



[MACHINING CENTERS]

by Andrea Pagani

Spark 2100X

**MANDELLI SISTEMI
SPARK 2100X USES ITS
MODULAR NATURE TO MEET
THE DEMANDS OF PRECISION
AND PRODUCTIVITY OF
AEROSPACE APPLICATIONS.**

The Spark project was developed by Mandelli Sistemi to meet the present and future needs of multipurpose HMC end-users. The HMC line includes different models, each with its own features framed on the basis of the specific sector of use : Spark 2100, for example, was born to ensure maximum flexibility during the design phase thanks to the HMC particular architecture leaving a large margin for multitasking applications. It features a rotary table provided with the rotation movement only so as to remain fixed on the base and make the layout of the HMC front part look " neat and tidy " and suitable for substantial accessories and modifications.

A MORE PRECISE SOLUTION

Spark 2100 is the solution by Mandelli Sistemi characterized by the gantry structure for heavy-duty machining operations. It guarantees excellent performance in terms of dynamics and stock removal both with traditional materials such as cast iron, steel and light alloys as well as with 5-axis machining on tenacious materials typical of aerospace applications such as titanium, nickel and cobalt alloys. In this case, Spark 2100X has been designed for the machining of an aero engine shaft where some critical dimensions are extremely precise. These shafts require typical horizontal lathe machining with additional drilling and milling operations. The accuracy required goes beyond the capabilities of a normal horizontal lathe since the holes on traditional architecture machines should be interpolated by rotating the shaft itself at the expense



Above: Mandelli's Spark 2100X in a 3-pallet configuration

Left: Spark 2100 has been designed to ensure maximum flexibility during the project configuration thanks to its special architecture

of the tolerance of the real positioning of the required holes. Mandelli Sistemi has thus created a solution for the finishing operations by interpolating the linear axes, a technology ensuring the correct positioning of bored holes with a few micron deviation from their nominal position.

FIXED TABLE, MORE POSSIBILITIES

The presence of the fixed rotary table in the machine base has allowed designers to rely on a truly modular approach that, over the years, has led to many special solutions from the more traditional ones with tilting table to the single-supported dividing head useful for processing energy sector components such as impellers, blisk etc. The most recent solution described in the article features the integration of a pallet change system into the machine to bring inside the work area special tables equipped with a double hollow dividing head with a tailstock. The use of this particular fixture has been necessary because of the nature of the component to be machined, essentially tubular in shape and with a very precise flange at the end. Spark 2100X performs machining operations on both ends: on one side the coupling flange and, on the other hand, a straight-toothed gear made with a "hobbing" technology. The use of a dividing head on a fixed machine has already been seen in the machine tool world but it is generally applied to large gantry machines where part of the work area is fixed and dedicated to the dividing head. The novelty lies in the use of an HMC equipped with pallet changer which allows for a series of



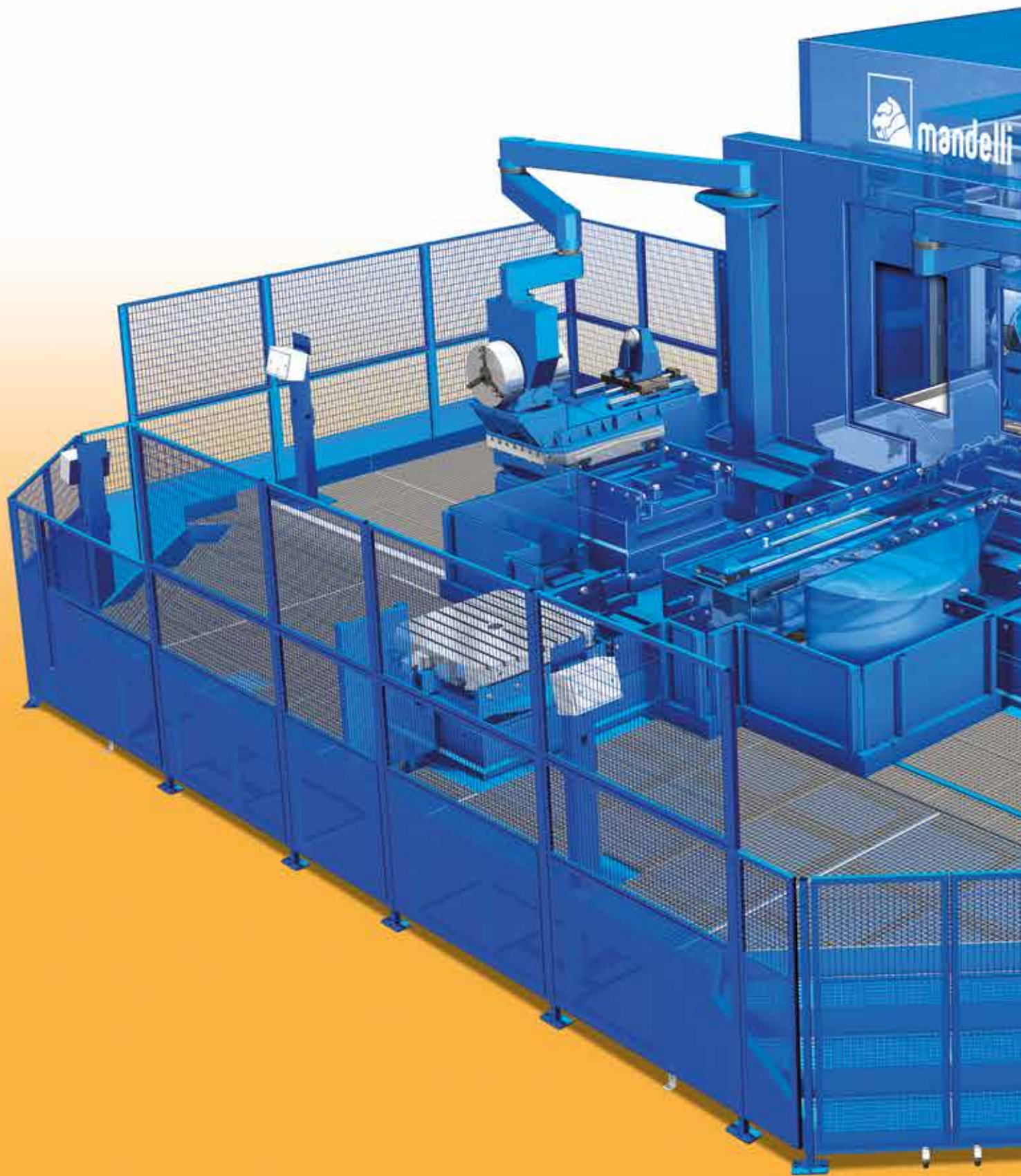
complex and articulated machining without any interruptions thanks to the presence of two tables dedicated to host a dividing head with a tailstock.

STRUCTURE

Spark 2100 was ideally designed as the "elder sister" of Spark 1600 from which it evolved: it follows the constructive philosophy with an electro-welded steel structure and linear slide-ways. This HMC combines both high dynamic characteristics (fast speeds up to 50 m / min) and robustness (the 60-ton overall weight is useful for effective vibration damping especially on tensile materials). The Z axis is divided into two parts thus leaving a large margin to customize the HMC rotary table area. An example for this is one of our latest applications for the machining of butterfly valves outer diameters: in general, for such operations the workpiece is clamped from inside but this type of valve is not hollow. We have therefore built on the rotary table an outer column on which a tailstock

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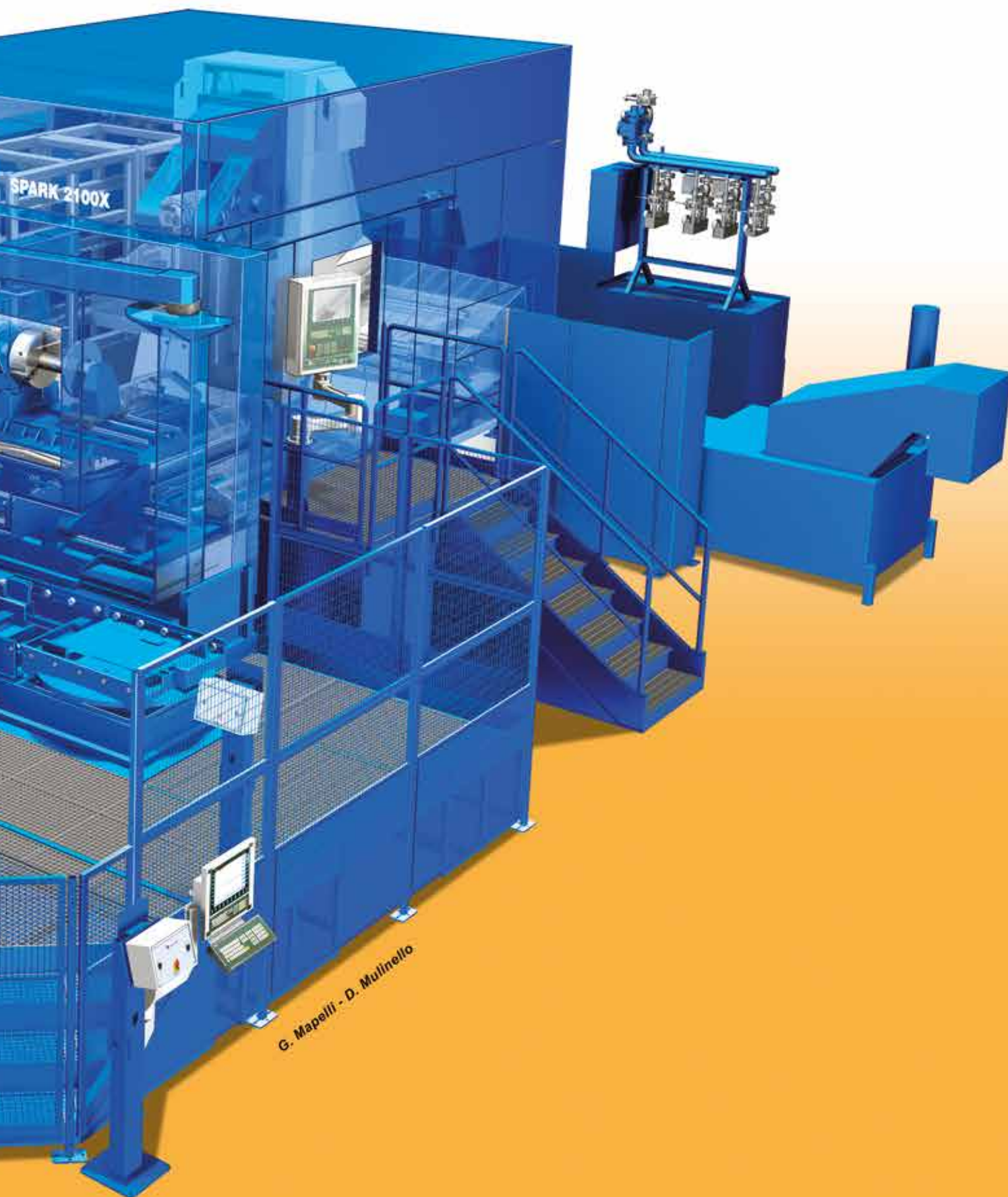
MACCHINA DEL MESE





Vista da Domenico Mulinello e Giovanni Mapelli

Mandelli Sistemi - Spark 2100X



IDENTITY CARD

NAME	Spark 2100X
TYPE	Machining Center
MANUFACTURER	Mandelli Sistemi Spa Via Caorsana, 35 29122 Piacenza Ph. +39 0523 548548 E-mail: mandelli.info@mandelli.com Web: www.mandelli.com

TECHNICAL DATA

X axis	2.100 mm
Y axis	1.700 mm
Z axis	1.800 mm
X, Y, Z rapid speed	50 m/min
A axis (range)	190°
Spindle power	70 kW
Spindle torque	500 Nm
Spindle rotation range	0÷14.000 rpm
Work-piece max overall dimensions	2.500 mm
Work-piece max weight	8.000 kg
NC	Siemens 840D SL
Tool magazine	300 pockets
Max admitted tool weight	35 kg

Mandelli Sistemi - Spark 2100X

has been installed to keep the workpiece in place leaving the areas for chip removal free. In other words, it is a mixture between a horizontal lathe (the tailstock) and a vertical one (vertical axis table) in a single machine. Without a fixed table structure this would not have been possible because otherwise the gantry would have had to be mounted on a linear axis to track the movement of the table itself.

MECHANICAL AND ELECTRONIC PRECISION

The stiffness and stability are important factors with machines such as Spark because they machine extremely tenacious materials such as titanium, Inconel and alloyed steels which strain the axes and cause vibrations. The appropriately dimensioned thermo-symmetric structure contributes to achieving the required accuracy while the mass dampens most of the vibrations. However, it is with the use of measuring probes that the best results can be achieved: the pieces have a slim and long shape so even a microscopic misalignment with the ideal plane can result in inaccurate machining. The machine has then been equipped with two probes (a traditional one and a star for measurements carried out while machining) to reset each single work-piece and micro-adjust the part program on the basis of the effective



Left: the layout of the front part is neat and fit for important accessories and modifications

Right: the onboard NC handling the 3 pallet tables



Left: the 300-pocket TM can house tools up to 35 kg including angular transmission heads

Right: the pallet changer can take inside the working area special tables equipped with a double dividing head equipped with a tailstock

positioning of the shaft. Once some critical measures are taken, the part program "repositions" the reference quotes and sets the axes accordingly. This is a fundamental condition for making the serration at one end of the shaft: a perfect synchrony between the rotating axes is needed, obtainable only because the spindle is an electro-spindle while the dividing head is equipped with a direct encoder on the axis, without any returns which may cause backlash or affect the tolerances. The result is a maximum synchronization error of less than $1/1000^\circ$ leading to the creation of class 5 gears using a hard metal maker.

A SPECIAL PALLET

One of the critical issues in using such a fixture on the pallet changer is the transfer of utilities (pneumatic, hydraulic and electric); this is possible through a long arm which serves only for the pallet handling and positioning. Once in place, the pallet is anchored to the table and from now on the arm acts as a simple "umbilical cord" allowing the machine to maintain high dynamics as all the axes movements are on the side of the tools. The dividing head and the two self-centered cams however move the pallet center of gravity which is decentralized with respect to the table axis itself. To ensure maximum reliability even during the rotation, the table has been reinforced with an additional double bearing system that

SPARK 2100 HAS BEEN DESIGNED TO ENSURE MAXIMUM FLEXIBILITY DURING THE PROJECT CONFIGURATION

maximizes precision even in the presence of an eccentric load. In addition to two pallets of this type, this HMC is also equipped with a table for traditional fixtures: although it is a plant dedicated to a specific machining, it is also extremely flexible as it can carry out other 5-axis operations.

A GREENHMC

The destination of this specific Spark is a Norwegian company manufacturing aerospace components. Norway is a nation that cares much about energy saving: for this reason this machine - as well as most of the others already present - has been equipped with a kind of technology called Ice Water that uses the water of a river suitably conveyed into special heat exchangers for the cooling of various components and to keep the process fluid temperature under control. In this regard, high pressures (up to 100 bar) and a 2,000 liter tank are used: a large amount of lubricant is treated every minute and the Ice Water technology significantly contributes to the reduction of energy costs.

PRECIOUS DETAILS

Titanium processing requires the use of ceramic tools which in turn require very high cutting speeds (up to 1,000-1,200 m / min in milling). For this reason the spindle is suitably dimensioned with 70 kW of power, 500 Nm of torque and up to 14,000 rpm. However, ceramic tools have a lifespan that can be measured in minutes: this is why residual life management is important (the numeric control takes care of it by recalling the tools according to their remaining minutes to end a particular operation) as well as having a particularly large tool magazine. Mandelli Sistemi has designed a range of tool magazines from 100 to 500 pockets: in this specific application, the customer has chosen a 300-pocket tool magazine and up to 35 kg for each tool, including angular transmission heads and hobs. The tool management logic optimizes the positioning in the tool magazine of the most frequently used tools, especially when the operations take only a few seconds. There is also the possibility of using an intermediate buffer in which the machine pre-positions up to two

successive tools according to the machining cycle timing. With regard to the numerical control, this machine is equipped with Siemens Sinumerik 840D SL with Operate interface which allows for the simultaneous management of the various multitasking technologies (turning, milling, toothed, etc.). Our collaboration with Siemens has also allowed them to simplify the programming which would have been rather complex instead. For example, when a pallet with a dividing head is called back into the machine, it is possible to work with the same part program regardless of whether it is the right or the left one because the machine axes are renamed and redirected according to the pallet chosen without the operator being forced to set the appropriate program. Preparing the sub-program package to facilitate the operator has represented an equally complex challenge: even in this

case, Siemens support has been crucial to achieve an ideal solution.

PROCESS RELIABILITY

Spark 2100X is designed to work in unmanned mode on three shifts: hard conditions since a typical FMS process reliability is required to a special application which involves a number of additional critical issues.

This is why it is also equipped with three chip conveyors: not so much because of the volume of chip generated as the use is mainly intended for finishing, but for a quick and efficient removal of the material to reduce the heat transfer to the machine structure. Special sprays also wash the slides every time the spindle is started so that the HMC surfaces are kept clean from any residual chips.

LARGE DIMENSIONS

In this version, the work-piece max overall dimension can be 2.100x1.700x1.800 (X/Y/Z) and the maximum capacity on the table up to 2.500 mm in diameter and 8.000 kg in weight. The HMC head is tilting with a total range of 190 ° configurable according to the customer's requirements: those customers who need to work undercut, for example, will appreciate the range from -130° to +60° while others may regard more useful the traditional -90° ± +100°. The head is equipped with a kinematic system with zero backlash: the double preloaded pinion allows for a high torque during machining and to reset the backlash during the inversion of motion. This results in perfectly smooth surfaces in 5-axis continuous machining.

AN INTELLIGENT PLANT

This machine fits within the *iPum@Suite 4.0* project as it has a high degree of sensorization (temperatures, accelerometers, etc.) in the structure and spindle.

The latter is also equipped with a diagnostic cycle that, when launched, gives a feedback on the bearings status. A special calibrated and balanced tool is used when the spindle is new to record a kind of "electrocardiogram" of the bearings. This information will be used as a reference for evaluating subsequent conditions and detecting any significant variations (vibrations) associated with the wear of the internal component of the spindle itself. The results obtained will be analyzed to determine if it is possible to continue with the machining if the bearings wear is at the limit, if a collision has compromised the spindle and thus allow the customer to arrange a technical intervention without any unpredicted stoppages in the production of critical components. ■



The holes on the shaft are interpolated between the spindle axis and the dividing head axis, both equipped with linear motor



Rigidity and stability are important factors on HMCs like Spark as it machines extremely tough materials