# Properties of Braided Tungsten Ribbon Tubes

# タングステンリボン製ブレーディングチューブの特性

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**Key words;** tungsten, ribbon, wire, visibility, bend test, buckling displacement, deformation resistance, braiding

**キーワード；**タングステン、リボン、ワイヤー、視認性、曲げ試験、座屈変位、変形抵抗、ブレーディング

**Abstract**

Although difficult to form, tungsten is used in various shapes for different applications. We developed tungsten ribbons (flat wires) in which we can precisely control the ratio between the width and the thickness. Tungsten ribbon is used widely in medical and environmental applications because it is highly visible on X-ray images, and has high strength. We evaluated the visibility on X-ray and the mechanical properties of braided tubes made from tungsten ribbon or wire. We compared these properties with those of braided tubes made from stainless steel. We confirmed that tungsten ribbon has high visibility on X-ray images owing to the increased surface area increases. Braided tubes made from Tungsten are more resistant to deformation than those made from stainless steel.

タングステン材料は難加工材でありながら、用途に合わせて様々な形状に加工されて利用される。当社で開発したタングステンリボン（平線）は厚みと幅の比率を調整することが可能で、近年ではＸ線写真における高い視認性や高強度といった特性から医療分野や環境分野での利用が盛んに行われている。本稿ではタングステンリボンおよびワイヤーをブレーディングしたチューブを作製し、Ｘ線写真における視認性とチューブ形状での機械的特性の評価とSUS製との比較を行った。評価の結果、タングステンリボンは表面積増大により高い視認性が確認され、SUSに比べて変形抵抗が大きいことが分かった。

# 1. Introduction

Tungsten is brittle and has thus far been impossible to process into thin sheet. We have developed a process to manufacture Tungsten ribbons as thin as 5 $\mu$m. The tungsten ribbons are then processed, such as by coiling or braiding, for practical use. It is thought that the coiled or braided tungsten ribbon has mechanical characteristics that are unlike similar structures made from tungsten wires, but the differences remain unclear.

In the present study, we evaluated the appearance, visibility on X-ray images, and mechanical characteristics of tube samples manufactured by braiding tungsten ribbon or wire. We compared these properties with those of stainless steel.

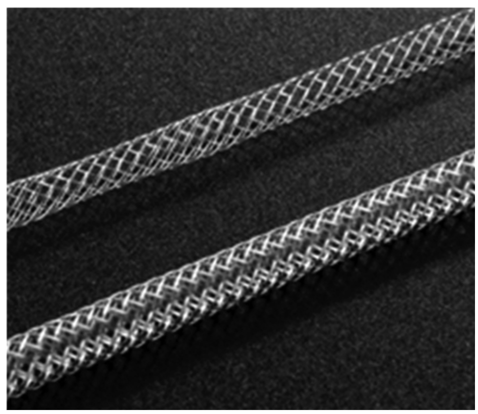

Fig.1 Braided tubes made from tungsten wire (upper) and tungsten ribbon (lower)

# 2. Experimental Procedure

We manufactured braided tube samples from ribbon and wire with a circular cross-sectional structure, as shown in Fig.2. The braided tubes were manufactured with support of Yamaguchi Sangyo Co., Ltd., using a HS80 series horizontal fine wire braiding machine (Steeger USA Inc). Manufacturing conditions are detailed in Table 1. After braiding, the tubes were coated with a heat-shrinkable Polyolefin tube to prevent sliding between the raw wires

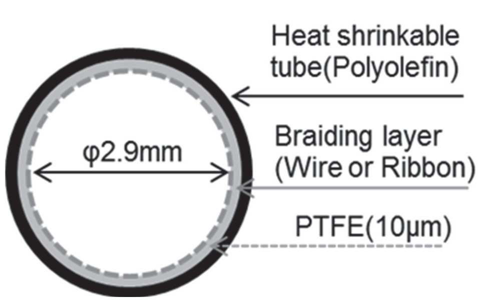


Fig.2 Cross-section of the braided tube

Table 1 Manufacturing conditions

| **Materials** | **Tungsten (B001), SUS304*[1]** |
|---|---|
| **Size of wire** | φ50μm |
| **Size of ribbon** | 25×80μm |
| **Braiding pitch** | 35, 50,70 PPI*[2] |
| **Braiding tube size** | Inner diameter 2.9mm |

*[1]SUS304 is X5CrNi18-10 stainless steel (ISO standard)

*[2]PPI, picks per inch

## 3. Results and Discussion

(1) Visibility on X-ray imaging

We compared the braided tubes by evaluating appearance using digital photography (Fig. 3). We also used an X-ray inspection system (TOSRAY-V150M2/6S; TOSHIBA IT & CONTROL SYSTEMS Co., Ltd.) to confirm the visibility of the tubes (Fig.4). Tungsten ribbon is most clearly visible. Tungsten shows high visibility on the X-ray images because the specific gravity of tungsten is up to twice that of stainless steel. In addition, the tube made from tungsten ribbon has a larger surface area than does wire of the same diameter (thickness). Thus, ribbon covers the tube better, improving visibility.

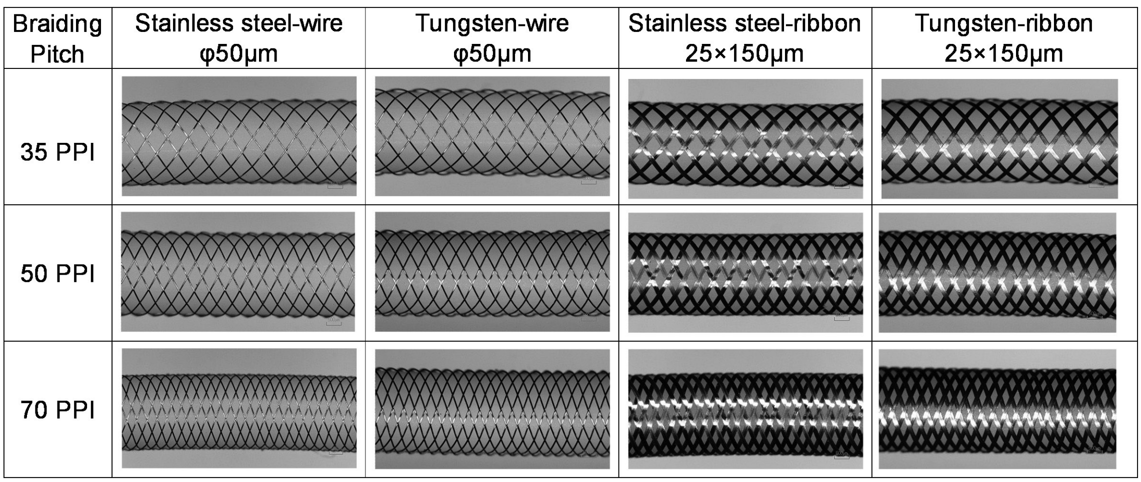


Fig.3 Digital images of tubes made from braided tungsten or stainless steel wire or ribbon

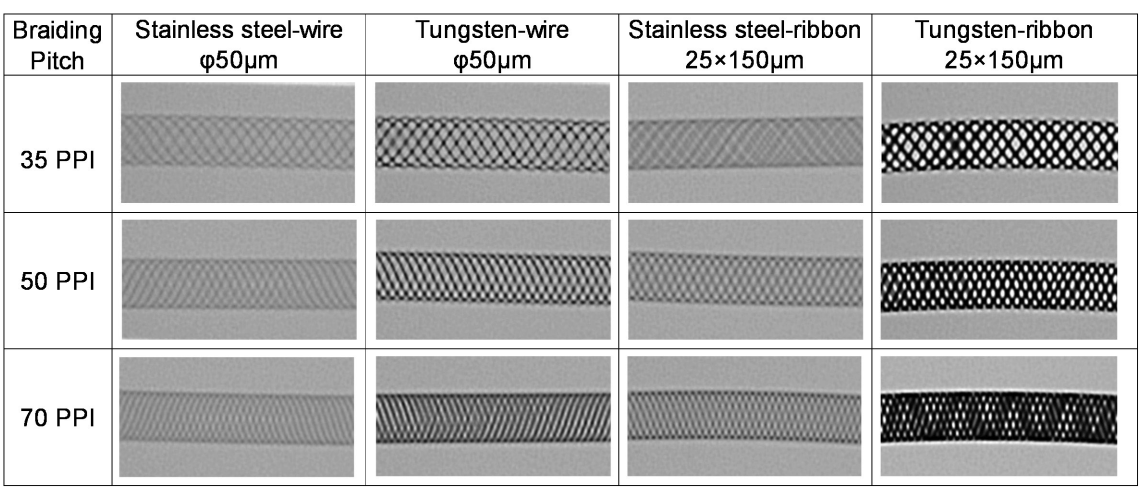


Fig. 4 X-ray images of tubes made from braided tungsten or stainless steel wire or ribbon, captured using a TOSRAY-V150M2/6S X-ray inspection system (Capture condition is 40kV and 0.1mA)

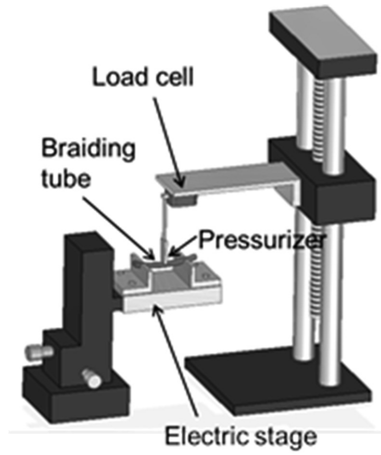


Fig.5 Experimental setup for the reverse bend test

(2) Evaluation of mechanical properties using a reverse bend test

To evaluate the mechanical properties of the braided tubes, we performed a reverse bend test as shown in Fig. 5. The braided tube was fixed on an electric stage, and the load applied to the braided tube was measured using a load cell. The distance between the fixed ends of the tube was set at 20 mm; pressure was applied at the mid-point, 10 mm from the fixed ends. The electric stage moved the pressurizer up 0.50 mm and then down 0.45 mm in each cycle. Cycles were repeated until the tube buckled. The obtained load–displacement curves are shown in Fig. 6.

① Buckling displacement

In this evaluation, we defined $\Delta$ L to be variation of maximum load between cycles from the load–displacement curve. We considered the point where $\Delta$ L varied most substantially to be the buckling displacement.

Blue lines in Fig. 6 show the transition of $\Delta$ L. When using the heat shrinkable tube only (a), buckling displacement was 4.8 mm; that of stainless steel ribbon tube (b) was 5.3mm; and that of tungsten ribbon tube(c) was improved to 7.3mm. Buckling displacement was better for the metal tubes than for the heat shrink only. We confirmed that braided tubes made from tungsten are more resistant to buckling than those made from stainless steel.

② Deformation resistance

Red lines in Fig.6 show transition of the load for the displacement. When the displacement is 1 mm, the load is the same for tungsten and stainless steel (thick black arrow). However, when the displacement is 4 mm, the load on the tungsten braided tube is about 0.2–0.3 N higher than that on the stainless steel braided tube ribbon (thick orange arrow). This indicates that the tungsten braided tube has a higher deformation resistance than does the stainless steel braided tube. Although tungsten is a known high-rigidity material, we showed that tungsten also has high rigidity after secondary processing such as braiding.

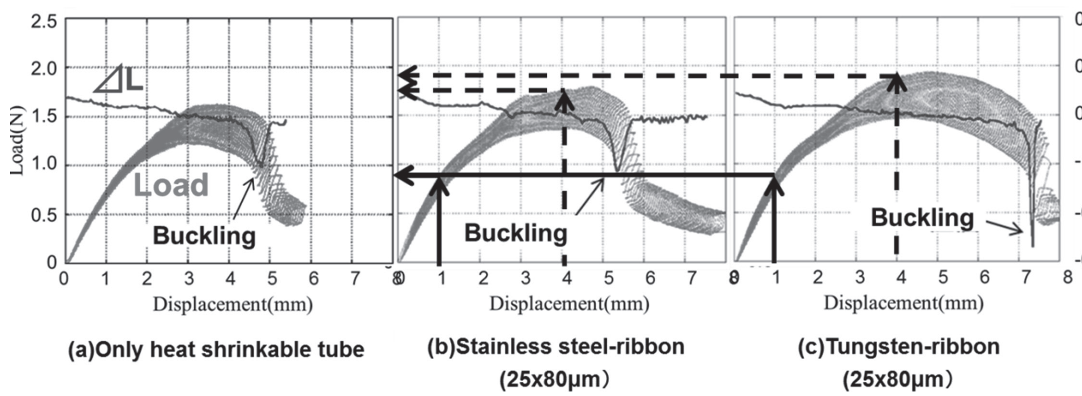


Fig.6　Load–displacement curves

## 4. Summary

We evaluated the mechanical properties of braided tubes made of tungsten ribbon and wire, and the visibility of these tubes in X-ray images. We compared these properties with those of general stainless steel braided tubes. Tungsten has high visibility on X-ray images because tungsten ribbon has a greater surface area than does wire of the same diameter (thickness).

In a reverse bend test we showed that tungsten needs a larger load than does stainless steel to produce the same displacement. Although tungsten is known to be a high rigidity material, we found that tungsten also retains high rigidity after secondary processing such as braiding.

## 5. Acknowledgments

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