

Application News

Observation of Urethane Foam Using a Microfocus X-Ray CT System

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User Benefits

- ◆ A wide variety of items can be observed by changing the magnification rate based on the objectives.
- ◆ The causes of adhesion failures can be analyzed by observing nonuniformities in bonded areas or voids in adhesive interfaces.
- ◆ The volume and wall thickness of voids inside urethane foam can be analyzed simultaneously to help improve quality.

Introduction

Due to the diverse performance characteristics of urethane foam, such as its cushioning, thermal insulation, sound absorption, and filtering properties, it is used for a wide variety of applications in our daily lives.

Quality control of urethane foam by observation and evaluation of its internal structures is necessary because the shape, volume, and wall thickness of internal voids in foam can affect its properties. A variety of shapes can be accommodated by bonding foam pieces together with adhesive, but that can result in lower performance due to the adhesive interface debonding. Consequently, for quality control, it is also important to understand the adhesive status. But cutting foam to inspect it can change the void shape or adhesion status, so foam should be inspected non-destructively.

X-ray CT imaging offers a useful way to non-destructively observe and evaluate internal structures of urethane foam. This article describes using the inspeXio SMX-225CT FPD HR Plus X-ray CT inspection system (Fig. 1) to scan packaging material for a consumer electronics product and analyze the adhesion interfaces and voids.



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

Target of Analysis

In this example, an X-ray CT imaging system was used to scan urethane foam used as a cushioning material in packaging for a consumer electronics product (Fig. 2). This workpiece was bonded with adhesive between the parts indicated by arrows. (Samples were provided by the Chemicals Evaluation and Research Institute.)

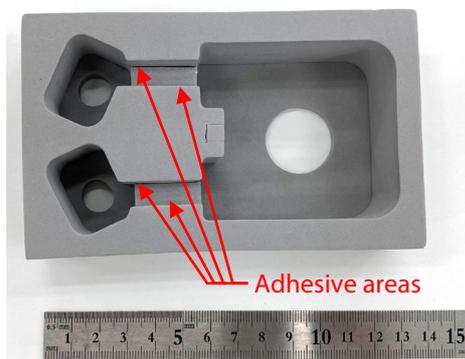


Fig. 2 Consumer Electronics Packaging Material

CT Scan Settings

In order to understand a wide range of tendencies, such as nonuniformities in adhesively bonded surfaces, images must be acquired with low magnification rates. However, magnified images are needed to achieve the resolution levels appropriate for the size of the area being analyzed. Therefore, in this example, images were acquired using the 3 sets of conditions indicated in Table 1. Increasing the magnification rate decreases the voxel size, which makes it possible to capture even more detail.

The left side of Fig. 3 shows the exposure fields for an unmagnified overview and a magnified view. The right image in Fig. 3 shows the approximately 5 mm square foam piece cut from the workpiece in order to achieve the necessary void magnification rate.

Table 1 Observation Purpose and CT Scan Settings

	Overview of Adhesive Area	Magnified View of Adhesive Area	Magnified View of Void
Purpose	Overall Trends, Such as Adhesive Nonuniformities	Detailed Observation of Adhesive Interface	Analysis of Detailed Areas, Such as Voids, and Void Walls
Tube Voltage	200 kV	200 kV	120 kV
Tube Current	70 μA	70 μA	70 μA
Number of Views	2400	2400	2400
Exposure Field (FOV)	98.7 mm	36.4 mm	5.8 mm
Voxel Size	0.1 mm	0.04 mm	0.006 mm

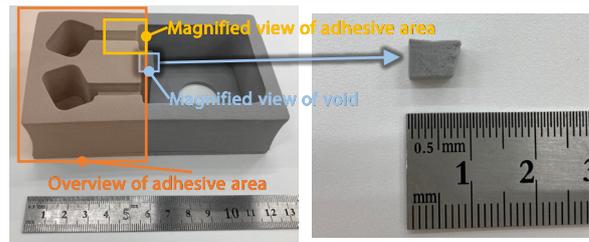


Fig. 3 Exposure Fields
(Left: Workpiece Overview; Right: Piece Cut from Workpiece)

Imaging Results of Adhesive Areas

Fig. 4 shows a cross-sectional image of the overall adhesive areas. The adhesive appears white and the foam gray. Given that high-density materials generally appear white, it can be assumed that the adhesive has higher density than the foam.

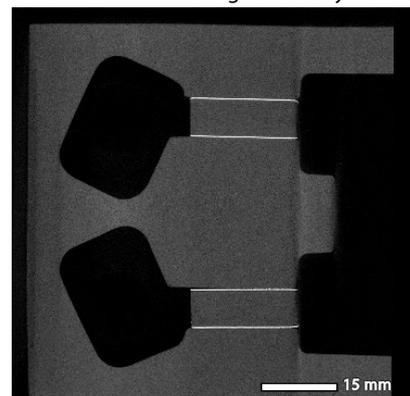


Fig. 4 Cross-Sectional Image of Overall Adhesive Area

Fig. 5 shows 3D data generated with the optional software VGSTUDIO MAX. Because the adhesive area can be isolated and shown by itself, as in the right image of Fig. 5, the extracted image can be quickly checked for any adhesive nonuniformities or skewing. In contrast, in the cross-sectional image of both the adhesive area and the foam (Fig. 6), it is difficult to determine the interface status due to inadequate resolution. Data acquired from a broad area is suitable for observing the overall area, but it is not suitable for observing detailed areas.

Fig. 7 shows a cross-sectional image obtained from the magnified scan of the adhesive area. It shows that when the area near the origin of externally visible debonding locations (the green box in Fig. 7) is magnified, it can be seen that one side of the interface has fewer voids and is tightly attached, whereas debonding has started on the other side, and there are more voids. Even in locations without debonding (the yellow box in Fig. 7), one side has many voids, and the other side is tightly attached, which presumably indicates a high probability of debonding on the side with more voids.

A comparison of the magnified images on the right side of Fig. 6 and Fig. 7 indicates a large difference in how easily voids between adhesive and foam can be identified. However, even in Fig. 7, the small voids inside the foam are blurry, so analyzing them would probably require additional magnification.

Thus, the ability to observe overall adhesive nonuniformities and voids between adhesive and foam materials enables the causes of adhesive failures to be analyzed.

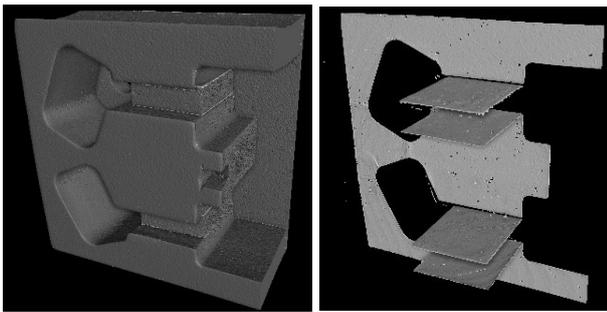


Fig. 5 3D Overview Images of Adhesive Areas (Left: Entire Foam; Right: Piece Cut from Adhesive Area)

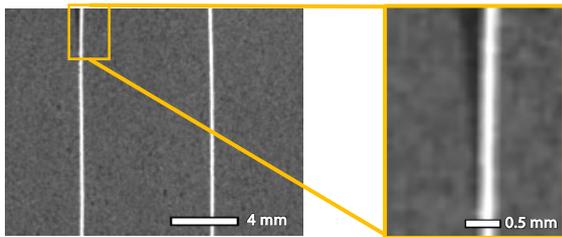


Fig. 6 Cross-Sectional Image of Overall Adhesive Area

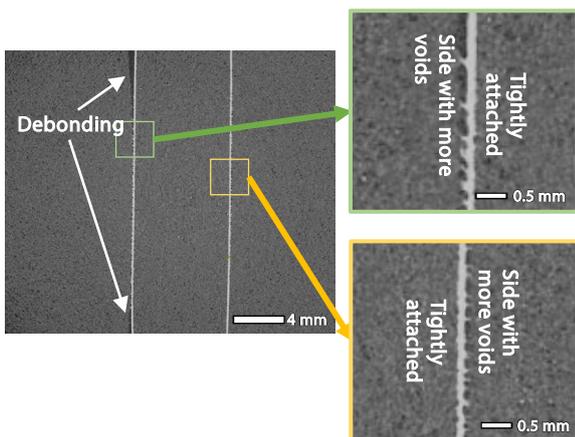


Fig. 7 Cross-Sectional Image of Magnified Adhesive Area

■ Imaging Results of Voids

Fig. 8 shows magnified cross-sectional images of the voids. Compared to Fig. 7, each void can be clearly identified in Fig. 8, which shows that most of the voids are interconnected pores. Fig. 8 (the right image) also shows particulate matter present within the foam that was not visible in Fig. 7.

VGSTUDIO MAX includes foam powder analysis functionality, which can be used to analyze voids and void wall thicknesses in porous materials. It can separate the interconnected pores, color-code them by volume (Fig. 9), and output a corresponding histogram of the volume distribution (Fig. 10). In a related Application News article (No. N138), 5 mm³ and smaller voids were analyzed. However, in this example, 0.005 mm³ and smaller voids were analyzed by cutting a piece from the workpiece and using magnified imaging.

Furthermore, Fig. 11 shows an example of analyzing void wall thickness using the same functionality. Images color-coded by wall thickness can be obtained in the same manner as for void volumes in Fig. 9. The ability to simultaneously analyze both volume and wall thickness, as described above, is useful for evaluating cushioning and other foam properties.

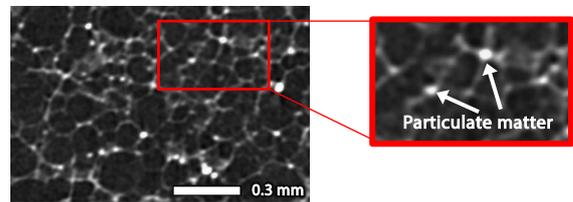


Fig. 8 Magnified Cross-Sectional Images of Voids

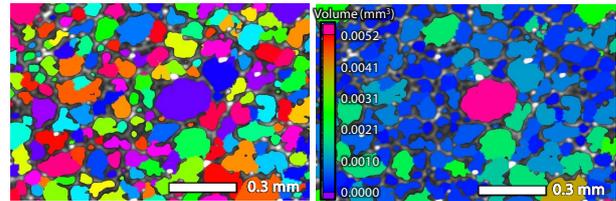


Fig. 9 Foam Powder Analysis Results (Left: Ratio of Interconnected Pores; Right: Color-Coded by Volume)

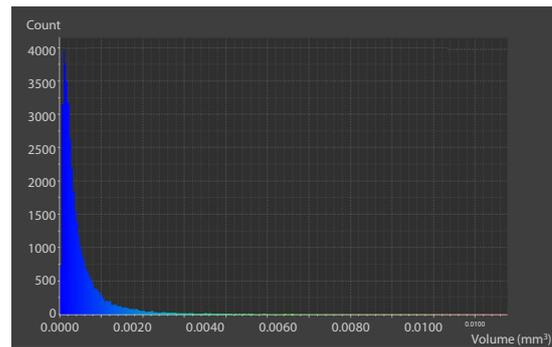


Fig. 10 Histogram of Void Volume Distribution (Using Foam Powder Analysis)

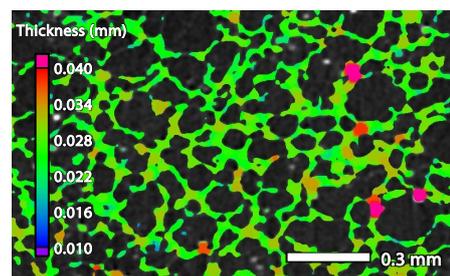


Fig. 11 Void Wall Thickness Analysis Results (Using Foam Powder Analysis)

Lastly, 3D images of the magnified voids are shown below (Fig. 12). In addition to color-coding voids by volume and wall thickness, particulate matter in Fig. 8 can also be color-coded with any color, which enables their respective positions and distributions to be observed three-dimensionally. In this case, a commercially available packaging material that is actually being used was scanned. The images show that void volumes, wall thicknesses, and additives are distributed uniformly. During product development or defect inspections, all these distributions can be observed and analyzed at the same time, which is helpful for assessing quality.

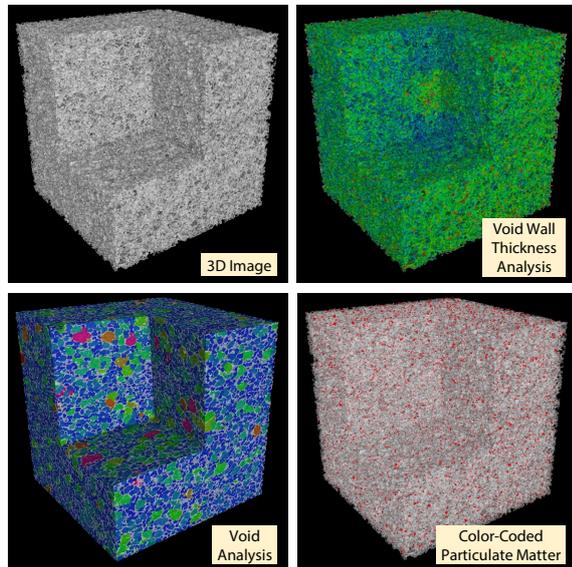


Fig. 12 3D Images

■ Conclusion

The adhesive area of urethane foam with an adhesive-bonded area (packaging material for consumer electronics) was observed and the voids were analyzed using a microfocus X-ray CT system. By adjusting the CT scan settings based on the purpose of observation, a wide variety of data can be obtained, ranging from observing overviews of the adhesive area to analyzing detailed voids. This can be useful for improving urethane foam quality by analyzing the causes of adhesion failures or analyzing void or wall thickness data.

Acknowledgments

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Related Applications

1. Observation of Dishwashing Sponge with inspeXio™ SMX™-225CT FPD HR Plus [Application News No.N138](#)

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