RFID – a key technology in modern production

TOOL IDENTIFICATION AND WORKPIECE TRACKING

It's not just the IIoT that has focused attention on RFID as a central component of automation. As a key technology, radio frequency identification has been long established in production. The inductive operating principle guarantees ruggedness and resistance to environmental stress factors. This makes the system highly reliable in function and operation. With unlimited read/write cycles and real-time communication, RFID has become indispensable.

The beginnings for the industrial use of RFID go far back. RFID was first successfully used on machine tools in the mid-1980's. This continues to be a success story to be used in modern production processes with the IIoT. In this contribution you can read about what technical prerequisites have to be met for RFID to play such an important role in tool identification and workpiece tracking, and what RFID means for modern production.

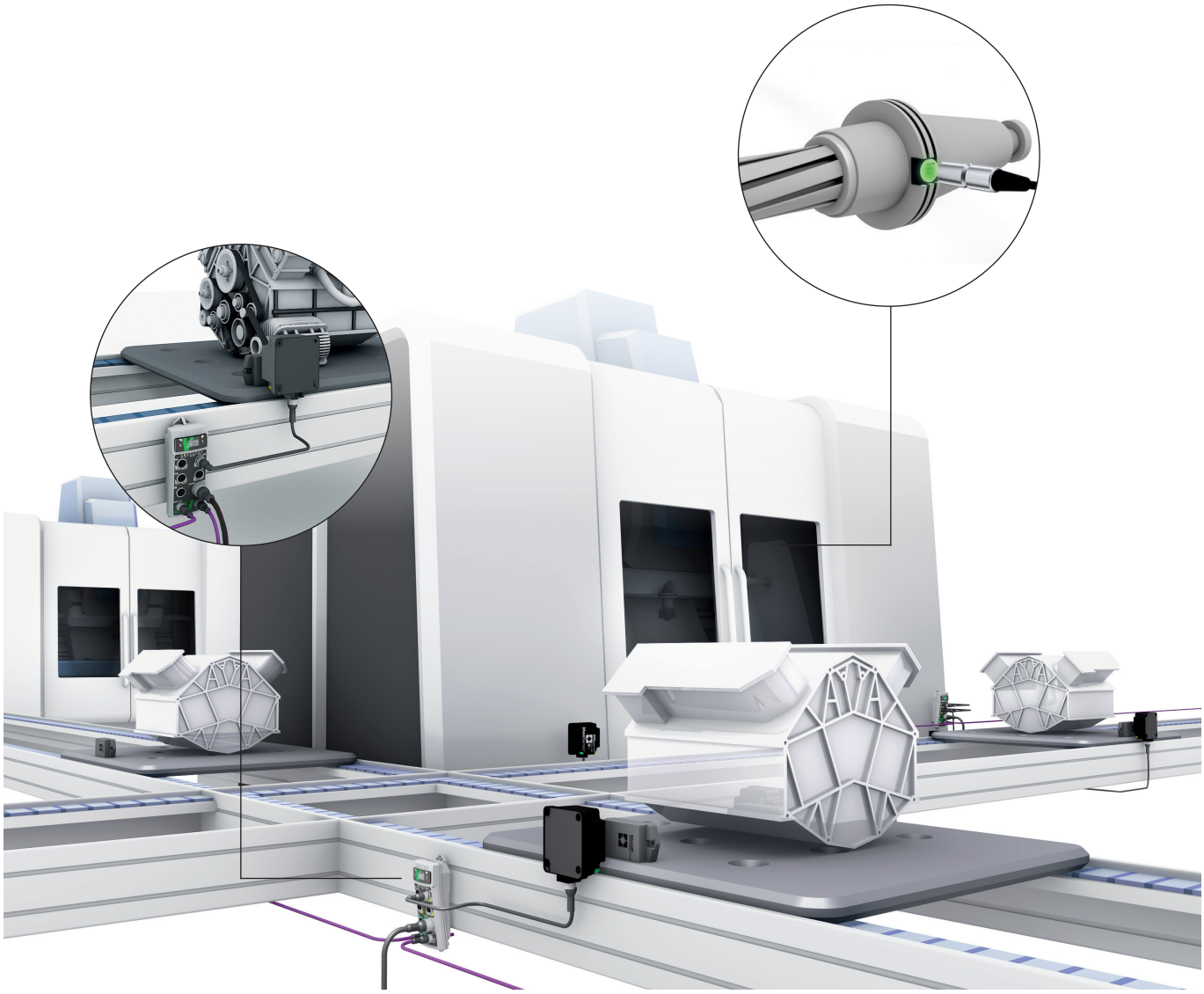

Fig.1: Machining center with RFID processor unit and RFID read heads for tool identification and workpiece tracking

A HIGH LEVEL OF AUTOMATION REDUCES COSTS WHILE INCREASING QUALITY

Modern production processes need the highest possible level of automation. On one hand, this reduces the cost per unit after the investment and in the long term. In addition, automated processes result in fewer quality deviations than manually guided processes. On the other hand, industrial manufacturing requires ever more flexible use of the production equipment as the part variety continues to grow. For example, to be able to realize individual, custom-tailored solutions for customers.

To meet these challenges of the manufacturing processes in metalworking, modern machine tools must automatically control and monitor material flows. This applies to both the path of the workpieces through the plant (as components of the product to be manufactured) and to the tools used for the machining process. RFID, offering fast data communication in real-time, meets these requirements. The autonomous system gathers and documents production and quality data on a continuous basis, so that the data can be recalled at any time.

TOOL IDENTIFICATION

Tool Identification

Tool Identification using RFID has been successfully used on machine tools for around 30 years. Since the mid-1980's, inductive sensor technology made it possible even then to transmit data by means of inductive oscillation. Signals were modulated over the oscillation. This allowed for the first time tool-relevant data, i.e. the specific information about the respective tool, to be stored without contact on a data carrier attached to the tool holder. This ensures unambiguous recognition and matching of the tool (Fig. 2). And with the help of RFID read heads, the tool data can be read out wherever desired (such as on the machine tool) or both read and written (such as on the tool presetter). The automatic process of the data ensures that all the data are always correct and current.

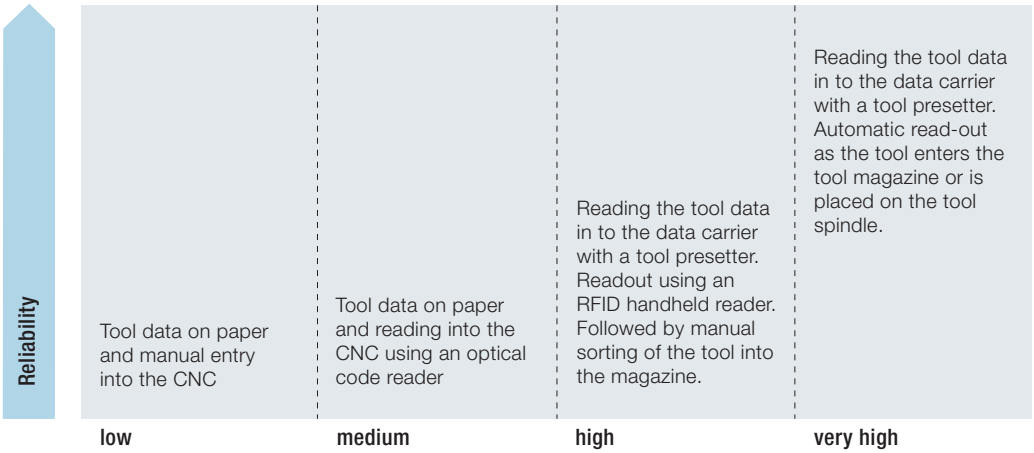

Fig. 2:
As the level of automation increases, the reliability of tool allocation rises.

CNC controllers as a prerequisite for automatic tool monitoring

Preceding automatic tool monitoring was the development of CNC controllers in the mid-1980's, which was intended to provide better workpiece quality and greater yield rates at lower cost. The Computer Numeric Control allows among other things path corrections to be represented. This was a decisive step in tool identification. One can now determine what offset is needed to correctly produce workpieces. This also makes it possible to determine the optimal tool life and tool change intervals as well as tool sharpening at just the right time. As a result, the best possible tool utilization and greater machine up-time can be achieved.

Technical details

The travel commands issued by CNC controllers, the so-called G-codes and DIN codes, require that the values for the tool radius compensation R be known. In the 1980's, the data was sent to the CNC controller and then combined with the G41 code (tool radius correction left) and G42 code (tool radius correction right) to correctly determine the tool path in the X/Y axis (such as on a milling machine, Fig. 3). Another relevant piece of information that needs to be considered is the tool length, which is measured from a defined reference point. This allows the correct distance of the tool from the workpiece in the Z-direction to be known. Today these tasks are preformed by CAD/CAM systems.

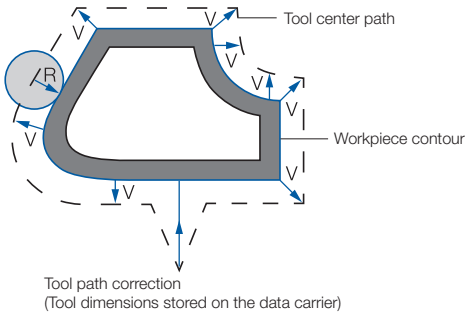

Fig. 3:
Path correction: After each machined workpiece the tool radius is automatically detected and the tool path modified based on wear.

Standardization contributes to the breakthrough

Two types of attachments are possible for placing the data carrier on the tool. RFID data carriers can be attached at the side on the tool holder (Fig. 4) or the data carriers are mounted in the pull studs (Fig. 5). This approach, which is widely used in Asia, differs in its hollow design which allows the flow of coolants (Fig. 6).

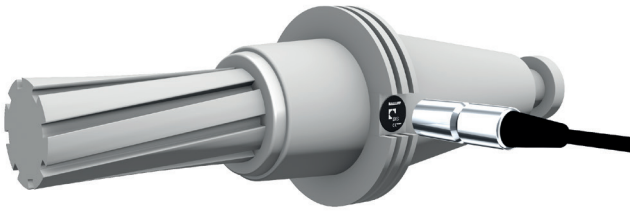

Fig. 4:
Side attachment of the data carrier on the tool holder

Side mounting became standardized as early as the mid-1990's by standards such as DIN 69873 and DIN 69871, which specified the dimensions of the data carriers and their position on the tool holders (e.g. type SK and HSK). This standardization brings ISO norms with it (e.g. DIN ISO 7388-1), which help achieve the breakthrough for RFID on an international basis. With standardization come economical solutions. Standardized automation concepts now make modular assemblies possible.

At the same time, automated tool identification using RFID received another boost from Computer Integrated Manufacturing. Because CIM had already anticipated the complete automation of production, it was only able to achieve it in part.

Fig. 5:
Pull stud

Fig. 6:
Data carrier for mounting in the pull stud

Tool management through tool identification

Automated processing of tool-specific data opens up new vistas for tool management. Instead of error-prone, manually kept tool logs, the data is continually recorded as the tool is loaded and unloaded and further use of the tool is autonomously controlled by RFID (Fig. 7).

The following stations are typical of a functioning tool management system: tool measurement (using a presetter), tool transport and tool storage, the machine tool and tool monitoring, and the tool sharpening station as needed. The RFID data carriers associated with the tool allow it to always be associated with the correct location in the production flow.

In this way, RFID ensures high machining quality and optimal tool utilization. The bottom line is that non-contact data communication results in greater value creation.

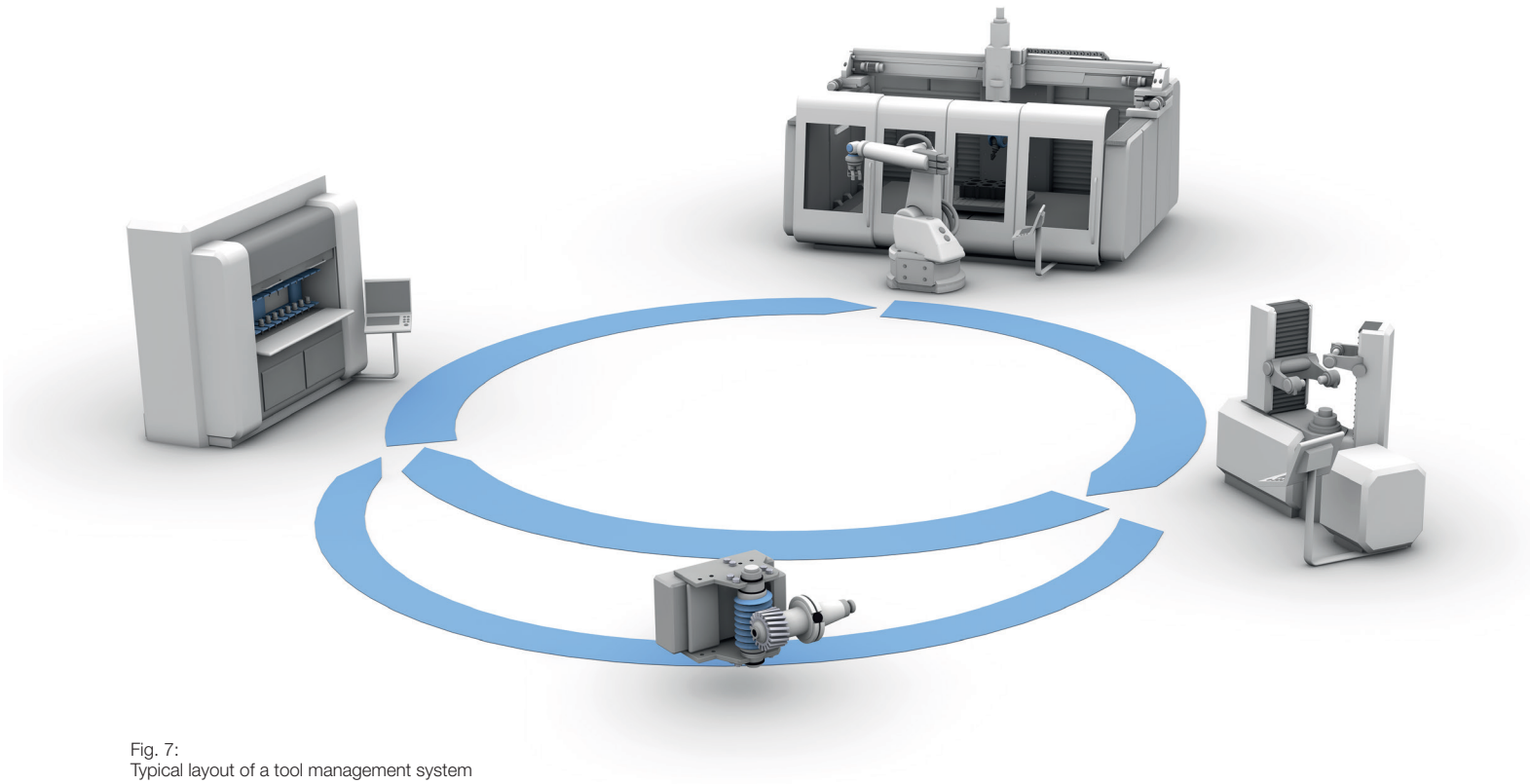

Fig. 7:
Typical layout of a tool management system

Centralized and decentralized data storage

All the data can be directly classified and uniquely assigned. A distinction is made between two types of data storage, centralized and decentralized. In centralized data storage the tool is identified by means of a unique number and the tool data is stored in a central database.

With decentralized data storage, the RFID data carrier stores not only the unique number, but also tool parameters such as tool diameter/radius, tool length, machining time since the last sharpening, planned tool life and other data (Fig. 8). This has the benefit that all tool-relevant data is always available on the tool itself, enabling flexible utilization of the tools even beyond the walls of the plant.

Format	Description	Value range	Example	Comment
Data head – General tool information – Basic data				
ASCII	ID number	Max 32 alphanumeric characters	ID23467TXD...	Tool number
BCD	Duplo number	6 digits in 3 bytes	000000–999999	Detection of a sister tool for multiple instances of the same tools in the magazine
BCD	Tool size	4 digits in 2 bytes	0000–9999	Definition for determining the pocket requirements in the magazine
BCD	Pocket type	2 digits in 1 byte	00–99	Type must agree with the pocket type in the magazine (e.g. fixed or variable coded)
BIN	Tool status	8 bits, 1 byte	00000000	Each bit can have a tool status or a function assigned to it. For example: Bit 1: Active tool Bit 2: Released Bit 3: Blocked Bit 4: Measured Bit 5: Warning threshold reached Bit 6: Tool being changed Bit 7: Fixed pocket coded Bit 8: Tool was in use
BCD	No. of cuts	2 digits in 1 byte	00–99	Maximum number depends on the size of the tool data records and the data carrier capacity - here max. 03
BCD	Type of tool monitoring	2 digits in 1 byte	00–99	e.g.: 01 = time, 02 = piece
BCD	Type of tool search	2 digits in 1 byte	00–99	Search strategy definition Tool search and empty pocket search, e.g.: 01: For active tool of the same type 02: For the next tool of the same type 03: Forward from 1st pocket 04: Forward from current pocket 05: Backward from last pocket 06: Backward from current pocket 07: Symmetrical from current pocket ...
Tool-specific data – Cutting edge 1				
BCD	Tool type	4 digits in 2 bytes	0000–9999	01xx - Milling tool 02xx - Drill 04xx - Grinding tool 05xx - Turning tool 1xxx - Extra long tool Special tool: 0130 - Angled milling tool 0131 - Angled milling tool / edged
BCD	Cutting edge length	2 digits in 1 byte	00–99	
BCD	Geometry - length Multiple length data may follow depending on the tool	6 digits in 4 bytes with sign and decimal point	±000.000–±999.999	Geometry values (6 digits) 1st place sign: B hex = + D hex = - E hex = Dec. point (floating) Example: +001.450 = B 01 E 50
BCD	Geometry - radius Multiple radius data may follow depending on the tool	6 digits in 4 bytes with sign and decimal point	±000.000–±999.999	Like geometry length
BCD	Geometry - angle Multiple angle data may follow depending on the tool	6 digits in 4 bytes with sign and decimal point	±000.000–±999.999	Like geometry length

Format	Description	Value range	Example	Comment
Tool-specific data – Cutting edge 1				
BCD	Wear length Multiple wear data may follow depending on the tool	6 digits in 4 bytes with sign and decimal point	±000.000–±999.999	Like geometry length
BCD	Wear radius Multiple wear radius data may follow depending on the tool	6 digits in 4 bytes with sign and decimal point	±000.000–±999.999	Like geometry length
BCD	Wear radius angle Multiple wear angle data may follow depending on the tool	6 digits in 4 bytes with sign and decimal point	±000.000–±999.999	Like geometry length
BCD	Additional geometry data may follow depending on the tool	6 digits in 4 bytes with sign and decimal point	±000.000–±999.999	Like geometry length
BCD	Max. speed	7 digits in 4 bytes without sign and decimal point	±000.000–±999.999	7 digits without sign E hex = Dec. point (floating) Units - rpm Max. possible speed
BCD	Overhead use	2 digits in 1 byte	00–99	Specially attached cutting edge on tool
BCD	Tool life	4 digits in 2 bytes	0000–9999	Units customer- or tool-specific In pieces or minutes Referenced to the tool monitoring type
BCD	Warning threshold for tool life	4 digits in 2 bytes	0000–9999	Units customer- or tool-specific In pieces or minutes Referenced to the tool monitoring type
BCD	Quantity	4 digits in 2 bytes	0000–9999	Customer- or tool-specific
BCD	Warning threshold for quantity	4 digits in 2 bytes	0000–9999	Customer- or tool-specific
Tool-specific data – following cutting edge 2 and additional cutting edges				
Same structure as Cutting Edge 1				
Machine-specific data				
BCD	Product number	6 digits in 3 bytes	000000–999999	Machine-specific
HEX	NC designation	2 digits in 1 byte	00–FF	Machine-specific
BCD	Machine number	6 digits in 3 bytes	000000–999999	Machine-specific
BCD	Operation number	4 digits in 2 bytes	0000–9999	Machine-specific
BCD	Magazine pocket	4 digits in 2 bytes	0000–9999	Machine-specific
BCD	Total tool length	8 digits in 4 bytes	00000000–99999999	Total time of use
BCD	Cleaning type	2 digits in 1 byte		Cleaning method definition

Fig. 8:
Example for decentralized data storage on an RFID data carrier

TRACK-AND-TRACE – TOOL TRACKING

Modern manufacturing with a wide bandwidth of batch sizes and ever compressed production times demands maximum transparency. This is the only way to meet the high requirements for flexibility and quality, and to keep costs down as much as possible. Not only do the tools need to be optimally managed, but also the finished parts and materials used must be unambiguously recognized and assigned (Fig. 9).

To reduce setup times and increase overall system efficiency, workpieces are therefore automatically brought to and removed from the machine tools. RFID has established itself as a key technology for workpiece tracking because RFID offers seamless documentation and automation of the entire manufacturing process. Each process step is recorded on the data carrier, so that possible errors are limited and can be analyzed when they do occur.

Using track-and-trace, the tracking of workpieces, RFID has become an integral part of flexible manufacturing. Workpieces can be reliably moved through the production line as needed all the way down to lot size 1.

And in contrast to CIM in the 1990's, the context of Industry 4.0 communication enabled "cyber-physical systems“[1], which combine production machines with Internet technologies and prioritize manufacturing jobs to be accomplished with a high degree of variability. This makes it possible to determine the path of workpieces through production on short notice so that individual customer orders can be quickly accommodated.

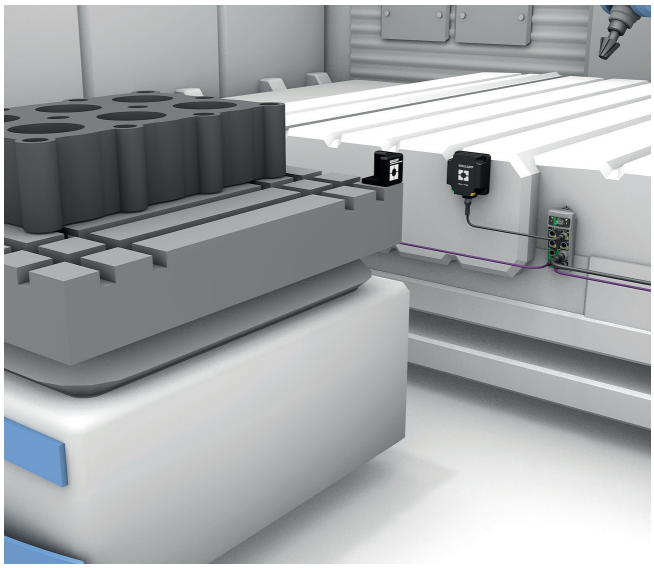

Fig. 9:
Pallet system with RFID data carrier for workpiece tracking

LF AND HF – BOTH RFID WORLDS COME TOGETHER

In terms of data transmission for tool management, which is to say tool identification, established system since the 1980's have settled on LF (Low Frequency), since this band has proven to be especially robust and reliable in metal surroundings. Data are read with LF at a frequency of 455 kHz and written at 70 kHz.

When it comes to intralogistics and tracking of workpieces, HF (High Frequency) has become the standard in recent years. This is because HF systems with a working frequency of 13.56 MHz offer greater traverse speeds and a more generous read/write distance.

However, it is increasingly common in modern production and assembly systems that different frequency bands are needed – not least to be able to meet the requirements for greater flexibility and ever more complex tasks. Until recently, each system was designed for specific applications. But new technical developments portend a fundamental shift.

New RFID processor units have recently been introduced that offer frequency-independent application. And thereby the possibility of using RFID data carriers with different frequencies at the same time. Just one version of the processor unit can be used to cover different application requirements. Now the machine is no longer the measure of all things, but rather can – as the Association of German Machine Tool Manufacturers (VDW) now requires – "be optimally embedded in the working processes of a company“[2]. In the words of the VDW, "thinking in terms of networking solutions" has become essential.

RFID IS A KEY TECHNOLOGY FOR THE IIOT

What the VDW combines with the motto of shifting from a vertical to a horizontal way of looking at things means nothing less than the central component for implementing the IIoT. Which area of expertise would therefore be better suited for interlinking "production with the most modern information and communication technology“[3] than RFID which is based on experience with automated tool identification and workpiece tracking. Due to the fact that the intelligent interplay between all the levels of production has for many years already been a proven strength RFID, the of non-contact data communication in real-time, ensuring reliable monitoring as well as transparent processes. Tool identification and parts tracking with RFID are therefore two key qualifications for meeting the challenges of the fourth industrial revolution.

Sources:

[1] Industry 4.0
https://en.wikipedia.org/wiki/Industry_4.0 [Last modified: 15 August 2016]
[2] Machine tool builders reinvent themselves
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[3] Industry 4.0 Platform
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www.balluff.com

Balluff GmbH · Schurwaldstrasse 9 · 73765 Neuhausen a. d. F. · Germany · Phone +49 7158 173-0 · Fax +49 7158 5010 · balluff@balluff.de

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