

# Analysis of the Working Principle, Applications and Limitations of Traditional Industrial Endoscopes

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**Abstract:** In the industrial production process, the interior of machines is prone to quality problems such as rust and damage due to factors like corrosion and impact, and the complex internal structure makes it difficult to observe directly. As a non-destructive testing tool, traditional industrial endoscopes can penetrate into curved pipes and areas that are out of reach of the human eye, achieving imaging, recording and storage of internal conditions. This article systematically expounds the optical imaging principle of traditional endoscopes, the standard operating procedures, and their practical applications in typical scenarios such as engine oil passage burrs and iron filings in bolt holes. Meanwhile, the limitations of traditional endoscopes in terms of imaging quality, detection range, detection efficiency and functional diversity were analyzed. Analysis shows that although traditional endoscopes have met the basic needs of visual inspection, their reliance on visual judgment and lack of automatic recognition and three-dimensional measurement capabilities have made it difficult to meet the development requirements of modern industrial precision manufacturing.

**Keywords:** Traditional Endoscope; Non-Destructive Testing; Engine; Imaging Principle; Limitations

## 1. Introduction

With the development of technology, industrial endoscopes have been widely applied in fields such as shipbuilding, machinery, and aerospace<sup>[1-3]</sup>. Due to their simple operation and single functions, traditional industrial endoscopes have gradually revealed their shortcomings in current applications<sup>[4-7]</sup>. For instance, they are unable to perform functions such as depth measurement, length measurement, and image editing, which restricts the efficiency

and accuracy of inspection. This article aims to systematically sort out the working principle, usage methods and typical applications of traditional endoscopes, and objectively analyze their limitations, providing a basic reference for understanding the technological upgrade of new multi-functional endoscopes<sup>[8]</sup>.

## 2. The Working Principle of Traditional Endoscopes

Traditional endoscopes usually form images based on optical principles. They rely on optical lenses, light reflection and refraction, as well as photosensitive elements to capture and convert images. Most traditional endoscopes are industrial electronic endoscopes. They convert light energy into electrical energy through a photoelectric coupling device installed at the very front of the endoscope, and then restore high-definition and realistic images through an image processing system. Among them, the optocoupler is the core component of the electronic endoscope, which can determine the image quality.

## 3. Traditional Endoscopy Usage Method

Traditional industrial endoscopes can conduct in-depth inspections of curved pipes and can detect areas that are beyond the reach of the human eye. This greatly reduces manpower, material resources, and financial costs.



**Figure 1. Components of Traditional Industrial Endoscopes**

The usage method of the endoscope is as follows:

(1) Installation of the instrument: Remove the endoscope from the instrument box, install the battery, memory card and insertion tube onto the main unit, and protect the front probe well during the installation process.

(2) Prepare for startup: Check the integrity of the equipment and hold down the power button for a long time to turn it on.

(3) Function calibration: Check whether the image display function of the endoscope is normal. Rotate the joystick to check the steering function of the probe. Turn on the LED of the probe to view the lighting function.

(4) Inspection operation: Insert the endoscope probe steadily and accurately into the interior of the machine to be inspected to prevent the probe from bumping into the channel. Turn on the probe LED and adjust the brightness to make the picture clear. Slowly operate the joystick to adjust the movement direction of the probe and conduct a comprehensive inspection of the interior of the machine.

(5) Take photos and store them: Take photos of the test results and store them in the memory card.

(6) Instrument placement: After the detection is completed, slowly remove the probe, clean the probe and cable sections as per regulations, organize the instrument and place it in the instrument box.

#### 4. Practical Applications of Traditional Endoscopes

The inner cavity of the engine block is narrow and the structure is compact, making detection inconvenient. As a non-destructive testing tool, traditional industrial endoscopes play a significant role in engine manufacturing. Industrial endoscopes can be inserted into small holes and other areas that are invisible to the naked eye, quickly and clearly observing the specific conditions of the inspection area, and collecting image data for storage, providing a strong technical guarantee for engine fault detection and greatly saving financial resources.

The oil passage openings of the machine body are narrow and the oil passages are crisscrossing and penetrating. The flexibility of the endoscope can be utilized to inspect the internal oil passage conditions of the machine body, identify burrs, cracks, iron filings and cast sand, and take photos of the problem areas for archiving. Due to processing technology issues, there are burrs inside the oil passage that are undetectable to the

naked eye. These tiny burrs will fall off during the flow of the liquid and enter various parts of the engine body, even critical parts, affecting the overall performance of the engine and causing irreparable consequences. An industrial endoscope can be used to conduct a comprehensive inspection of the oil passage of the machine body. Smoothly insert the debugged endoscope probe into the oil passage of the machine body. Turn on the light and operate the joystick to adjust the probe Angle. Check the internal condition of the oil passage. A normal and undamaged oil passage is shown in Figure 2, clear without any foreign objects or defects. Figure 3 shows a photo of burrs in the oil passage, which can be clearly and accurately inspected for their location and size with an endoscope.



**Figure 2. Inspection of the Oil Passage in the Machine Body**



**Figure 3. Photo of Burrs in the Oil Passage**  
During the machining process of the engine body, iron filings tend to remain inside the bolt holes, which are difficult to detect with the naked eye. Therefore, an endoscope can be used for inspection. Figure 4 shows the inspection process of the engine body bolt holes. The probe

is inserted into the bolt hole to check the condition of the iron wires and iron filings inside. The iron filings in the bolt hole are shown in Figure 5. They can be clearly observed and photographed for storage through the endoscope.



**Figure 4. Inspection of the Bolt Holes**



**Figure 5. Iron Filings in the Bolt Holes**

### 5. Limitations of traditional endoscopes

Traditional endoscopes are widely used for internal inspection of machines, but they also have certain limitations, mainly reflected in the following aspects:

- (1) Traditional endoscopes can provide intuitive images of the interior of machines, but their imaging quality is affected by factors such as lighting conditions, lens quality, and probe wear, resulting in insufficient image clarity.
- (2) The probe length and bending Angle of traditional endoscopes are limited, which may prevent them from reaching some hard-to-reach areas, thereby restricting their detection range. Furthermore, for the inner walls of pipes with severe dirt accumulation, traditional endoscopes are unable to conduct in-depth observations.
- (3) The detection efficiency of traditional endoscopes is relatively low. When recording and analyzing a large amount of image information, it takes a longer time to complete.
- (4) Traditional pinching mirrors mainly rely on visual inspection and cannot provide advanced

functions such as automatic recognition and three-dimensional measurement, which to some extent limits the inspection content.

Traditional endoscopes have limitations in terms of imaging quality, detection range and detection efficiency. With technological progress, new and multi-functional endoscope devices have developed rapidly and been widely applied.

### 6. Conclusion

With the advancement of technology and the rapid development of the global economy, the market demand for industrial endoscopes has increased sharply. While meeting market demands, various manufacturers are constantly improving and perfecting the quality and production efficiency of endoscopes, and further expanding their application fields. Traditional endoscopes have addressed the fundamental issue of the "invisibility" inside machines and have played a significant role in non-destructive testing in fields such as engine manufacturing. However, its limitations in imaging quality, detection range, efficiency and functionality have become increasingly prominent, making it difficult to meet the demands of modern industry for precise measurement and intelligent analysis. Therefore, the development of new multi-functional endoscopes with capabilities such as three-dimensional measurement and automatic recognition has become an inevitable trend. These advancements will enable industrial endoscopes to be widely applied in more fields, providing strong support for equipment maintenance, repair and renovation, while promoting the continuous development and innovation of related industries.

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