Bra Underwire Analysis and Non-metal Support Creation

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**Motivation**

Our project is fueled by complaints and returns made by real women, below are some of the most common problems found in underwire bras.

- Bending/Twisting
  - “The bra is rather flimsy, underwire is not strong”
- Breakage
  - “After only a couple of months wearing, the wires snapped on every single one of them!”
- Poke Through

**Customer Needs**

<table>
<thead>
<tr>
<th>Mechanical Functions</th>
<th>Aesthetics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Metal Support</td>
<td>Support</td>
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<tr>
<td>Replacement for metal underwire</td>
<td>Must provide lift and hold the breast tissue without straining.</td>
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</tbody>
</table>

- Durability:
  - The underwire will not break, twist or distort through extreme usage.
- Fit:
  - Allow the bra to conform to the user’s body and accommodate daily movement.

- Maintain Integrity:
  - The bra will hold its shape through regular use.
- Comfort:
  - Will be comfortable throughout a full day and after many launderings.

**Material Analysis**

- CES Edupack: Database that analyzes various properties and determines the sufficient materials for the application.
  - Table shows resistance to salt water and distilled water.
  - Upper right hand corner contains materials such as ABS, PET, and PP
- Graph displays fracture toughness and flexural strength
- Blue area includes several types of ABS
- Brown area includes PET and PP

**SEM Imaging**

- Wires made out of galvanized steel
- Portions of wires shown under 50x, 200x and 500x
- Images display non-uniform surface of the wire
- Determined that the zinc coating is not preventing corrosion along the cracks

**Corrosion Baths and Fatigue Testing**

- Plain wires submerged in three types of baths:
  - Deionized water
  - Salt water
  - Bleach and Detergent solution
- Wires remained submerged for 1, 2, 3, and 4 weeks
- After removal from the bath, wires were submitted to the fatigue test which grips wires and applies a cyclical load until breakage

**Hydrogen Embrittlement**

- Rising Step Load (RSL): load increases step-wise over time
- Notched wire is clamped on either end and surrounded by salt water with an electrical current
- Load increases every 4 hours
- Allows hydrogen to diffuse and crack the metal
- Concluded that underwire is susceptible to cracking over time

**Controlled Wash Testing**

- Three Playtex 38C style 4421
- Control bras had about 0.5 inches of “wire play” in the casing
- Completed 5 complete wash and dry cycles with 6 pound ballast
- Wash cycles: 45 minute cold/cold cycles using AATCC 1993 Standard Ref Detergent WOB
- Dry cycles: 60 minutes at 135° F (high heat)
- Conclusions: Casing had significant shrinkage resulting in minimal “wire play”; early evidence of wire corrosion and surface defects

**Materials and Methods**

- **SEM Imaging**
- **Fatigue Test**
- **RSL Hydrogen Embrittlement Susceptibility Test**
- **Controlled Wash Testing**

**Prototyping and Evaluation**

**Metal Solution**

- Bare wires coated in BlueStar V-04 primer, cure for 20 minutes at room temperature
- Coat both sides of wire with BlueStar RTV 3400 silicone using a pipette, cure 17 hours at room temperature for each side
- Tested in corrosion baths: Water, Salt, and Bleach/detergent

**Non-Metal Solution**

- Created an AutoCad drawing based on the curvature of the bra cup. Thickness 2.5mm
- 3D printed the solution using ABS plastic
- Evaluated in deflection test: deflected 5.1 cm while metal deflected 0.95 cm. Plastic spring constant: 74.81 Kg/s², Metal spring constant: 322.88 Kg/s²

**Out of the Box Solution**

- Created an AutoCad drawing based on the bra cup shape. Thickness 2.5mm
- 3D printed the “half cup” using ABS plastic
- Will be printed with a gradient of materials ranging from hard plastic at the bottom to a flexible rubber material at the top
- Objet Connex 350 which prints 2 materials: Vero White and Tango Black

**Moving forward**

- Develop continuous method for coating metal underwire
- Continue with 3D printing in ISE
- Incorporate solutions into bras and conduct wear trials

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**HANES Brands Inc**

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