PREFERRED
RELIABILITY
PRACTICES

SOLID ROCKET MOTOR JOINT RELIABILITY

Practice:

Critical design features that reduce joint rotation, improve seal features, provide close tolerances, provide for leak checks, and provide venting are used to improve the reliability of case-to-case and case-to-nozzle field joints for large solid propellant rocket motors. Principal design drivers are the combustion chamber pressure vs. time profile, segment stacking and assembly tolerances, insulation and sealing configurations, launch dynamic loads, flight dynamic loads, and environmental temperatures.

Benefit:

Proper design of solid rocket motor case-to-case field joints reduces joint rotation and potential leakage during ignition and operation. With detailed dynamic loads analyses, thermal analyses, careful insulation design, and suitable “o”-ring sealing, the leakage of hot combustion gasses through field joints is eliminated. This prevents potentially catastrophic burning or melting of the solid rocket motor and adjacent metal components. Similar benefits are obtained by using improved design practices for case-to-nozzle joints and factory joints between case segments.

Programs That Certified Usage:

Space Shuttle Redesigned Solid Rocket Motor (RSRM)

Center to Contact for More Information:

Marshall Space Flight Center (MSFC)

Implementation Method:

1. Background

The Challenger accident (Space Shuttle Flight #51L) which was caused by the escape of hot gasses from case-to-case field joints in the SRM, triggered an in-depth, detailed review of analytical, design, manufacturing, assembly, and testing methods for solid rocket motor field and factory assembly joints. The case-to-case field joint was the primary target of the investigations and subsequent redesign efforts. However, other joints in the motor such as the case-to-nozzle joint and the factory joint between motor segments were thoroughly investigated and redesigned when the investigation allowed for optimization of the noted

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configurations. Reliable joint performance was achieved by a detailed review of the design drives and by comprehensive analysis, test, and redesign processes.

2. Case-to-Case Field Joint Improvements

Space Shuttle Redesigned Solid Rocket Motors (RSRMs) are made up of four segments in which propellant is cast in monolithic form. The four segments are connected by the field joint shown in cross-section on Figure 1.

The case portion of each segment consists of two cylinders connected in the center by a factory joint. A dynamic launch and flight load analysis confirmed that the field joint design, which has been the main focus of attention, needed to be modified after the Challenger accident to incorporate several improvements. The most significant of these improvements was the addition of a “capture” feature, which is essentially an added circumferential band that is incorporated as an integral part of the “tang” on the male side of the three case-to-case field joints. This capture feature creates an interference fit with the inner clevis surface and restricts the movement of the tang away from the two “o”-rings on the internal leg of the field joints during initial motor pressurization. The capture feature also incorporates a third “o”-ring which potentially serves as a heat barrier to the combustion process, in event of anomalous insulation performance. In addition to the change in the metal parts, the configuration of the internal insulation interface between adjacent segments was changed to permit an interference fit between adjoining insulation elements. This insulation joint is bonded with a pressure sensitive adhesive around its full circumference, and aided in its contact during motor operation with a circumferential “J” shaped pressurizing slot in the tang insulation. With the addition of the capture feature and its “o”-ring, a second leak check port, which also serves as a vent during assembly and a means of positioning of the primary “o”-ring, was added in the redesigned joint. This ensured that a redundant seal existed in the new design. A “V-2” fluorocarbon filler material was placed at the clevis tip between the primary and tang “o”-rings to reduce the free volume of the joint and limit the quantity of hot gas that would enter the joint in the event of leakage of the “J” seal and capture feature “o”-ring.

In the new design, the inner clevis leg surface is machined to provide a sealing surface for the capture feature “o”-ring. The compression of both the primary and secondary “o”-rings was increased by increasing the “o”-ring diameter by 0.010 inch from the pre-Challenger configuration, and the “o”-ring grooves were widened by 0.005 inch to prevent four wall contact by the “o”-ring. All sealing surfaces were smoothed to an average roughness of 63 micro inches (63 millionths of an inch). A chamfered clevis leg was provided to aid in the assembly process. Each field joint in the Redesigned Solid Rocket Motor is connected by pins (a cross sectional drawing of one of these pins appears on Figure 1). A key reliability enhancement feature is an increased-length pin with a circumferential

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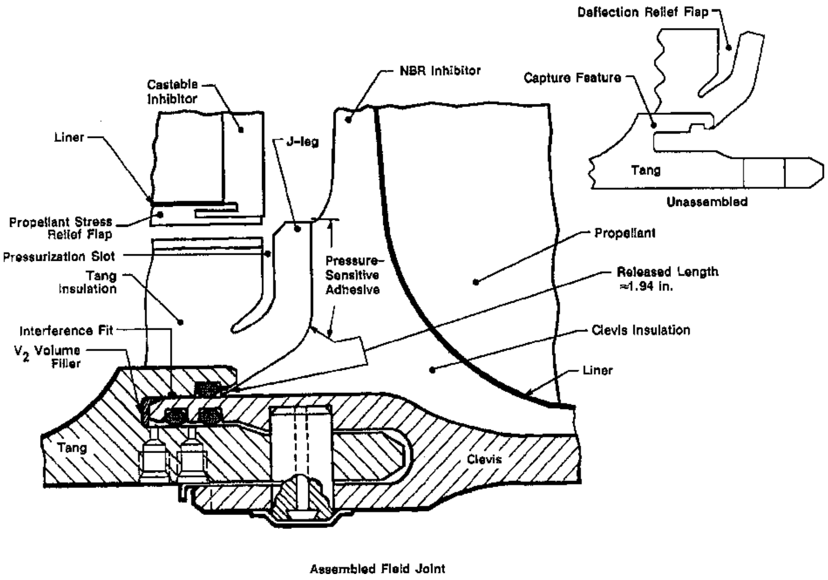

Figure 1. Cross-section of Field Joint

pin retainer band. Each pin includes a hole which assists in assembly, and an opening with a dovetail cross-section to assist in pin extraction for refurbishment after flight. The increased pin length causes the dovetail to lie outboard at the outer clevis leg outside diameter. A stress analysis confirmed that this would reduce unit area shear stress on the pin because the dovetail is outside of the high shear area. This modification eliminated the potential for pin deformation. Custom shims were inserted between the inside surface of the outer clevis leg and the outside surface of the tang to maintain a constant gap between the two surfaces and to limit the growth of the metal-to-metal gap at the primary and secondary “o”-rings during pressurization.

3. <u>Case-to-Nozzle Joint Improvements</u>

Concurrent with the improvements in the case-to-case field joints, case-to-nozzle joints were also improved to obtain higher reliability and to achieve a more robust design. Changes to the insulation configuration, joint adhesive material, “o”-ring and “o”-ring groove configurations, and the nozzle attachment fasteners provide positive assurance of sealing. As in the instance of the insulation surrounding the case-to-case field joints, a pressurizing slot in the case insulation, coupled with a layer of sealant between the case and nozzle insulation, provides protection against combustion gasses reaching the nozzle or case metal parts. A circumferential slot is located in the case insulation near the interface between the case and nozzle insulation. A circumferential flow baffle is installed in this slot to prevent erosion of the insulation, and a stress-relieving radius former is included at the base of this slot to prevent cracking. To provide an additional margin for reliability, polysulfide adhesive material is used to bond the carbon phenolic nozzle insulation material to the asbestos/silica-filled, nitrile butadiene rubber insulation in the rocket motor case.

A wiper “o”-ring in the glass phenolic layer of the nozzle insulation and wiper vent slot in the rubber case insulation were incorporated to prevent entrapment of air in the case-to-nozzle joint during assembly, and to prevent the polysulfide adhesive from contaminating the primary “o”-ring. The wiper “o”-ring also provided the second of two barriers (the first is the polysulfide material in the insulation joint) to inhibit gas flow to the primary seal. Stress analysis studies and strength testing proved that radial bolts, as well as longitudinal bolts, were required to ensure an impenetrable seal between the nozzle and case metal parts under all environmental and motor performance conditions. Radial bolts ensure that sufficient compression of the primary “o”-ring is maintained to provide effective sealing. Increasing the diameter of the “o”-ring and redimensioning the “o”-ring groove to provide optimum “o”-ring squeeze while preventing “o”-ring entrapment were required reliability enhancement measures in the RSRM case-to-nozzle joint.

4. Factory Case-to-Case Joints

Custom shims, widened “o”-ring grooves, slightly larger “o”-rings, increased pin length, and revised pin retainer bands were improvements made in the factory case-to-case joints. Because of the continuous insulation and propellant strata over the factory joints, special joint provisions were not required in the insulation. Clevis legs were chamfered and undercut at the leg tips for consistent final configurations after assembly.

Technical Rationale:

Based on detailed analyses of key design and manufacturing/assembly drivers, the SRM case-to-case field joints have exhibited satisfactory performance in close to 100 solid rocket motors since the Challenger accident without evidence of hot propellant gas leakage through the insulation to the joint sealing system. The critical parameters associated with the case-to-case field joint, case-to-case factory joint, case-to-nozzle joint, and ignition system mounting joints continue to be closely monitored on a flight-to-flight basis to prevent the occurrence of undesirable hot gas transmission through any of the multiple seals provided.

Impact of Nonpractice:

These design solutions, while suitable for pinned joint configurations in large segmented SRM Systems, are not universally suitable for all SRM systems. Failure to adhere to the design principles described in this practice could result in leakage of hot combustion gasses past one or more sealing

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surfaces or seals during start-up or operation of solid propellant rocket motors. The result could be an anomalous trajectory, premature mission termination, or loss of life.

Related Guidelines:

None

References:

1. 360L001 Acceptance Review: Morton Thiokol, Inc. Aerospace Group, Brigham City, Utah, March 14-15, 1988.

2. Design Data Book (DDB) for Space Shuttle Redesigned Solid Rocket Motor (RSRM), Thiokol Corporation, Space Operations, November 1990.

3. "Space Shuttle Solid Rocket Motor Program, Lessons Learned," AIAA Paper #91-2291-CP, A. A. McCool, George C. Marshall Space Flight Center, Alabama, 1991.