

NB 151

The machining solution for Blisks
Model version 2023/2024



The best solution

Starrag has established an excellent reputation around the world as a technology partner to leading turbine manufacturers. Whether for aero engine manufacturers and their suppliers or for manufacturers of gas and steam turbines for power generation, Starrag is the name the world uses.

This technology partnership includes everything from customer specific engineering to application development including CAM programming, tool and fixture design and automation.

Starrag offers comprehensive process know-how and for many years has successfully delivered complete turnkey projects. Our customers benefit from leading manufacturing technology, flexible production support, individual user training and a global service.





Blisks

No matter if it is called a «Blisk» (bladed disk) or an «IBR» (integrally bladed rotor), no matter if it is single stage or multi stage, Starrag's dedicated machine concept of the NB 151 provides the best solution for efficiently machining of these parts.

Blisks made from Titanium, Nickel-based superalloys and the Blisks made of blade steels for stationary gas turbines triggered the development of the NB 151. The challenges posed by the thin, unstable airfoils are easily met by the new productive manufacturing approaches that Starrag provides.

For all the necessary manufacturing operations Starrag provides the benchmark: Efficient roughing for Blisks machined from solid, adaptive machining for friction welded Blisks, high dynamic finishing of the airfoils in point contact. Shortest cycle times and zero scrap rate production are what the Starrag NB 151 stands for.

The NB 151 is based on the very successful Starrag LX series.

Starrag – Technological competence

Planning reliability, productivity and efficiency are the decisive factors in the industrial production of Blisks. Starrag strives continuously to increase the real life performance.

Productivity

Machine design and axis concept are critical for process stability during roughing and for high dynamics when finishing. Consequently shorter process times with reduced tool wear are possible.

In comparison to universal machine concepts used for Blisk milling today—like trunnion machines—the dedicated concept of Starrag's NB 151 provides a number of advantages:

- No restricting element in the machine design (like quills) allows for much higher process stability and material removal rates
- Minimum rotating masses to increase machine dynamics
- Tilting movement of the NB 151 is (almost) around the tool center point. With that, the compensation movements required of the linear axes are much smaller in comparison to tilting the blisk (as on a trunnion)

In addition to the classical machine building methods, Starrag also provides productive solutions specific to the demands of machining of thin-walled airfoils where the low stiffness of the workpiece means the cutting conditions are not stable.

Machine and control systems are seen as a unit. Control behavior and NC path planning are developed and optimized in great detail to achieve the perfect combination of geometry precision, surface quality and of course productivity. Depending on the required application, the machine can be optimally set using five settings: roughing, pre-finishing, fast finishing, finishing and super finishing. Starrag machines are built for milling. Non-productive times are systematically analyzed and eliminated, providing increased productivity without generating additional costs.

All in all, best in class productivity is reached both in roughing and finishing.

Integrated turning functionality

For all machines of the NB 151, a full turning capability can be included (with freeform turning, specific measurement cycles etc.), making complete and accurate machining of Blisks in one setup possible.

Surface quality

Producing unblemished milled airfoil surfaces is Starrag's explicit aim – milling workpieces in such a way that they can be assembled directly or after a minor additional process such as barrel finishing.

Any influence, which manifests itself as a defect in the workpiece's quality is systematically analyzed by Starrag, and the system is subsequently optimized. Whether it is the elimination of chatter or reversal marks, or perfecting the quality of the milling path generation, Starrag sets new standards with the NB 151.



Precision / process capability

In modern production, quality is an absolute must. For Starrag this means that reliable manufacturing must be possible in less than ideal conditions such as fluctuating temperatures or lack of warm-up phases. Additionally energy cost for temperature stabilization of shop and machine can be reduced.

To achieve standard deviations of just a few microns on consecutive parts, a number of approaches are followed:

- The prerequisite is to have a basic mechanical design of the NB machines based on engineering principles. This includes symmetry, suitable cooling, efficient chip removal etc.

- Homogeneous temperature level in the machine is the basis for thermal stability. The temperature of the cooling agents is controlled to match the ambient temperature
- Expansion of the spindle through thermal drift or centrifugal forces is constantly measured and compensated for by direct measurement.
- The effects of machine displacements due to thermal drift can be corrected directly on the workpiece before the green button process starts.

With all of these measures a new level of process capability is achieved. Expensive scrap can be avoided. Subject to the application, external measuring operations are eliminated and air conditioning requirements reduced.

Adaptive machining

Productivity and accuracy are no longer just a question of machine and tool. Adaptive machining of the individual workpiece is a quantum leap for many applications.

The actual shape of the workpiece is captured on the machine using Starrag's own 5-axis measuring cycles. The NC program can then be specifically adapted or created anew – reliably, and fully automated. This technology provides advantages for a multitude of applications:

- Non-machining time («air cut») on forged blanks is eliminated
- Adaptive machining of blade edges and snubbers on precision-forged blades that blend seamlessly to the finished airfoil
- Detection and compensation of blade distortion
- Detection and compensation of thermal drift of the machine

Adaptive machining is completely integrated and the process is fully automated. The potential of adaptive machining is perhaps best illustrated by Starrag's subsidiary TTL in their adaptive repair of turbine components.



Optimal process cooling

One key factor to lowering your tooling costs and increasing your productivity is selecting the right cooling method.

All state – of – the – art through – spindle cooling medias are available throughout the NB range.

- High pressure coolant (water-based or oil)
- Through spindle air
- Aerosol (minimum quantity lubrication)
- CO₂ cryogenic cooling through the spindle
- Aerosol plus CO₂ through spindle

Of course external cooling with coolant or CO₂ is possible too. With these options, breakthroughs in tool life are achievable, giving your largest saving on consumable items.

Innovative clamping concepts

The special workpiece geometries create specific demands on the clamping fixtures. Starrag has in-house specialists who develop individual clamping concepts to meet the specific requirement of Blisk machining. As a customer, you benefit from:

- Use of a standard adapter system makes manual machine loading very easy. The workpiece is mechanically clamped onto the adapter outside of the machine, the adapter is then loaded into the machine by crane. The adapter can be clamped hydraulically via foot pedal.

- A single adapter design solution is used for all NB machine sizes.
- Workpiece specific fixtures on the adapter can be integrated for optimal clamping and highest repeatability.
- Besides mechanical clamping, hydraulic or vacuum solutions can be implemented on the adapter.
- Geometric deviations between multiple fixtures can be stored in the control system. Measuring of blank position can therefore often be eliminated.

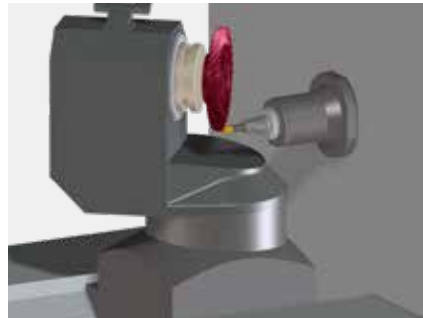
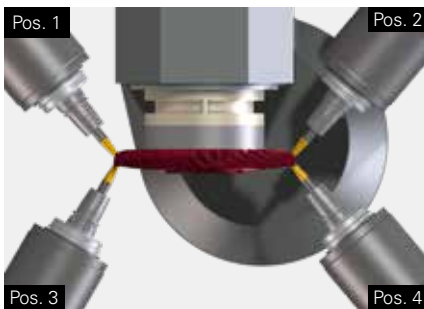
Designed for Blisks – Starrag made Rotary Axis

The keys for any efficient blisk machining strategies are the accessibility to the part and the dynamics of the A and B axis. The rotary axis of the NB 151 are designed and built based on the extensive know-how of its application engineers. Thus the machines do not just offer rotary axis, but rotary axis that have been specifically designed for blisk machining.

Dynamic and Powerful

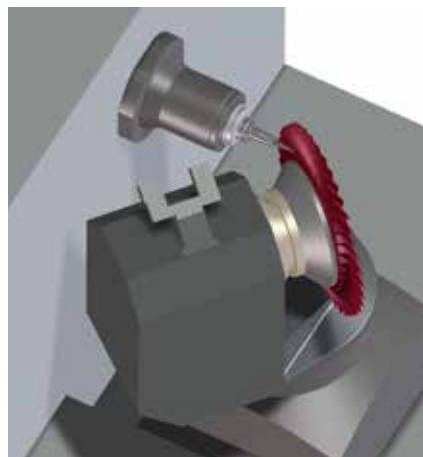
Machining blisks has extreme demands on any rotary axis, especially high accelerations are especially required if the cutter should keep the feed rate over the increasingly thin edges of modern blisks. The rotary axes of the NB 151 offer an unrivalled torque in its class. A new level of dynamics in blisk finishing can be reached, thanks to their torque and low inertia.

Blazing quick finishing operations are not the only advantage of Starrag's custom design, but also heavy roughing cuts can be achieved. These roughing cuts are extremely important when efficiently opening the channels between blades in Inconel and Titanium blisks. Special attention thus has been given to combine the powerful motors with highly rigid and stable bearings.



Accessibility

The NB 151 offers a superior accessibility for all kinds of multi-blade parts, be it blisks, impellers, diffusers or nozzle guide vanes. The B-axis has an extremely large stroke to allow machining from any side. This is especially important for blisks when side-entry machining is required and where access from the front and back is required. Usually two setups are required for side-entry machining on common blisks machines, but thanks to the NB 151 large B-axis stroke they can be done in only one setup.



The ultra-compact design of the A-axis and spindle makes the best possible use of the large B axis stroke.

This compact design ensures there won't be any collision between the A-axis and the spindle, when doing side entry machining from the back side of the blisks.

Starrag – Technology partner

To have the overall most efficient production running, every factor must be taken into account. Starrag strives to be a technological partner for the blisks manufacturers. In close collaboration, continuous improvement in productivity can be achieved.

Technology support

Precision and efficiency in the production of blisks are dependent on the process expertise of the application engineer.

To continuously improve productivity, Starrag constantly is very active in the field of process development. Newly developed milling cycles and tools allow the process time to be significantly reduced. To be able to use the new machines to their full potential, the process is analyzed in great detail and the optimization potential is evaluated. Strategies, tools, cutting conditions and fixtures are constantly evaluated and improved by Starrag.

Starrag strives to work closely together with blisks manufacturers so that they can benefit from these innovations. Within such a partnership, Starrag can contribute in different fields:

- **Process development and optimization:** Based on the individual customer needs, the machining technology can be developed according to the latest state of the art
- **Process analysis:** In depth analysis can be made for challenging applications to come to optimal solutions, e. g. FEM analysis and tool geometry optimization, NC path analysis for blade geometry optimization
- **Fixture design:** Optimized fixtures can be provided that allow for highest cutting stability and lowest distortion, no matter if they are for blanks or forgings
- **Post processors:** State-of-the-art post-processors making full use of all the capabilities and functionalities of the NB machines can be provided for the leading CAM systems
- **Machine upgrades:** Starrag wants customers to profit from the continuous progress made at Starrag for existing machines. Control and mechanical upgrades are on offer that allow existing NB machines to become more productive

With Starrag, continuous productivity improvement can be made even with existing machines. With such technological collaboration the competitiveness can be constantly increased. These customer-specific improvements are effective, target-oriented and cost transparent.



Virtual Machining

Virtual machining is a highly-developed simulation program for Starrag blade machining centers which enables users of CAM software to simulate, check and optimize complex blade manufacturing processes in full on a computer screen.

Cutting tools

Customers in the turbine and aviation sectors require milling tools of the highest quality. Modern machine tools and increasingly complex parts, made from materials that are difficult to machine, require cutting tools with specific contours, corners, radii and micro geometries. Starrag provides special tools which are adept to these very tasks.

These tools are tested intensively in our modern machine park (Aerospace and Turbines competence center) and undergo constant development. Starrag offers not only standard industry tools but also tools manufactured to customers' individual specifications.

ATCC Aerospace and Turbines Competence Center

In the Aerospace and Turbine competence center new and demanding machining processes are tested and optimized and small and one-off series are produced. For this purpose, the most modern 5-axis machining centers are available for producing the complex work-pieces that the industry demands, ranging from the heavy-duty milling of titanium alloys to high-speed machining of light metals with an IT 5 finish quality.

Automation / FMS

For over 30 years Starrag has been acting as a main contractor designing and supplying linked FMS systems for the fully-automated manufacturing of complex parts across multiple machines. Other operations and follow-up processes such as washing, measuring, labeling, deburring or grinding can of course be integrated into the FMS system. The complete manufacturing process is planned, steered, monitored and documented by user-friendly central computer software with integrated PPC (production planning and control).

Each automation solution is customer-specific designed and delivered as a turn-key solution. To ensure the required reliability for fully-automated and unmanned production in an FMS, at the design and development stage of the machine, considerations are already made on the best methods to integrate the FMS including the various clamping solutions necessary. The modular buildup also allows a gradual expansion of the system.



The NB 151 machine

Starrag has established an excellent reputation around the world as a technology partner to leading manufacturers in Blisk production.

NB machines are designed and built for optimum Blisk machining. All technical parameters, such as axis strokes, forces, torques and accelerations are set according to the application requirements. With its application-specific design, the NB 151 offers a number of unique advantages:

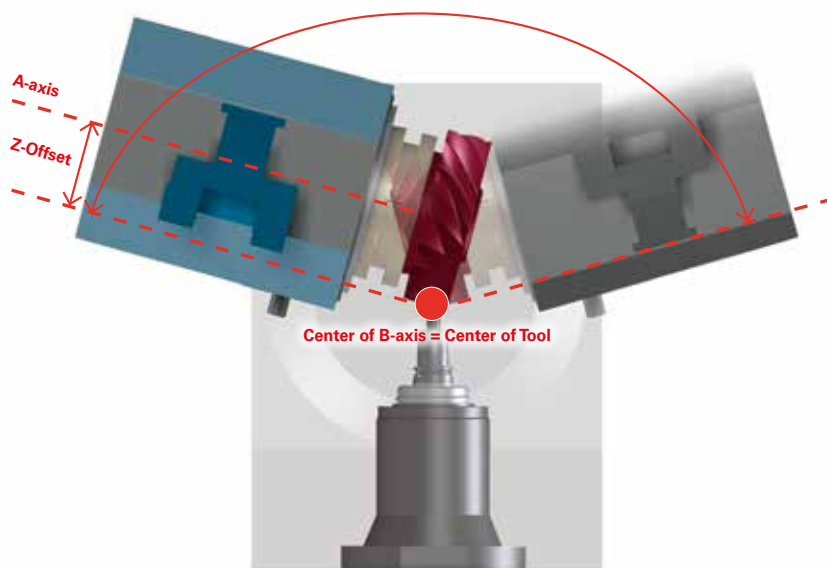
- Highest dynamics due to low masses of linear and rotary axes
- Shorter cycle times due to greatly reduced compensation movements (tilting around the tool center point)
- Efficient roughing with high material removal rates due to an axis concept without weak points (like e.g. quills)

- Ergonomic manual workpiece loading with a dedicated adapter solution (automated loading via FMS possible)
- Optimal chip flow into the chip conveyor

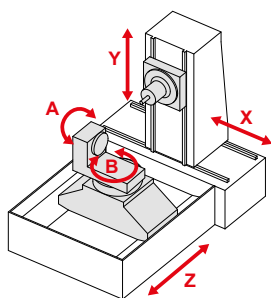
The NB 151 distinguishes itself through specific design features:

- All rotary and linear axes are backlash-free with high stiffness and damping to achieve the best finishing qualities.
- All vertical axes use counterbalances to provide the highest levels of dynamic contour accuracy.
- Intelligent Starrag motor spindles are specifically designed for Blisk manufacturing and are used throughout the entire series as well as on the LX series for turbine blade manufacturing.

- The design and build up of the NB machines is modular, allowing for utmost reliability whilst simultaneously enabling continuous system improvements.
- Critical components such as motor spindles and rotary axes are maintained by Starrag exchange pools, ensuring the shortest repair time in case of replacement since only an existing assembly must be replaced as a whole.



Axis configuration diagram



NB 151

Workpiece dimension

\varnothing = Swing Diameter
Length = Max. Workpiece length incl. Fixture

\varnothing 620
L = 450



NB 151

Machine intelligence

The installation of intelligent systems can significantly increase the productivity and the availability of machine tools.

The NB machines are pioneers in this respect:

- Process analysis and evaluation is greatly simplified by integrated sensors.
- Critical parts of the program are automatically identified enabling systematic process optimization.
- Damages caused by collisions are significantly reduced thanks to rapid detection and machine shutdown. This is an excellent addition to Starrag's simulation solutions.
- The imbalance of all tools and the state of the spindle bearings are automatically monitored.
- Any spindle displacements due to centrifugal forces or thermal drift are directly measured and compensated.

The right tools for getting parts right

Highest flexibility, benchmark quality – this is what Starrag cutting tools sets apart

Specific applications require specific tools. For any batch size, Starrag is an experienced and flexible partner to provide custom-made tools quickly and reliably.

With the specific applications in mind, carbide grades, specific contours, angles and radii are selected. For stable machining of instable workpieces, Starrag designs and provides part-specific tooling that significantly increases your productivity and lowers your cost per part.

Starrag works directly with the end-user to deliver the best tools for your parts, and you profit from the expert knowledge of our application engineers who deliver complete turnkey solutions for productivity breakthroughs.

In Starrag's unique «Aerospace and Turbine Competence Center», we machine turbine and aero structure parts under benchmark conditions.

Customer-specific tool solutions

Starrag designs and produces milling tools based on the requirements for your specific parts. Your components are machined using innovative solid carbide milling tools produced the highest quality for aluminum, steel, titanium, and nickel-based material applications.



Global reconditioning service with Oerlikon Balzers

Additionally to regrinding worn tools in its facility in Switzerland, Starrag has partnered up with the global leader for coatings – Oerlikon Balzers. Oerlikon Balzers uses the original grinding processes from Starrag, applying the same coating as on the original tool.

With this partnership, you save on inventory and receive OEM grinding standards globally in short lead times.

We can offer professional reconditioning services in:

- › **Switzerland** Rorschacherberg
- › **Austria** Stainz
- › **Romania** Maracineni (Pitești)
- › **Turkey** Bursa
- › **Argentina** Buenos Aires
- › **Mexico** Querétaro, Saltillo
- › **China** Chengdu, Suzhou
- › **India** Ahmedabad, Aurangabad, Bangalore, Chandigarh, Chennai, Jamshedpur, Manesar, Pune
- › **Korea** Pyeongtaek, Busan
- › **Philippines** Calamba City
- › **Thailand** Chonburi

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balzers

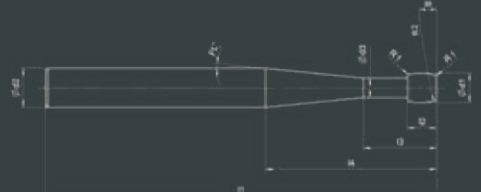
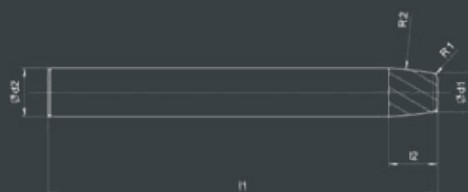
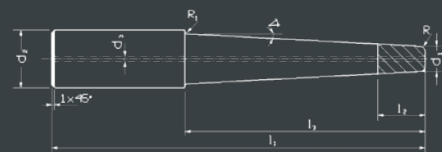
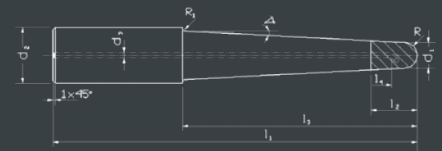
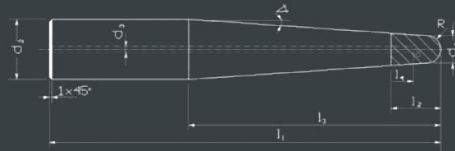


Find your local regrinding support center.



Tools for Blisks/IBRs

Chatter free airfoil machining.



Efficient and chatter free finishing of Blisks or IBRs is one of the most difficult tasks in machining. For such challenging components, Starrag has developed special cutting tools for point milling.

The product range starts with taper ball nose cutters that provide good access to the part.

Starrag also developed special geometries like the torus and barrel cutter

to reduce cutting pressure on the airfoil flank. To reduce workpiece regenerative excitation that leads to chatter, Starrag also delivers variable pitch cutters. With the help of in-house testing, such tools can be adjusted ideally to your specific part.

Note Standard: coated, also available raw. Other cutter dimensions and coatings are available on request. Available also as **Duo-Lock**

Taper ball nose cutters

| units | d ₁ | R | d ₂ | l ₁ | l ₂₋₃ | angle | z |
|-------|----------------|----------|----------------|----------------|------------------|-------|-----|
| mm | 4-20 | 2-10 | 6-32 | 50-330 | var. | var. | 2-6 |
| inch | 0.16-0.8 | 0.08-0.4 | ¼ - 1¼ | 2-13 | var. | var. | 2-6 |

Material: Solid carbide

Torus cutters

| units | d ₁ | R | d ₂ | l ₁ | l ₂₋₃ | angle | z |
|-------|----------------|------|----------------|----------------|------------------|-------|------|
| mm | 4-20 | var. | 6-32 | 50-330 | var. | var. | 4-14 |
| inch | 0.16-0.8 | var. | ¼ - 1¼ | 2-13 | var. | var. | 4-14 |

Material: Solid carbide

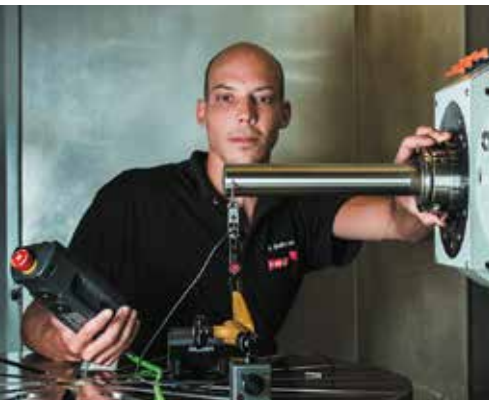
Barrel cutters

| units | d ₁ | R ₁ | R ₂ | d ₂ | d ₃ | l ₁ | l ₂₋₄ | angle | z |
|-------|----------------|----------------|----------------|----------------|----------------|----------------|------------------|-------|-----|
| mm | 4-30 | var. | var. | 6-32 | var. | 50-330 | var. | var. | 2-6 |
| inch | 0.16-1.2 | var. | var. | ¼ - 1¼ | var. | 2-13 | var. | var. | 2-6 |

Material: Solid carbide

Service: Expertise and Availability

Machines from the Starrag Group are known for their extremely high levels of productivity and precision. In order for a customer to achieve a rapid return on investment, a high level of availability and working in three-shift operation must be assured at all production sites.



A further factor for reliably high availability numbers is preventative maintenance tailored to the operating conditions and production requirements. With the aid of condition monitoring along with planned component inspections, consistently high availability rates are achieved, and unplanned downtime is reduced to a minimum.

Retrofits and upgrades ensure that machines are brought fully up to date regarding technology, and are adapted to meet new requirements. This safeguards the machine's value and extends its life cycle.

With these service products Starrag can guarantee machine availabilities. Starrag is fully transparent so that the total cost of ownership (full life cycle cost) can be calculated in detail.

With its 300 employees, the Starrag Group's global service network is specifically set up to meet these requirements. The range of services offered covers everything from the supply of spare parts, a repair service, to guaranteed availability and optimized life cycle costs. Together with the customer, our service experts draw up individually tailored service solutions, and offer advice as they are implemented.

Every incident is dealt quickly with the 24/7 hotline support, remote diagnostic tools, a local network of technicians close to the customer, and a global spare parts supply service through regional hubs.

Qualified operating and maintenance staff are important key factors in maintaining a high level of plant availability. This is why the Starrag Group offers comprehensive training programmes in the relevant language, both at its training centers at its own plants, and at the customer's own site.

Key benefits:

- Planning reliability due to guaranteed uptimes
- Optimized life cycle costs
- Sustained machine value



On-site around the world

Europe

Benelux / Denmark / Germany / Finland
 France / United Kingdom / Italy / Austria
 Poland / Sweden / Switzerland Slovakia /
 Spain / Czech Republic / Belarus

Middle East

Israel / Turkey

Americas

USA / Canada / Mexico / Brazil

Asia

China / India / Indonesia / Japan / Korea
 Malaysia / Singapore / Thailand / Taiwan

Oceania

Australia / New Zealand

Africa

Egypt / South Africa



- Logistic Center
- Service Center
- Service Technicians

Technical Data

| NB 151 | | |
|--|--------|-----------------------|
| Working Range | | |
| Number of Spindles | | 1 |
| Max. Blisk Diameter | mm | 620 |
| Strokes | | |
| X-Axis | mm | 650 |
| Y-Axis | mm | 650 |
| Z-Axis | mm | 600 |
| A-Axis | degree | 360 endless |
| Swivel B-Axis | degree | -240° / +60° |
| Axis Feeds and Rapid Traverse | | |
| Linear Axes XY Z | m/min | 62 |
| Rotary Axis A | rpm | 200 |
| Rotary Axis B | rpm | 60 |
| Main Drive / Motor Spindle | | |
| Speed | rpm | 18,000 |
| Power at 100% Duty | kW | 28 |
| Torque at 100% Duty | Nm | 181 |
| Tool Taper | | HSK-A63 (A80) |
| Tool Deposit / Chain Magazine | | |
| Max. Tool Weight | kg | 10 |
| Max. Tool Diameter | mm | 160 |
| Standard / Max. number of Tools | | 60 / 320 |
| Tool Chance Time Double Gripper | sec | 4.5 |
| Positioning According to VDI/DGQ 3441 | | |
| Linear Axes P | mm | 0.006 |
| Linear Axes Ps | mm | 0.0024 |
| Rotary Axes P | sec | 6.0 |
| Rotary Axes Ps | sec | 4.0 |
| Dimensions and Weight | | |
| Weight | kg | 13,000 |
| Length x Width x Height | mm | 5,500 x 3,100 x 3,150 |
| Safety Concept | | CE-compliant |
| CNC-Control | | |
| | | Siemens |



Engineering precisely what you value

Berthiez
Bumotec
Dörries
Droop+Rein
Ecospeed
Heckert
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