**Reason behind selecting or rejecting a particular threshold detection criterion**

Based on our code, we can evaluate the different thresholding techniques used for detecting issues in motor assembly monitoring through image analysis.

**1. Thresholds Used in the Code:**

* **SSIM-based thresholds:**
  + Statistical thresholding (mean + standard deviation).
  + Statistical thresholding (mean + 2 \* standard deviation).
  + Gaussian Mixture Model (GMM) based thresholding.
* **Pixel-based thresholds:**
  + Manual Thresholding.
  + Otsu's Thresholding.
  + Triangle Thresholding.
  + Adaptive Mean Thresholding.
  + Adaptive Gaussian Thresholding.

**2. Output Summary:**

* **SSIM-based analysis:** The code evaluates the Structural Similarity Index (SSIM) for different test images and uses multiple thresholding methods to classify the images. For the images, the SSIM value was in range of (0.6565-0.8765), which fell below both the statistical threshold approximately (0.88) and the mean + 2 \* standard deviation threshold (0.9960), indicating an assembly issue.
* **GMM-based threshold:** The GMM-based threshold was found to be 0.7629, which was lower than the SSIM score for images but indicated that some issues could still be detected.

**3. Analysis of Thresholding Methods:**

**a. SSIM Statistical Thresholds (mean + standard deviation / mean + 2 \* standard deviation):**

* These thresholds are based on statistical properties of SSIM values calculated for various test images.
* In this case, the statistical threshold (mean + standard deviation) is **0.9086**, which is close to the SSIM of the test images (0.6565-0.8765), making it sensitive enough to detect a minor misalignment or insertion issue.
* However, the mean + 2 \* standard deviation threshold is quite high (**0.9960**), which may be overly strict for detecting issues, possibly leading to missed detection of minor issues.

**b. Gaussian Mixture Model (GMM)-based Threshold:**

* GMM fits a probabilistic model to the SSIM scores, allowing for a more nuanced understanding of the distribution.
* The GMM-based threshold was **0.7629**, significantly lower than the SSIM for images (0.6565-0.8765).While this threshold would flag fewer issues (fewer false positives), it may fail to detect borderline cases.
* This threshold is useful when you want to minimize false alarms and only focus on significant deviations from the reference, but it risks ignoring subtle assembly defects.

**c. Pixel-based Thresholding Methods:**

* **Otsu’s Threshold** and **Triangle Threshold**: These are automatic thresholding techniques based on image histograms. They can segment the image by separating the foreground from the background based on intensity. While these methods are valuable for simple segmentation, they might not capture subtle differences in complex assembly images where local variations are important.
* **Adaptive Thresholding**: The adaptive methods (mean and Gaussian) adjust the threshold based on local properties, making them more robust for uneven lighting or varying textures in the image. This can be useful when examining fine details such as magnet insertion in varying surface textures.
* In the case, the **Adaptive Gaussian Thresholding** achieved a high percentage of thresholded pixels approximately (95%), indicating that it effectively highlighted relevant regions in the test image.

**4. Best Thresholding Criteria:**

**The SSIM-based statistical threshold (mean + standard deviation) of (0.9086)**, seems to be the most effective for this task for several reasons:

* **Sensitive Detection**: It closely matches the SSIM score of the misaligned image (0.6565-0.8765), providing a good balance between sensitivity and specificity. It can detect subtle issues without being overly strict.
* **Flexibility**: It takes into account variations in SSIM across different test images, allowing for adaptive decision-making.
* **Interpretability**: SSIM directly reflects structural differences between images, making it suitable for monitoring motor assembly, where alignment and structure are critical.

**Why Other Thresholding Methods are Less Suitable:**

* **Mean + 2 \* Standard Deviation Threshold**: This threshold (0.9960) is too strict and may only detect severe assembly issues, missing borderline cases like slight misalignment or partial insertion.
* **GMM-based Threshold**: The GMM-based threshold (0.7629) is too lenient for detecting minor issues, such as partial magnet insertion, as shown by its inability to flag the misaligned image. This may result in false negatives, especially in high-precision tasks.
* **Pixel-based Thresholding (Otsu, Triangle, Adaptive)**: These techniques are useful for segmentation but may not fully capture the subtle structural differences that SSIM can detect, particularly in complex tasks like motor assembly where alignment and fine surface details are critical.

**Conclusion:**

The **SSIM-based statistical threshold (mean + standard deviation)** offers the best balance of sensitivity and reliability for detecting assembly issues. It effectively detects subtle structural issues in images, making it more suitable for monitoring fine details like magnet alignment and surface quality in motor assembly tasks.