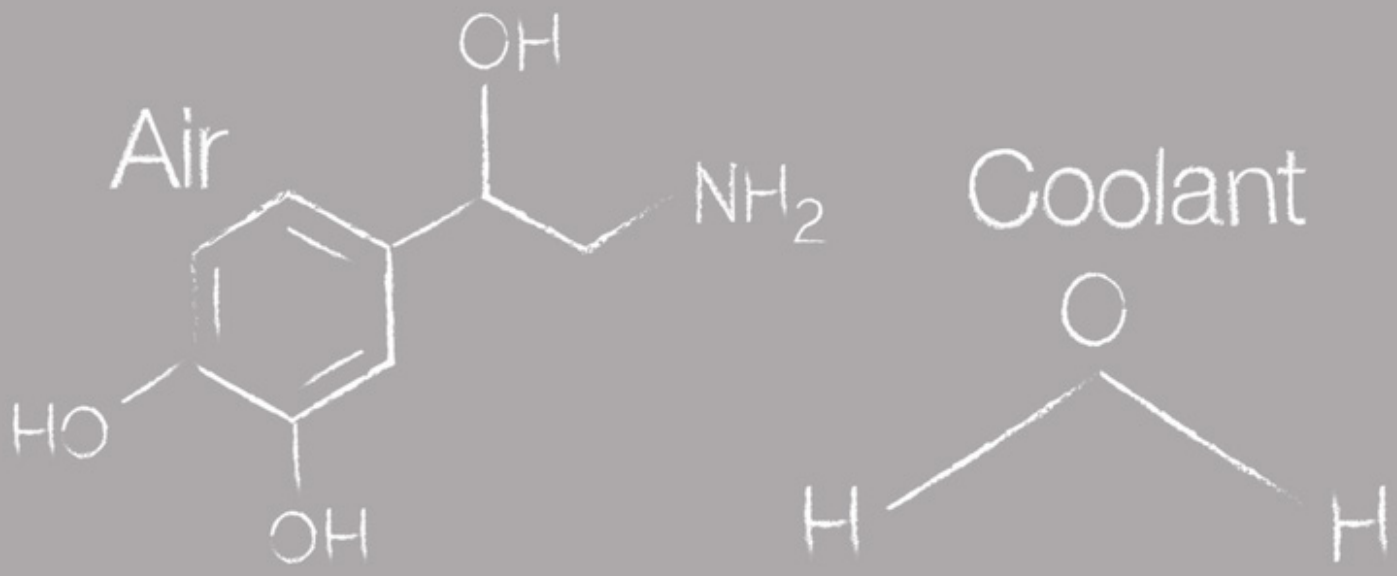
ROTARY UNION DESIGN FACTORS AND

SEALING TECHNOLOGY

FOR MACHINING CENTER APPLICATIONS



Be more Versatile.

DEUBLIN®

Rotary unions are a critically important element in through-spindle coolant (TSC) systems. TSC systems deliver coolant directly to the cutting edges of end mills, drill bits and other rotary tools, providing a distinct advantage over flood coolant methods. A spray of high-pressure coolant directly in the cutting zone can enhance machining processes by rapidly clearing chips, cooling work pieces and allowing extreme pressure (EP) lubricant additives to more effectively reach cutting tool edges. TSC systems normally allow a 20 percent increase in surface cutting speed, which provides higher chip removal rates and much shorter machine cycle times. Rotary unions for TSC systems in machining center applications must supply high pressure coolant fluids (up to 3,000 psi, 210 bar) at high flow rates while maintaining the rotary seal at high rotary speeds (over 36,000 rpm). The seal must be upheld even with intermittent operation and rotation changes.

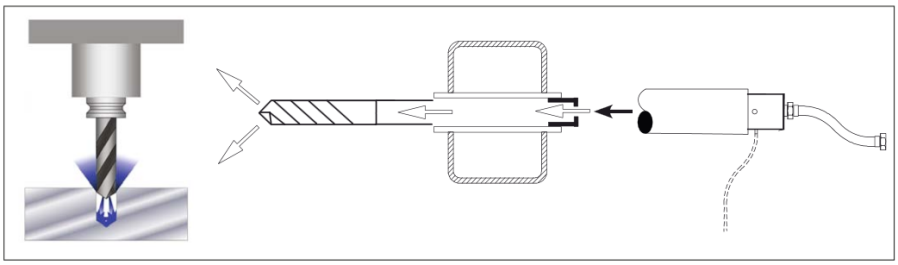


Figure 1. In a TSC system, a rotating union is attached to one end of the spindles and passes coolant into the shaft. The coolant flows through the tool to the cutting edges. Source: Deublin

The rotary union must provide a long life without seizing, seal failure and leaks. An advanced coolant recycling or filtration system should be deployed as part of the TSC design to remove as much particulate contamination as possible and extend seal life. The rotary union seals should exclude any machining debris such as swarf or metal chips, since some particles may leak past even the best filtration system. The materials in contact with the coolants have sufficient chemical resistance and compatibility with water-based cutting fluids, lubricants, straight oil and active machining additives. Rotary unions for TSC applications must also have the proper sealing geometry, low torque or rotary friction, high stiffness and precision tolerances to meet the mechanical accuracy demands of the machine tool industry. In addition to coolant delivery to cutting tool edges, rotary unions with multiple passages may also be required in some machine tool applications to enable hydraulic fluid flow for tool actuators or air flow for minimum quantity lubrication (MQL) oil mist systems.

Sealing Technologies

Advanced mechanical seal materials and seal technology lie at the heart of every high performance Deublin® rotary union. Standard Deublin rotary unions for machining applications always utilize mechanical seals with dual silicon carbide (SiC) faces. SiC is an extremely hard, high thermal conductivity and wear resistance ceramic. While fluids properly filtered to remove particles below 60 microns will maximize seal life, SiC seal faces can continue to perform even with dirty media or marginally filtered coolant. Different Deublin seal technologies can be selected depending on the specific performance requirements of the rotary union application. The SiC seals have an optimized balance ratio. A balanced seal design prevents lubricant or fluid between the seal from being squeezed out or vaporized.

Figure 2. Deublin 1112 series special two-passage rotating union for MQL mixed-in spindle applications. Source: Deublin

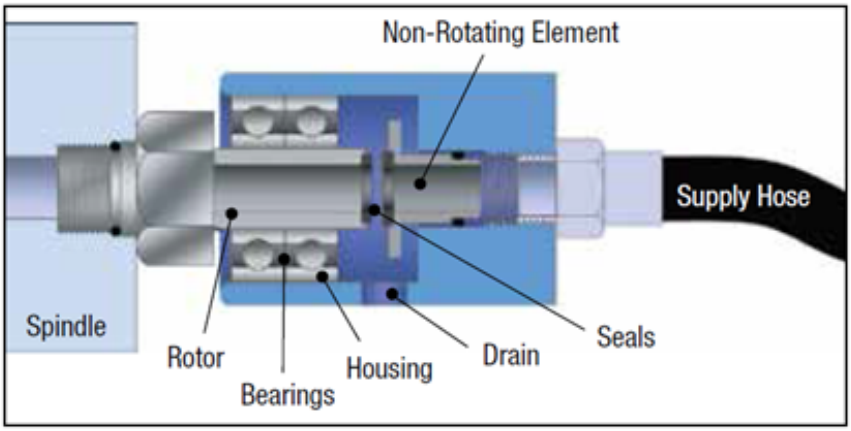


Figure 3. Schematic diagram showing the rotating and stationary seal surfaces in a rotating union for TSC applications. Source: Deublin

A loss of lubrication would increase seal wear and dramatically shorten life. Balanced seals have high pressure limits, low seal face loading and low heat generation. The higher thermal conductivity of SiC, mirror-smooth faces and balanced design keep the seal faces running cool and extend seal life.

Sealing technologies encompass the seal actuation mechanisms opening and closing the seal faces. Deublin seal technologies include closed seal, controlled-leakage, Pop-Off™, All-Media, AutoSense™ and a variety of other advanced technologies for all applications.

Closed seal rotary unions have no leakage through the seal faces and media (coolant or air) pressure is not required to maintain sealing. Generally, closed seal unions with standard SiC seals should not be run dry to avoid seal seizure and failure, but Deublin does have enhanced seal material combinations, such as SiC-graphite, capable of running dry for specific applications. Controlled-leakage seal technology allows a small amount of fluid to continuously trickle in between the seal faces. Controlled-leakage unions are typically recommended for high-speed applications with dry compressed air and can be used on MQL systems. Considering the contamination levels in machining fluids, controlled-leakage unions are not useful for TSC applications.

Pop-Off seals are actuated or closed only when pressure, either coolant or media such as air and cutting oil, are applied. In the absence of pressure, the seal faces pop open or separate slightly to eliminate friction and seal wear, preventing dry-run condition and seal wear damage. However, Pop-Off seal technology is still reliant on the presence of air or coolant pressure for seal actuation or disengagement. Pop-Off rotary unions require downward pointing drain line to return residual coolant to the sump tank when the seals faces are separated. Deublin's All-Media seal technology gives the machine tool designer control of seal opening and closing. Opening and closing are controlled by applying pressure to the appropriate ports on the rotary union. All media rotary unions require an additional drain line.

Figure 4. Deublin 1109 series Pop-Off rotary unions have seals that open automatically when coolant, air or other media flow is interrupted. Source: Deublin

A more sophisticated sealing technology from Deublin is AutoSense. AutoSense seals combine the benefits of both Pop-Off and controlled-leakage seal technologies. AutoSense technology senses the media type, differentiating between coolant pressure and air pressure, and automatically changes the seal operation. Like Pop-Off, AutoSense seals close when coolant pressure is applied and does not leak. If air pressure is applied, the seals form a micro-gap to allow for pressurized dry air running. The seals will operate in a controlled-leakage condition with a very small gap between the seal faces, allowing it to run wear-free. AutoSense unions can handle coolant, MQL and dry air media. A big advantage is the ability to run pressurized air with rotation. AutoSense unions deliver the greatest operational flexibility with multiple types of through-spindle media.

Machine Tool Design Considerations in Rotary Union Selection

Figure 5. Deublin AutoSense bore-mounted rotating union for coolant and air service with dry running capability. Source: Deublin

Deublin rotating unions have many benefits for designers developing the next-generation machine or TSC system. Modern CNC machining centers, gun drilling machines, milling machines, transfer or flex line and lathes require high-precision rotary unions. The long-life and trouble-free operation of Deublin rotary unions are making "lights out" factory automation a reality in the machining center realm. The precision machine tool mechanical design factors need to be met during selection of a rotary union such as precision tolerances, minimal friction and torque, elimination of vibration or chatter, high stiffness, positive sealing under high pressures, smooth rotation at high speeds and long service life (low wear).

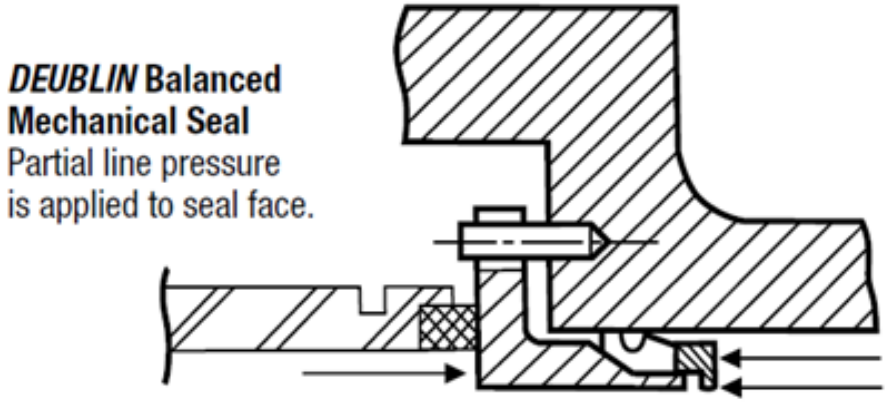


Figure 6. Deublin balanced mechanical seals provide higher pressure limits, lower seal face loading, less frictional heating and longer life. Source: Deublin

Deublin rotary unions have low torque and friction due to the use of micro-lapped seal faces and dual ABEC 7 (ISO class P4) angular contact ball bearings or deep groove radial ball bearings. The angular contact ba bearings provide the high precision and stiffness to handle axial (spindle or thrust loads. Deep groove radial ball bearings are useful in spindle ap plications with higher radial loads or in conjunction with thrust bearing.

The SiC faces of Deublin rotary seals are micro-lapped on proprietary machines to an extreme level of smoothness (optical flatness of 2 light bands, 0.58 microns or 23 micro-inches), which minimizes friction, contamination ingress and therefore wear. The balanced seals in Deublin rotating unions maintain consistent seal face-to-face pressure regardless of fluid pressure and they minimize axial loads or force in systems with bearingless unions. The stroke range of Deublin's rotary union can be used to compensate for thermal expansion of the spindle as well as variations in drawbar position from tool release or change cycles. Deublin rotary unions are constructed of corrosion-resistant materials to allow the use of machining fluids that might degrade other rotary unions, such as surface active coolants or electrolytes for electrochemical machining processes. Deublin typically has a rotary union that can meet the application design requirements of most TSC systems, or Deublin will develop a new rotating union.

Many of Deublin rotary unions are available in bearing-supported (bore mounted or rotor mounted) and bearingless configurations. Bearing-supported unions are easier to install and replace due to their one-piece design. However, bearingless unions have multiple advantages during machine tool design such as:

- Reduced union cost due to elimination of
- bearing
- Increased maximum rotary speed
- Elimination of a vibration source, since only a small rotor is attached to the spindle
- Immunity to side loading
- More compact size ideal for closely spaced
- multiple spindle machining centers

Figure 7. Bearingless and bearing-supported (bore or rotor mounted) rotary unions versions are typically available to meet specific machine tool design needs. Source: Deublin

Retrofitting and Upgrading Current Machine Tools

Deublin's rotating unions can be used in retrofitting applications to upgrade existing TSC systems on older machine tools. Replacing an older or competitive rotary union with an upgraded bearing can potentially provide an upgraded TSC system capable of operating at higher coolant pressures, higher spindle speeds and lower torque. Bearing-supported rotary unions are available with threaded rotors for easy installation and require no additional support. Bore-mounted and bearingless versions are available as well, which require support in a redesign or retrofit application.

The coolant recovery systems in older machine tools may not have adequate filtration systems compared to newer systems. The full-flow design of Deublin rotary unions has no obstructions to trap chips, debris or particulate contamination not captured by an older filtration system. The labyrinth system and large vents in Deublin products protects ball bearings in older systems. An older rotary union on TSC can be upgraded with a Deublin union to provide air service without the need to install additional plumbing. Replacing an older single-passage rotary union with a new multi-passage AutoSense union can provide a TSC system capable of handling different media types (e.g., coolant, MSC, compressed air) while enhancing overall performance and life in applications with frequent cycling and intermittent operation.

Conclusion and Next Steps

Deublin provides machine tool designers with an extensive selection of rotary unions from bearingless (two-piece) to bore- or rotor-mounted, bearing supported (single-piece) configurations with a wide range of seal technologies to handle almost any imaginable machine tool fluid. Deublin has rotating unions designed specifically for single or multiple (e.g., coolant plus oil plus compressed air) input fluids. The maximum pressures of Deublin's rotating unions range from up to 145 psi (40 bar) for compressed air to up to 3,000 psi (210 bar) for high-pressure coolants or lubricants. Specialized, hybrid, multiple channel unions can operate at speeds up to 2,500 rpm while some of Deublin's single-passage unions can operate at speeds over 36,000 rpm. Deublin rotary unions are available for all common machine tool spindle sizes and custom size can be developed.

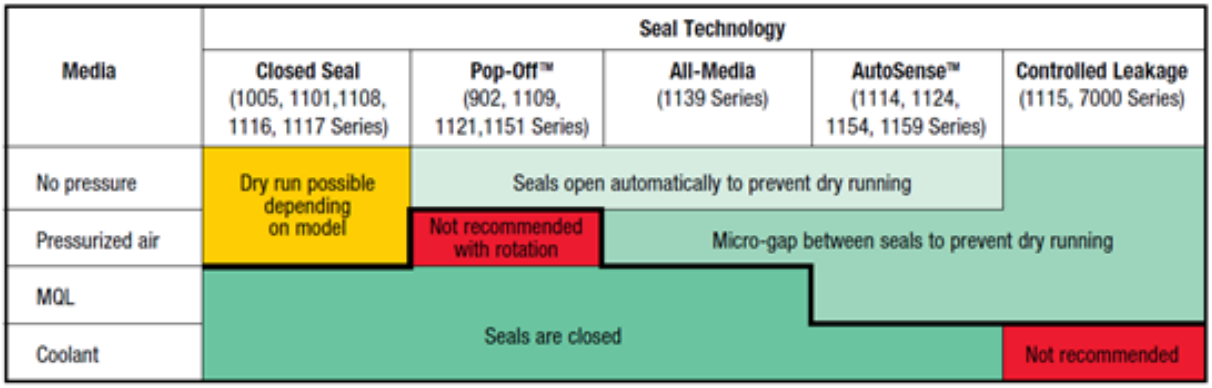


Table 1: Summary of rotary unions with various seal technologies for different media or machining fluids. Source: Deublin

Table 1 summarizes the recommended operation of the Deublin's rotating unions by seal technology for various fluids and application pressure. Pop-Off, All-Media and AutoSense unions open automatically to prevent dry running seals when no pressure is applied to the fluid. A micro-gap between the seals prevents dry running conditions on All-Media, AutoSense and controlled-leakage unions when handling pressurized air or MQL oil mists. Some of Deublin's closed-seal unions have proprietary seals with the ability to run dry under no pressure and compressed air applications. The seals close when machining coolants are fed into any of Deublin's rotary unions, with the exception of the controlled-leakage type.

In many applications, rotating unions with AutoSense seal technology are often the best choice because they are suitable for a wide variety of customer application requirements. In cases where no off-the-shelf rotating union meets the design requirements, Deublin is often willing to develop a new rotary union to meet the needs of certain high-performance applications. Deublin's application engineers' assistance in rotating union selection can optimize installation and assembly, minimize maintenance, maximize performance and increase longevity of your TSC system.

Contact Deublin's application engineers today to discuss your applications and evaluate the most suitable high performance rotary unions to evaluate for your machine tool applications.