The Tools of Present-Day Rocket Design

THE 1986 Challenger accident provided the solid-rocket industry an opportunity to demonstrate the extent of the tools available to solve motor design problems and the skill of the personnel employing them. The unquestioned leader of the redesign effort, Al McDonald, was kind enough to provide a documentation of this effort in the first paper in the special section that follows. His paper gives an excellent description of the booster characteristics and of the field joint that was the focus of the accident. The verification of the redesigned field joint is discussed in the paper by Perry et al. In this second paper, details are provided as to the many state-of-the-art analytical and experimental techniques that were brought to bear in the analysis of the field joint and of the verification of the results of the analyses. Together, these papers demonstrate one application of the potential that exists for solution of design problems within the solid-rocket industry today.

Other potential design improvements were considered in the many efforts that culminated in the use of the redesigned solid rocket motor to launch Discovery in 1988. To ensure that the case-to-nozzle joint did not encounter similar unexpected loads, an effort similar to that discussed in the Perry paper was conducted. The third paper in this group, by Cook et al., gives an in-depth description of this latter joint, its design features, its assembly, and the many innovative techniques employed to evaluate the ability of this joint to withstand the loads associated with Shuttle launch. Of special interest in this third paper is the comprehensive verification of the ability of the redesigned joint to withstand all the potential flaws identified; this verification matrix represents a demonstration of the thoroughness of all those involved in the redesign effort. A comparable effort is described in the fourth paper in this section, written by Moore et al. This paper describes, in detail, the testing on the O-ring seal following the redesign effort.

Reference is made in the paper to the application of cold-flow testing to the redesign effort. A paper by Waesche et al. concerning one of the efforts specific to the RSRM program appeared in *JPP* in 1990. This paper discussed how one cold-flow technique, the application of water-tunnel testing, could yield insight concerning the nature of the flowfield in a rocket motor; other studies employing ambient air and water tables are discussed in the Cook paper. The November-December 1990 issue of *JPP* contained a landmark paper by Dunlap et al. on the use of ambient air to provide detailed design data. The fifth and sixth papers in this group present studies aimed at a first effort to demonstrate that the application of water and air as the test media will provide comparable insight on the effect of design variables. These latter studies, together with the Dunlap paper and earlier papers in the journals of the AIAA by the same group at the Chemical Systems Division of United Technologies and by workers at the Marshall Space Flight Center, demonstrate the potential for growth within the solid-propellant industry.

In addition to the efforts reported above, continued studies in computational techniques and their applications to the complex two-phase flowfields in solid-propellant rocket motors have led to further growth in the analytical area. Two papers in this special section present two different approaches to the understanding of these flowfields. The paper by Madabhushi et al. represents an elegant use of present-day computational techniques and the capabilities of high-speed machines to obtain rigorous solutions. An equally suitable approach is represented in the work of Carrier et al., who go to the basic physics of the problem in an attempt to determine what simplifications may logically be made that will provide design information and an understanding of flow phenomena, while not requiring sophisticated information-processing capability. In addition to the work reported in these two papers, there are studies, currently in progress or planned for the next two years in the U.S. and in France, which demonstrate the extent to which analytical and experimental techniques can assist in the design of the highly reliable solid rocket motors that will play an important role in propulsion systems of the future.

Such techniques are also being employed in the liquid-propellant community. Cold-flow techniques have been employed to detect phenomena that can lead to premature failure of feed system components. Similarly, analytical techniques are being developed that can predict the potential for such premature failure; such techniques were discussed by McConnaughey in the article on liquid propulsion in the July 1990 issue of *Aerospace America,* and several papers on these techniques will appear in *JPP* in the near term.

In summary, then, this group of eight papers is an indication of the strength of the rocket propulsion industry in 1991. Other segments of the propulsion industry are demonstrating equal abilities; the contents of the pages of the *Journal of Propulsion and Power* bear testament to the extent of these abilities. It is hoped that groups of papers such as the one in this issue will inspire other authors to share tools for progress with the audience provided by *JPP.*

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