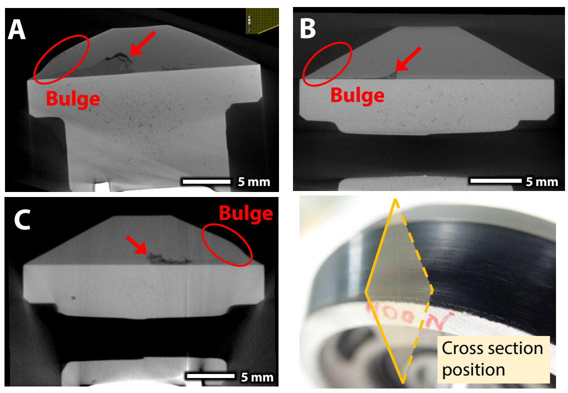

Fig. 4 Cross-Sectional Images of Bulges
(Upper Left: A; Upper Right: B; Lower Left: C;
and Lower Right: Illustration of Cross-Section Position)

Fig. 5 is a magnified cross-section image inside the bulge on workpiece A. As mentioned above, the interior area of the bulge is darker than the original rubber material. This is presumably due to its lower density. One possible cause of the lower density inside the rubber is air generation, but no air bubbles or cracks are visible in Fig. 5. Therefore, it is possible that air bubbles smaller than the voxel size (indicated as 0.037 mm in Table 2) were generated. A more detailed observation of the other locations found stratified cracks and a darker color than the other rubber in the corresponding locations. This indicates that the level of deterioration varied within the area of deterioration. It also confirms that all cracks on the surface of the area of the bulge extended to about the same depth, which indicates that the level of deterioration can be observed not only in the interior but also on the exterior.

If the optional software VGSTUDIO MAX is used to color-code images, the position and shape of deterioration in the area of the bulge can be observed three-dimensionally (Fig. 6). Using the software to calculate the volume of color-coded portions resulted in the inequality A > C > B. A visual inspection of the roller exteriors to compare the sizes of the bulges resulted in the same A > C > B relationship, which indicates a correlation between external bulges and the volume of internal deterioration. A correlation with the travel distance was also confirmed, based on a Table 1 comparison of workpieces B and C with known test parameters. In this example, CT data was compared with the visual size of external bulges, but the level of bulges could also be numerically quantified by comparing the CT data with the design (CAD) data.

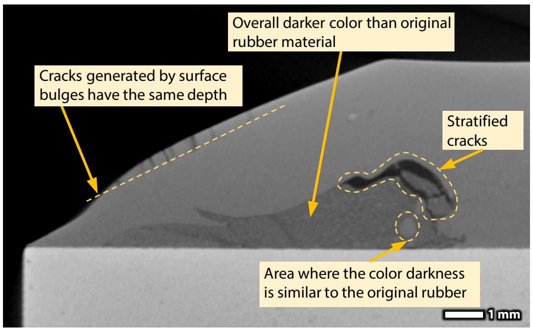

Fig. 5 Magnified View Near Bulge on Workpiece A

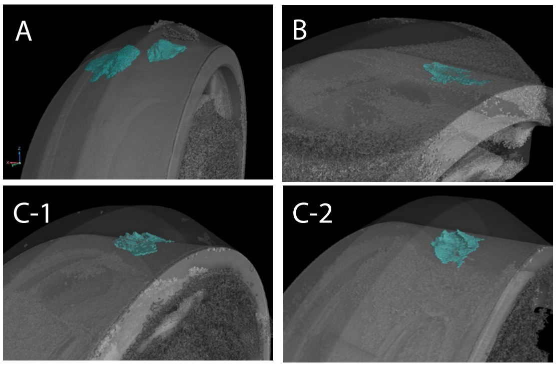

Fig. 6 Color-Coded Interior of Bulge
(Bulges in C are shown in separate images due to the distance between them.)

■ Observation of Rubber Debonding

The overview cross-section images showed internal voids in areas of workpieces A and B that externally appeared normal (Fig. 7). Given the dark gray color of the interior of the bulge, the black color of the void presumably indicates rubber debonding from the metal.

Debonded areas can be color-coded in the same manner as shown in Fig. 6 to enable observation of both internal rubber deterioration and debonding at the same time (Fig. 8). Thus, X-ray CT imaging can be used to discover internal defects even in areas without any external irregularities.

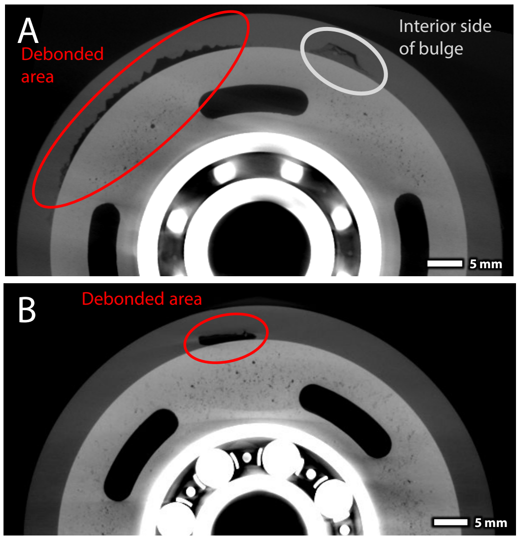

Fig. 7 Rubber Debonding

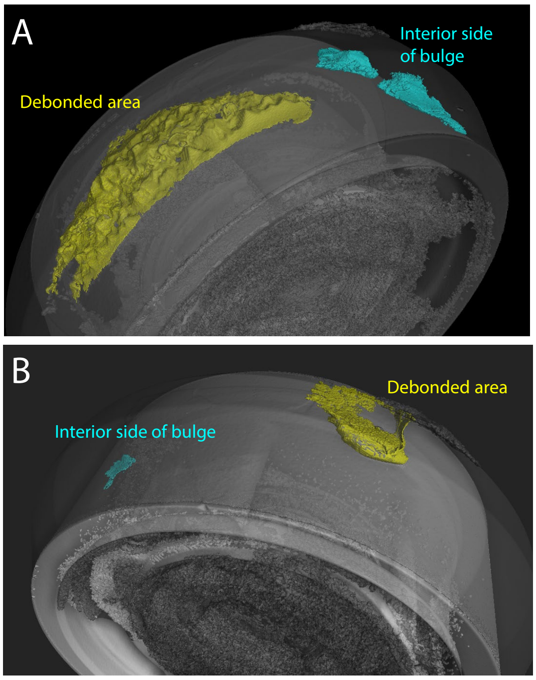

Fig. 8 Rubber Debonding (3D Color-Coded Void)

■ Conclusion

This article describes using an inspeXio SMX-225CT FPD HR Plus microfocus X-ray CT system to scan rollers made of rubber bonded to metal.

The system enables non-destructive discovery of rubber deterioration and debonding, regardless of whether or not the exterior appears normal. The progression of rubber deterioration can be observed by detailed observations of cross-sectional images or by comparing the volumes of deteriorated portions. Color-coding the deteriorated or debonded areas can provide a 3D understanding of the position and shape of those areas. Thus, X-ray CT imaging provides a useful way to inspect the quality of parts made with rubber bonded to metal.

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