Duct and Casing Design for Long Term Reliability

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Discussion...

- Uses of Duct and Casing Structures
- Various ways in which ducts fail
- Structural Design
- Importance of stress and elastic design
- Implications of conveying velocity
- Effects of Thermal Gradients and Deformation
- Questions / Answer Sessions
Uses and Applications

* Equipment
  * Precipitators
  * Fabric Filters
  * Scrubbers

* Applications
  * Moving Gases
  * Transportation of Dust or other material
Duct Failures

- Localized overstress
- Broken welds
- Excessive Wall Flex
  - Fan Pulse
  - Thermal Movements
- Collapse of supporting structure
Structural Design

- Design Stress
- Allowable Deflection
- Plate Thickness (Corrosion allowance)
- Duct Supports
- Internal Duct Braces
Standard Design Stress

* Common Grades of Steel yield strength
  * Standard Hot Rolled Steel: 36,000 psi
  * High Strength Steel: 50,000 psi

* AISC suitable design factor (steady state)
  * Standard Hot Rolled Steel: 22,000 psi
  * High Strength Steel: 30,000 psi
Absolute Maximum Stress for any duct component…
<18,000 psi recommended. (no real code here)

Factoring for:
- Unusual areas or shapes
- Deflection of components
- Long term fatigue
Allowable Deflection

* AISC Code Deflection:
  * Structural Member \( L/180 \)
  * Support Cranes or Moving Equipment \( L/360 \)

* Deflection of Duct (Recommended)
  * General \( L/300 \)
  * Critical areas, or anywhere near a fan \( L/400 \)
  * Be careful of deflection changing critical clearances
Design Considerations

* Plate section deflection
  * <1-1/2 x Plate Thickness is a good general reference
  * Check rotational stress at welded joints and stiffeners
* Hybrid Girders (aka Walls)
  * Side walls do not flex vertically
  * This causes 1, 1, 1 sharing rather than 1, 2, 1 as in normal structures.
* Corner angles limit joint rotation
Corner Angles
* Methods
  * Pencil and Paper
  * Computer
**Heavy Plate Uniform Load Calculations**

- **a**: 120-in  |  Dist. Between Primary Stiffeners  |  By: ____________
- **b**: 48-in  |  Dist. Between Secondary Stiffeners  |  Date: ____________
- **l**: 120-in  |  Length of Primary Stiffeners  |  Project: ____________
- **\( a/b \)**: 2.5  |  Stiffness Ratio  |  Primary Stiffeners: W8x15#
- **\( \beta \)**: 0.662  |  Stiffness Coefficient  |  \( l_1 = 68.9 \text{-in}^4 \)
- **\( \alpha \)**: 0.122  |  Stiffness Coefficient  |  \( r_1 = 3.95 \text{-in} \)
- **w**: 50-in/wg  |  Uniform Load  |  Secondary Stiffeners: C6@8.2#
- **t**: 0.3125-in  |  Thickness of Plate  |  \( l_2 = 13.1 \text{-in}^4 \)
- **E**: 29,106-lbf/in^2  |  Modulus of Elasticity  |  \( r_2 = 2.34 \text{-in} \)

**Plate Calculations**

- **s**: \( \frac{\beta \cdot w \cdot b^2}{l^2} \)  |  Maximum Plate Stress
- **y**: \( \frac{\alpha \cdot w \cdot b^4}{E \cdot t^3} \)  |  Maximum Deflection of Plate

**Primary Stiffener Calculations**

- **\( M_1 \)**: \( \frac{w \cdot a \cdot l^2}{8} \)  |  Maximum Moment on Primary Stiffener
- **\( s_1 \)**: \( \frac{M_1 \cdot r_1}{l_1} \)  |  Maximum Stress on Primary Stiffeners
- **\( y_1 \)**: \( \frac{5 \cdot w \cdot a \cdot l^4}{384 \cdot E \cdot l_1} \)  |  Maximum Deflection of Primary Stiffeners

**Secondary Stiffener Calculations**

- **\( M_2 \)**: \( \frac{w \cdot b \cdot a^2}{8} \)  |  Maximum Moment on Secondary Stiffeners
- **\( s_2 \)**: \( \frac{M_2 \cdot r_2}{l_2} \)  |  Maximum Stress on Secondary Stiffeners
- **\( y_2 \)**: \( \frac{5 \cdot w \cdot b \cdot a^4}{384 \cdot E \cdot l_2} \)  |  Maximum Deflection of Secondary Stiffeners

- **s**: 28.203 Kip/in^2
- **y**: 1.325 in

- **\( M_1 \)**: 32.513 Kip-ft
- **\( s_1 \)**: 22.368 Kip/in^2
- **\( y_1 \)**: 0.293 in

- **\( M_2 \)**: 13.005 Kip-ft
- **\( s_2 \)**: 27.877 Kip/in^2
- **\( y_2 \)**: 0.616 in
Finite Element Analysis
Conveying Velocity

* 3500 feet per minute = Successful conveyance of most fly ash without accumulation in the duct work

* Higher velocity = cleaner duct + pressure drop + abrasive wear

* Sticky dust...not good
* Flat horizontal ducts...not good either
Well known and understood but still a constant cause of failures

Common Causes

- Temperature variation across flow
- Dust layers or fallout
- Inside vs. outside (poorly insulated areas)
- Connecting cold exterior structures to hot parts (see photo)
Thermal Gradients and Deformation

- Thermal limitations of material
  - Steel loses ~25% of its strength at 700°F
- Thermal expansion cannot be overcome
  - Stronger components make for higher stresses
- Change in static pressure due to temperature
  - Fans move volume
  - Pressure is determined by density
- Transport velocity is calculated at standard conditions since friction is determined by mass not volume
Questions and Answers...