STEEL FORGINGS

Second Volume

Edward G. Nisbett and
Albert S. Melilli, editors

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Foreword

This publication, *Steel Forgings: Second Volume,* contains papers presented at the Second Symposium on Steel Forgings in Hyatt Regency New Orleans, New Orleans, Louisiana, on November 20-21, 1996. The symposium was sponsored by ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys. The symposium was chaired by E. G. Nisbett, National Forge Company; A. S. Melilli, Consultant, Winchester. They also served as editors of this publication.

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TEST METHODS

TURBINE AND GENERATOR FORGINGS

Overview

Steel is supplied in many product forms, most of which are produced in terms of basic dimensions such as width and thickness, or diameter and with length describing quantity. These products may be used by the foot for example as concrete reinforcing bar, or railroad rails or may be fabricated by bending, and welding into products such as storage tanks. Often they essentially lose their identity in the process. Forgings and castings by contrast are diverse in shape and form and are individually made for a specific purpose, either as self contained units such as crankshafts, valve bodies or turbine rotors, or as discrete components to be fabricated into a larger assembly, as for example a nozzle for a pressure vessel. The specification and testing of forgings is therefore more varied, complex, and demanding than is the case for other product forms. This is augmented by the fact that forgings are often expected to give better reliability and service performance than can be expected when the same part is fabricated from sections of other steel product forms, if this were in fact practical. Given these unique circumstances the exchange of ideas on forging manufacturing techniques and experience, materials data and service experience has been an essential driving force in developing forging techniques and applications in every industrial field. In turn these user driven needs and producer developments for manufacture have promoted the development of product specific standards that ASTM, by virtue of its organization capabilities and goals, is able to supply promptly and efficiently. This then was the underlying purpose for both this symposium, and its predecessor held in Williamsburg Virginia in November 1984.

The symposium was sponsored by ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys, and was organized by Subcommittee A01.06 on Steel Forgings and Billets. The symposium was international both in terms of the papers presented and the attendance. The format of the symposium was similar to that of Williamsburg, focusing on the scope of the subcommittee in the areas of pressure vessel and nuclear forgings, turbine and generator forgings, general industrial forgings, and test methods for forgings. Several of these authors who contributed to the first symposium also submitted papers for this the second symposium and so demonstrated an expansion of the developments in their organizations. This was gratifying because time and financial restraints on travel have had a tendency to reduce the exchange of experience and data between those making steel forgings and those who use them—to the detriment of both. Although the maximum benefit will be gained by those who both attended the symposium and obtain this record of the proceedings, it is hoped that this publication extending as it does the published work of the Williamsburg conference will serve as a valuable reference volume for future forging applications.

The keynote address, developed by Mike Gold at very short notice but with keen insight into the current way in which business is being done in the international market, shows that the traditional way of manufacturing equipment in the established industrialized countries and exporting it to the underdeveloped nations is changing to the point that the equipment tends to be built in the destination country itself under a cooperative arrangement. However there is still a niche where critical components, that may possibly include forgings, are made by the more experienced producers.

Although forgings for the domestic commercial nuclear applications are limited to the replacement of items such as steam generators for existing power generating stations, it will

be seen that the development of new manufacturing techniques, such as the forged stainless steel reactor piping units in France that will reduce in service inspection demands and improve component reliability, and the steam generator forging developments in Japan indicate that the nuclear technology continues to progress. Developments intended to improve the mechanical properties of the ASTM A 508 Grade 3 steel, used for many nuclear and other pressure vessel applications, have been described both from domestic and Korean producers, and these may result in revisions to that material grade in A 508, a potential example of specification development through technical exchange. Developments in pressure vessel materials for forgings to be used in high pressure hydrogen environments in the petrochemical industry, and for the manufacture of spent nuclear fuel transportation casks also show how progress is being made in other sections of the pressure vessel industry. The demand for very large and complex components for high temperature catalytic cracker vessels again for the petrochemical industry has spurred material development with consequent material specification revisions.

A potpourri of forging information was included in the General Industrial forging session. This included process model development for the optimization of forging disks, and finite element modeling for open die forging. Both of these papers were from domestic sources, and illustrate the drive to improve forging techniques. A third paper on the forging process this time from China discussed forging hammer force calculation. Sub harmonic treatment of forgings to relieve thermally induced residual stresses and the latest developments in the unique nitrogen alloyed stainless martensitic steels produced in Germany by the pressurized ESR melting process increased the diversity. Other papers in this session also looked at current forging ingot production for the sole remaining domestic producer of very large open die forgings. The manufacture of continuous grain flow crankshafts for medium speed diesel engines is described together with the required materials and properties. The demand for this product has continued to increase, in part because of the use of natural gas for fuel and the potential for high thermal efficiencies when waste heat recovery is included in the installation. Improved toughness grain refined high strength steels for forgings are described in the paper by Leap.

The information given is of a very practical nature and could prove to be useful in specifying heat treatments. The often used sequence of normalizing, quenching, and tempering possibly owes its success to the mechanisms described in that paper. One last area of interest here that could lead to specification revision also was the paper from England on the copper bearing age hardening steels for offshore tension leg platforms. An area of forging problems—all too rarely written about, but none-the-less real was discussed by two very experienced and long time members of the subcommittee. This and their other paper on hydrogen flaking problems—or the apparent lack of them—in forgings gave rise to some spirited discussion which although it does not appear in this account, gave food for thought for those present, and deserves close attention to readers of this volume. The germ of an idea for future papers on failure analysis in forgings came out of these discussions.

Always a source of information on the extremes of forging application the turbine and generator forgings session discussed developments in the martensitic stainless steels for turbine rotors and blades, as well as the combined high pressure—low pressure rotor shafts in a modified 9Cr1Mo high temperature steel. A study in the control of segregation in CrMoV steel ingots for the combined high pressure—low pressure rotors was also presented, both papers coming from Japan. The reader's attention is drawn to the excellent review of the superclean steel forging technology for rotor manufacture that has been spearheaded by EPRI. This steel making practice, made possible by great strides in steel making technology was in its early days at the time of the Williamsburg meeting. It is being

extended to the high temperature pressure vessel field as a way to reduce in service embrittlement.

The steel forgings subcommittee has developed several widely used standards for specialized test methods for forgings, and this subject was covered by two papers on the ultrasonic examination of rotor forgings, one of which is included in this volume. The advantages of being able to record ultrasonic examinations for base reference purposes will spur further activity in this area.

Although forging is an ancient production process long predating the industrial revolution, the development of steel forgings shows no sign of being exhausted, new forging machines continue to appear to make better use of the starting material and reduce cost, and new applications are put forward to meet the expanding needs of industry. Symposia such as this one will assist in obtaining the best from our resources.

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symposium co-chairman and STP editor

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