Edge-Welded Metal Bellows

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- Senior Aerospace Metal Bellows
What is an edge-welded metal bellows?
Edge-Welded Metal Bellows Terminology

<table>
<thead>
<tr>
<th>Material Thickness (inch)</th>
<th>Weld Bead Diameter (inch)</th>
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</thead>
<tbody>
<tr>
<td>.005</td>
<td>.012 - .017</td>
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<tr>
<td>.007</td>
<td>.017 - .024</td>
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<tr>
<td>.010</td>
<td>.024 - .034</td>
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<tr>
<td>.015</td>
<td>.036 - .051</td>
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Weld Bead Size vs. Material Thickness

Weld

Pitch

Active Span

Span

CL
Effective Area

The area that pressure acts upon to produce a force output

- Similar to the piston in a air cylinder
- Force (lbs) = Pressure (psi) x Area (sq.in.)

\[
A_E = \frac{(OD + ID)^2 \pi}{16} = \frac{(2+1.4)^2 \pi}{16} = 2.27
\]
Convolution Spring Rate (Kc) (lb./in/convolution)

\[ K_c = \frac{10.3 \times 10^6 t^2}{S} \]

Capsule Spring Rate (K) (lb/in)

\[ K = \frac{K_c}{N} \]

t = Diaphragm Thickness
S = Span
N = Number of Convolutions
Spring Rate

Convolution Spring Rate (Kc) (lb./in/convolution)

- Thickness = .002"
- Span = (OD - ID)/2
  Span = (2 - 1.4)/2 = 0.3"

\[ K_c = \frac{10.3 \times 10^6 \times (0.002)^2}{0.3} = 137 \]

Capsule Spring Rate (K) (lb/in)

- Convolution K-rate = 137
- Number of Convolutions = 56

\[ K = \frac{137}{56} = 2.4 \]
**Force/Pressure Balance**

\[ \Delta P \cdot A_E = k \cdot \Delta L \]

- \( \Delta P \) = differential pressure (psid)
- \( A_E \) = effective area (in\(^2\))
- \( K \) = spring rate (lb/in)
- \( \Delta L \) = change in length (in)

**Example:**

\( \Delta P = 1 \text{ psid} \)
\( A_E = 2.27 \text{ in}^2 \)
\( K = 2.4 \text{ lb/in} \)

\[ \Delta L = \frac{(1 \text{ psid})(2.27 \text{ in}^2)}{2.4 \text{ lb/in}} = 0.946 \text{ in} \]
Edge-Welded versus Formed

Stroke

- Edge-welded bellows can be compressed up to 90% and extended up to 30%
- Formed bellows are limited to about 10%

Flexibility

- Edge-welded bellows are relatively soft in the axial, angular, and radial directions

Cost

- In general, edge-welded bellows are more expensive due to the extensive welding
Materials of Construction

Heat Treatable:
- AM-350 Stainless Steel
- Inconel 718
- Haynes 242

Non-Heat Treatable:
- 300 Series Stainless Steels
- Inconel 625
- Titanium
- Hastelloy C276

Mate bellows with compatible fittings including Incoloy® 945/945X
Methods of Manufacture

Micro-welding
- GTAW (TIG)
- Laser
- Electron Beam

Cleaning
- Aqueous
- Electropolish
- Pickle
Sizes and Thicknesses

Outside Diameters

- < 0.125"
- Up to 6 feet

Thickness

- 0.001" - .050"

3 feet? | 4 feet? | 5 feet or more?
Types of Edge-Welded Bellows

Nesting Ripple Bellows

- Long Stroke Capability
- Compact Nested Length
- Good Linearity
- Moderate Pressure Capability
Types of Edge-Welded Bellows

Single Sweep Bellows

- Good Pressure Capability
- Good Stroke Capability
- Compact Nested Length
- Good Linearity
Types of Edge-Welded Bellows

HIPRES® Bellows

- Withstands tremendous pressure in the nested position

Conventional Bellows

HIPRES® Bellows
Types of Edge-Welded Bellows

HIFORCE Bellows
- Transmits tremendous force in the nested position
- Excellent for holding and locking

Other Bellows Configurations
- Coned OD & ID, flat plate, crescent, torus, multi-ply bellows
Design Considerations

- Fatigue Life
- Stroke
- Pressure
- Cost
Extreme Temperatures

- Temperatures up to 1400°F (760°C) and higher
  - Flexible exhaust ducts
  - Thermal switches
  - Thermal valves
  - Thermal actuators
  - Firewall penetrations
Extreme Pressures

- Pressures up to **25,000 psi**
  - Gas-lift valves
  - Pressure/temperature compensators (e.g. for ESP’s)
  - Pressure switches
  - Sub-sea junction boxes
  - Accumulators (e.g. for aircraft hydraulic systems)
Reliability/Zero Maintenance

- 1,000,000,000 cycle bellows
- Gas-lift valves to 13,000 psi
- Medical implants
- Maintenance free accumulators
  - Fully welded and hermetically sealed for life
  - Space shuttle and space station applications
Leakage

- Helium mass spectrometer leak tight up to $1 \times 10^{-10}$ scc/sec helium (1 cc in 320 years)
- Elastomeric seal replacements
  - Dynamic seals in the desert
Questions?
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