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FABRICATION OF COMPLEX MECHANICAL COMPONENTS

Yves BEROUD
S.I.C.N.
BP 1, 38113 Veurey-Voroize, FRANCE

Abstract

Precision mechanical components consist of parts which are difficult to fabricate due to their materials of construction and because of the state-of-the-art techniques required to fabricate and assemble them.

This paper presents various materials and fabrication techniques, including combined machining-welding techniques, uranium metallurgy, niobium-steel soldering and micromechanical techniques. It also illustrates each technique with specific examples.

The mechanical components described in the present paper are used primarily in the nuclear industry, as well as in equipment for scientific research.

I. INTRODUCTION

SICN has fabricated nuclear fuel for its parent company **COGEMA** for over 30 years. Through its fuel fabrication activities, **SICN** has developed specialized capabilities in machining, welding and non-destructive examination for the fabrication of precision components.

Following a detailed description of the activities and resources of the company, examples of unique fabrication technologies will be provided.

II. SICN ACTIVITIES

SICN has worked with a wide variety of materials and alloys in fabricating precision mechanical components : the entire gamut of stainless steels, aluminium, tungsten, titanium, tantalium, magnesium, zirconium, uranium and inconel as well as graphite and ceramics.

In addition to its expertise in each step of the mechanical component fabrication process- machining, welding, soldering, surface finishing and non-destructive inspection- **SICN** performs all fabrication activities in accordance with stringent quality assurance requirements.

III. FABRICATION TECHNIQUES

SICN uses a wide variety of fabrication techniques for numerous different applications, from the nuclear industry to space programs, from the defense sector to aeronautics.

A. *Machining*

The equipment used for precision mechanics is of prime importance and must be constantly updated to reflect the lastest developments.

B. Welding

The primary purpose of welding is to fuse two components together. **SICN** uses several welding techniques, including :

. TIG electric arc welding, with or without filler metal,
. electron beam welding, using both 10 and 15 KW machines, which makes straight, deep welds with high specific energy and,
. laser welding, using the YAG 400 W machine, which makes welds in normal atmospheres with high energy.

When extremely accurate welds are required, **SICN** redesigns existing welding equipment, by supplying an electron gun, building a vacuum chamber and designing the associated control system to achieve the greatest operating efficiency for the proposed application.

C. Annealing

Annealing is performed at 1500 ° C in large capacity (500 x 600 x 900 mm) highly exhausted vacuum furnaces.

D. Non destructive examination

SICN uses five methods of non-destructive examination :

. x-ray gammagraphy to detect deep defects (NASA agreement),
. dye or fluorescent penetrant test to detect surface defects (NASA agreement),
. ultrasounds to detect deep and surface defects,
. dye penetrant test to detect leaks,
. calibration control : automatic, three-dimensional calibration benches in air-conditioned rooms are used to check component dimensions.

E. Surface finishing

SICN uses the physical vapor deposition (PVD) process on a machine of its own fabrication to deposit a very thin layer (less than 10 microns) of metal, alloy or composites on the surface of a component to increase its resistance to wear, among other purposes.

The plasma jet process is also used to spray metals, refractory metallic oxides, carbides, nitrates and borates onto the component's surface to increase its resistance to friction, to create a thermal barrier.

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IV. SPECIFIC PRODUCTS

A. Structural components for fuel elements

SICN, the sole fabricator of gas-cooled reactor (GCR) fuel in Continental Europe, has supplied approximately two million magnesium clad fuel cartridges. A special dry finishing process and a TIG-electron beam welding machine were developed to machine and assemble the magnesium fuel cartridges.

With the start-up of first fast breeder reactors, **SICN** was called upon to participate in the fabrication of fuel for this reactor series. **SICN** has supplied precision structural components in stainless steel for Phenix reactor fuel, including the upper and lower nozzles , the upper neutron shielding, and the hexagonal fuel cans.

Fuel mock-ups were made and prior to fabrication, special benches were set up for automatic ultrasonic inspection, TIG welding of fertile fuel pins, and electron beam welding of the lower nozzles of the fuel assembly.

SICN also fabricates standard components for pressurized water reactor (PWR)- fuel elements, including the stainless steel end fittings and the inconel springs. The electron beam welding system and the three-dimensional calibration system were automated to fabricate the end-fittings, which require an average of 1,500 measurements per piece.

B. Liners

The liner is a critical component of complex propulsion systems used for rockets and satellites.

The liner envelopes the pressurized tanks and is an integral part of their structure. With a lifetime of approximately 100 seconds to 10 years, depending on whether it is part of a booster rocket or a satellite, the liner must have a high degree of reliability under all conceivable circumstances.

The production blank is delivered to our facility by the client. The blank, first, undergoes visual examination, then measurements checking. The half spheres of the blank are mechanically prepared on a conventional lathe.

A digitally-controlled lathe with integrated production control is used to machine the outer surface of the half spheres to 1 millimeter. The inside of the blank then undergoes the same operation.

The half spheres are annealed under vacuum using a centering piece for rounding. The final machining of the half spheres is then performed with a digitally-controlled lathe.

The ends and the frame of the liner are machined with a conventional lathe. In the final machining operation, the ends are pierced with a digitally-controlled boring machine.

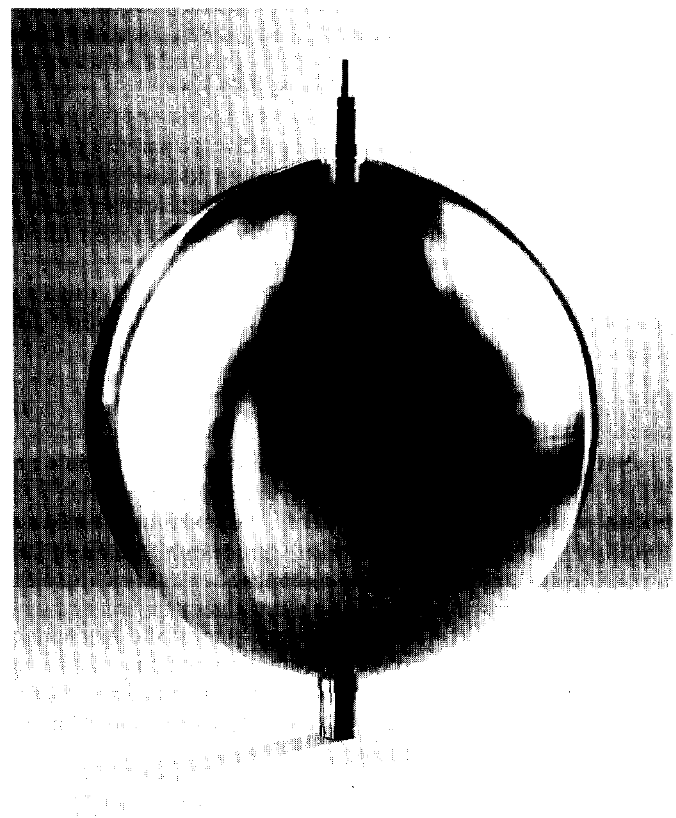
The liner is approximately 620 millimeters in diameter and 1.2 millimeters thick at the equator, which must be verified by geometric measurement control.

A dye and fluorescent penetrant test, for which **SICN** obtained NASA certification, is performed on the half spheres. The test is a highly accurate means of detecting metal cracking.

The half spheres are cleaned and their joint edges are chemically scoured before being welded.

A rigorous quality assurance system applies to all fabrication operations. Before equatorial welding can be performed on the half spheres, welds must be performed on test pieces and analyzed for integrity. After the half spheres are welded, weld quality is inspected by x-rays.

Final non-destructive examination of the finished product includes dye and fluorescent-penetrant testing of the weld, weld x-rays as required by contract, and a helium leak test. **SICN** 's x-ray examination procedures have also been certified by NASA.



LINER

C. Components for experimental equipment and scientific research

The Large Electron Positron Collider (LEP) is the large machine of the CERN and will likely remain the largest collider in the world for some time to come.

One of the technologies used in the LEP is radio-frequency. The LEP collider is circular and the loss of energy by synchrotron radiation is compensated by super-conducting radio-frequency accelerating cavities. The energy needed to accelerate the electrons and positrons and to replace the energy lost by synchrotron radiation is transmitted to the circulating beam from these cavities.

C.1 RF Couplers

RF couplers are also called "main couplers". The radio-frequency coupler is the interface between the RF emitter and the super-conducting cavity. The main coupler is made of a niobium-copper double casing stainless steel pipe connected at one end to the vacuum tank and at the other end to the cavity antenna connected to a ceramic window. The length of the antennna introduced inside the cavity is adjustable.

SICN makes the couplers out of stainless steel, copper and niobium, precision machines and welds them by TIG process for the stainless steel materials or by brazing under vacuum for the junction Cu/Cu or Cu/Stainless steel.

C.2 HOM Couplers

The high order mode couplers extract the radio-frequency current lost by the beam inside the non-accelerating areas of the cavities. The HOM coupler is made out of niobium and stainless steel. As extremely difficult area, from a fabrication point of view, is the vacuum brazing of the niobium-stainless steel junction.

C.3. Tuners

SICN also fabricates components associated with super-conducting cavities, called TUNERS.

This component enables the tuning of the cavity ot its fundamental resonant frequency. Each anchorage part consists of an assembly of concentric tubes welded together and mounted on a core to allow positioning of the cavity. Between the tubes a path is created for helium flow. The two other main devices belong to the Ni tube :

one heater cable brazed at the outer periphery of the middle of the tube,

two magnetic coils winded on and insulating material.

Both devices enable the tuning of the fondamental frequency through modification of the length of the Ni tube (wave length variation through thermal and magneto-striction effects).

SICN is currently producing 150 RF couplers, 300 HOM couplers and 300 tuners for the LEP project.

D. Instrumented test equipment

SICN has been involved for a number of years in the design and fabrication of instrumented equipment used in research reactor cores to study, for example, the behaviour of new fuel when exposed to radiation.

The systems are instrumented poles with numerous temperature, pressure and vibration sensors. Special measures must be taken during their fabrication particularly with respect to the density of the connections, precision machining using micro-mechanical techniques, and precise welding and soldering.

V. CONCLUSION

The fabrication of precision mechanical components requires special skills in the metallurgical, metallographic, machining, welding, surface finishing and non-destructive examination fiels. The equipment necessary to achieve the required level of precision, of technical excellence and of production throughput is one of the keys to success and it must be constantly updated to take advantage of progress in the field of precision mechanics.

The more complex the component, the more indispensable the skills of machining, assembly and quality control. **SICN** has created a team where all these skills are present under the same roof.

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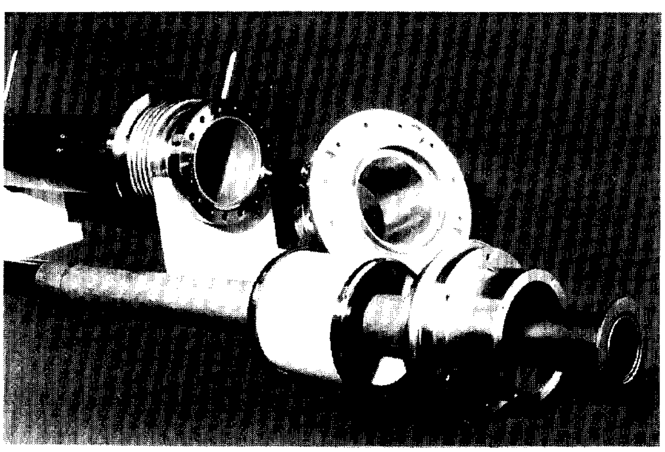
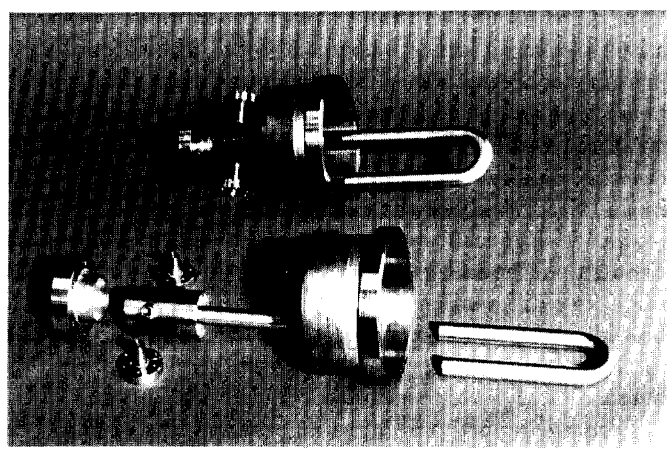


RF COUPLERS



HOM COUPLERS