Case Study #2: Breakage of Nail Polish Bottles

A retail store was experiencing a problem with breakage of small capacity, rectangularly shaped nail polish bottles. The bottles were breaking while being displayed on a store shelf when the ambient temperatures were somewhat higher than usual. Analysis of the fracture patterns indicated the bottles failed from an internal pressure load. In order to properly diagnose the cause of the breakage problem it was necessary to determine how the unexpected internal pressure load had been created and whether the tensile stresses that were associated with this load were too high or whether the glass strength was too low.

The fracture origins were consistently located in the mid-point of the upper sidewall of the bottles as shown by the example in Figure 1. Based on the physical dimensions of the mirrors that were present on the fracture surfaces, the average breaking stress was 5780 psi (405 kg_f/cm^2). Since glass strength is defined as the magnitude of the tensile stress at failure, this stress value represents the glass surface strength at the fracture origin site. Consulting a standard strength table, it was concluded that the glass strength was acceptable for a long-time load duration. Therefore, it was necessary to focus on the factors that led to the creation of an elevated level of tensile stress.

Upon heating of a capped container, if the headspace volume is inadequate, expansion of the liquid will totally consume this volume and the liquid will exert a hydraulic force on the inside surface of the container. As the pressure increases, the flat panels of the container bend outward creating a high tensile stress on the outside glass surface in the sidewall region of the containers. This would account for the presence of elevated tensile stresses and for fracture origins to be consistently located in the mid-point of the upper sidewall region.

Two factors have the potential to create a hydraulic internal pressure load. The first is the overflow capacity of the containers and the second is the total volume of the liquid product. The overflow capacity of representative unbroken containers ranged from 20.2 ml to 20.9 ml which met the blueprint specification of 20 ml ± 1.5 ml. The measured liquid volume ranged from 17.8 ml to 18.3 ml which exceeded the targeted volume of 16.0 ml to 17.5 ml.

Thus, the cause of the hydraulic pressure was an excessive liquid volume when the containers were filled. The total overflow volume of the cosmetic container must be designed to account for the product volume, the headspace volume, any mixing balls that might be present as well as the volume of the polish applicator. Failure to account for all of these "product" volumes will potentially result in hydraulic pressure situations.

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