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TOOL LIFECYCLE MANAGEMENT IN INDUSTRIAL PRACTICE

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Abstract:
The paper presents Tool Lifecycle Management (TLM) as an enhancement of traditional approach to the tool management. The most important assumptions and main research areas of modern tool management are introduced. The author describes functional areas and expectations of TLM. The components and design principles of Industie 4.0 are presented. The main part shows TDM System, developed on the basis of TLM, and an example of its implementation in industrial practice.

Key words: *Tool Lifecycle Management, tool management, material and information flows, simulation of manufacturing processes, requirement for tools*

INTRODUCTION

Tool managements organization performs a significant function in an industrial practice where production processes are based on subtractive manufacturing. Supplying of the right tools in the right time and proper cutting data ensures undisrupted manufacturing processes. Tools management needs a comprehensive approach to all of its tasks. Tool Lifecycle Management focuses on a holistic approach to the tool on each stage of its lifecycle: from the moment of its purchase through its work, the overall use and refurbishment up to its scrapping. Proper IT systems can support an efficient management of the tool system - starting from simple software supporting Tool Department to tool data systems integrated with other company systems supporting planning, simulating of technological processes and manufacturing.

TOOL MANAGEMENT IN INDUSTRIAL COMPANIES

Overall company activities connected with organization and planning the procurement of tools, their application in the production process, their storage and reverse logistics as refurbishment (re-grinding and re-coating) and scrapping of tools is defined as a tool management.

According to Liwowski and Kozłowski [8] the main tasks of tool management are:

- providing necessary tools to each workstation leading to effective machining,
- maintaining proper technical condition of tools,
- well-organized circulation of tools, in order to ensure the lowest costs of accomplishing tool management tasks.

Honczarenko [2] points out the fact that the tool management concentrates not only on the tool's attributes but he also mentions tools-planning requirements, preparing and presetting the tools, providing the tools to workstations, recommending of cutting data, maintenance and repairs.

The activities performed in tool management, connected with the flow of goods and data between particular company departments and surrounding partners (tool supplier, tool refurbisher, tool scrapper) are presented in Figure 1.

In the literature tool management tasks are also connected with Flexible Manufacturing Systems (FMS). Tool system is indicated among manufacturing system and logistic supporting systems (energetic, circulation of technological liquids, chips removal system) as a part of FMS by Krzyżanowski [6]. Its functions include:

- generating tool requirements (which type of tool, which tool, how many),
- structuring tool data by geometry, cutting material, cutting data,
- storing right tools at workstation,
- providing tools from central warehousing (for ex. tool cabinets) to workstations,
- replacement of the tools during the production cycle, according to the technology,
- controlling the condition of the tool during its work and replacing it.

TOOL LIFECYCLE MANAGEMENT

Tool Lifecycle Management (TLM) is defined as an IT strategy that encompasses organization of the tool management at every stage of planning, tool use simulation, order preparation and production, as well as tool storage and maintenance. TLM is a central link between ERP Systems (Enterprise Resource Planning), PLM (Product Lifecycle Management) and MES (Measuring Execution System).

The areas of using TLM embrace:

- on the one hand, storing and providing tool data, tool graphics and cutting data in CAM system and simulation processes,
- on the other hand, actual organization of tool circulation on the shopfloor.

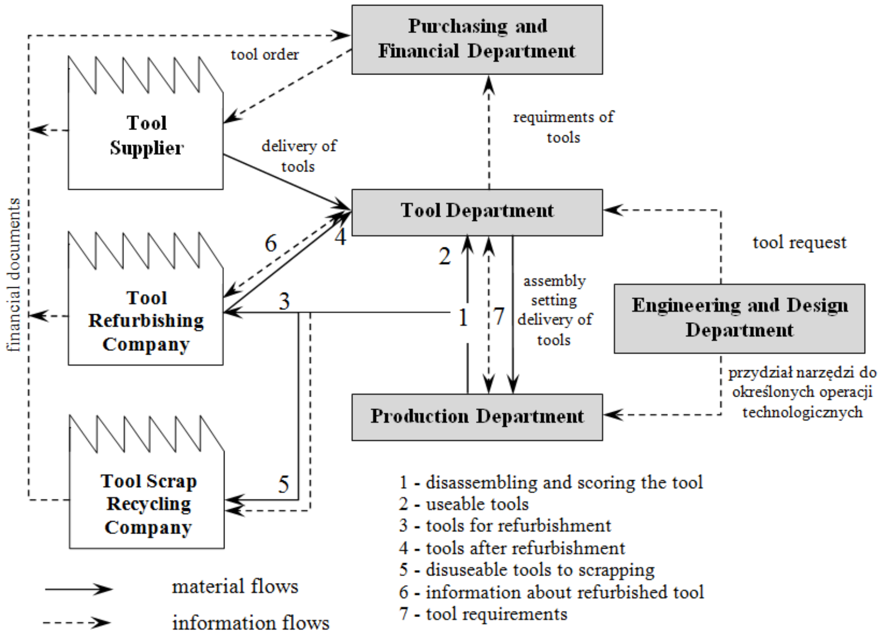


Fig. 1 Main material and information flows of tools data between business environment and departments of the company
Source: based on [11, 13].

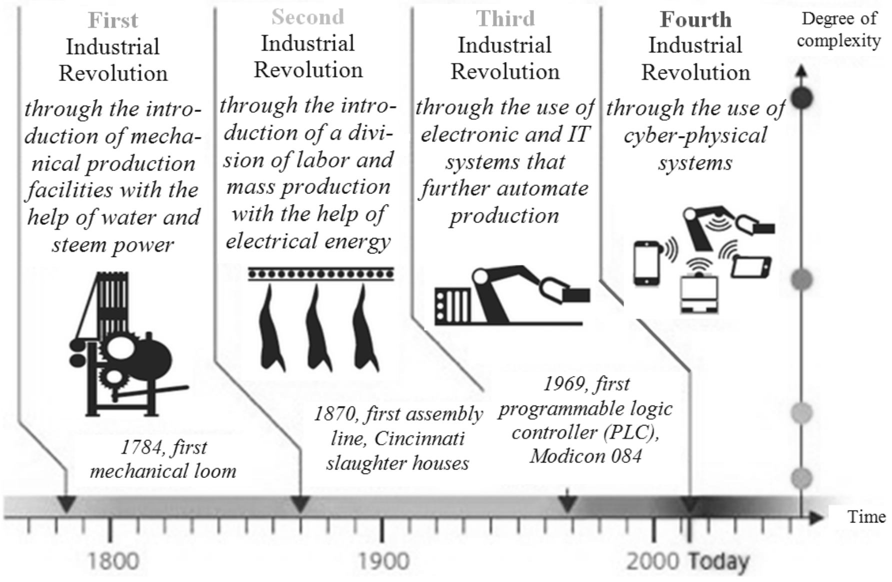


Fig. 1 Industrial Revolutions
Source: [12].

The literature emphasises that TLM is not oriented towards single processes or departments but on a seamless communication and data exchange between systems.

There are a lot of expectations from TLM systems. For example, Lynch lists the following:

- the ability to specify tool life, not only as the number of cycles, but also as the period of time, because in different tasks the tool can run for a different amount of time,
- reporting the tool exhaustion level and ability of automatic exchange of the dull tool, linked with the flow of the information to the system when the tool is being replaced,
- automatic flow of accurate data about tool work that enables automatic change of settings to hold surface quality,
- saving, storing and the ability of retrieving tool lifecycle data to minimize the initial setup time by the same work tasks,
- the possibility to modify the cutting data according to the workpiece material and also according to type of the tool, its geometry and cutting material.

The ultimate goal of tool life management system is to enable tool maintenance during the production run with no effect on the cycle time.

The ability to store and exchange tool data and graphics and the high capability of their integration into the existing company systems environment is the biggest advantage of the systems based on Tool Lifecycle Management conception. Thanks to them, planning is more precise and the manufacturing processes can be virtually simulated with the virtual models of the tools. Tool Lifecycle Management brings a complex view of the production process and is a strong support to implement Industrie 4.0.

THE CHARACTERISTIC OF INDUSTRIE 4.0

The term “Industrie 4.0” appeared in 2011 as a key initiative of High-Tech Strategy announced by the German federal government in planning perspective to 2020. The following year, the Working Group on Industrie 4.0 presented the recommendations for its implementations. The final report was presented at the Hanover Fair the following year.

Industrie 4.0 is a subject of many academic publications and many conferences have focused on this topic.

According to Herman and Pentek [1], there are two reasons for the fascination with Industrie 4.0:

- first of all, this change can revolutionize the industry, but this change can be predicted rather than observed ex-post, which gives the research institutes the possibility to shape the future actively,
- secondly, as experts predict, the economic effect of this change will be huge, it will increase the operational effectiveness and will define new models of business, products and services.

The term Industrie 4.0 in the literature refers to the fourth industrial revolution which is taking place right now. It was preceded by three earlier industrial revolutions, as presented in Figure 2.

In the history of the mankind three industrial revolutions had taken place. They are identified in the literature as:

- the first industrial revolution – dating back to the second half of the 18th and almost the whole 19th century, which was started by the invention of the steam engine and the development of mechanical production,
- the second industrial revolution – dating back to 1870s, introduced by electrification and mass production, as well as the division of labour,
- the third industrial revolution, also called the "digital revolution," initiated in 1970s by the developments in electronics, information technology and automatic production.

In the 2014, the experts from Dortmund Technical University undertook an initiative to create an explicit definition of Industrie 4.0 and to design the principles for its implementation. While trying to define Industrie 4.0 one encounters three problems:

- many academic publications and researches discuss different aspects of the term,
- Industrie 4.0 Working Group and Platform Industrie 4.0 create the vision, basic technologies and scenarios without introducing a clear definition,
- the term Industrie 4.0 is hardly known outside German-speaking countries.

The examples of different definitions of Industrie 4.0 are presented in the Table 1.

In the global perspective, there are other terms, comparable to Industrie 4.0, enumerated by Herman and Pentek [1], and also Lasi [7]:

- Industrial Internet, promoted by General Electric,
- Advance Manufacturing, created by American Advisors on Science and Technology,
- Integrated Industry, implemented by Bürger,
- Smart Industry and Smart Manufacturing, used by Davis and Porter.

The review of literature conducted by the authors of Design Principles for Industrie 4.0, based on the analysis of over 50 publications allowed to identify 6 components of Industrie 4.0. They are:

- Cyber-Physical Systems (CPS) – defined by Jaspernite [3] as systems, in which cybernetic and physical systems are integrated on all levels,
- the Internet of Things,
- the Internet of Services,
- Smart Factory,
- Machine-to-machine (M2M) Communication,
- Smart Products.

Drawing on the review of literature and academic and practical background, the experts from Dortmund Technical University identified six design principles for implementing Industrie 4.0. These are:

- interoperability – the ability of CPS, Smart Factory and humans to communicate via the Internet of Things and the Internet of Services,
- virtualization – creating a virtual copy of the Smart Factory by linking the data from monitoring of the physical process with the data from the simulation models,
- decentralization – the ability of making decisions independently by CPS and Smart Factories,
- real-time capability – the capability of collecting and analyzing data and providing them in real time,
- service orientation – services offered via the Internet of Services,
- modularity – the ability of Smart Factory modules of flexible adaptations to changing requirements.

The next part of the paper presents TDM System – system of tool management based on Tool Lifecycle Management and its implementation in industrial practice.

Table 1
Definitions of Industrie 4.0.

Organization/ author	Date	Interpretation
Industrie 4.0 Working Group, Kagermann	2013	In the future, businesses will establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of Cyber-Physical Systems (CPC). In the manufacturing environment the CPS will comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently.
Platform Industrie 4.0	2014	A new level of value chain organization and management across the lifecycle of products.
Technical University Dortmund, Herman, Pentek	2014	Industrie 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time. Via the IoS, both internal and crossorganizational services are offered and utilized by participants of the value chain.

Source: [1, 4, 17].

THE PROFILE OF TDM SYSTEM

TDM System is a complex solution for tool management. TDM System came into existence in 1987, when the first software supporting tool management was presented. During the 25 years, the system developed applying the latest technology, and expanded to a comprehensive solution that now integrates the tool management on each stage of tool lifecycle with planning and production, as well as simulation of processes and collisions.

The capability of its high integration with the company system environment is the most important feature of the TDM System.

Figure 3 presents the possible areas of integration.

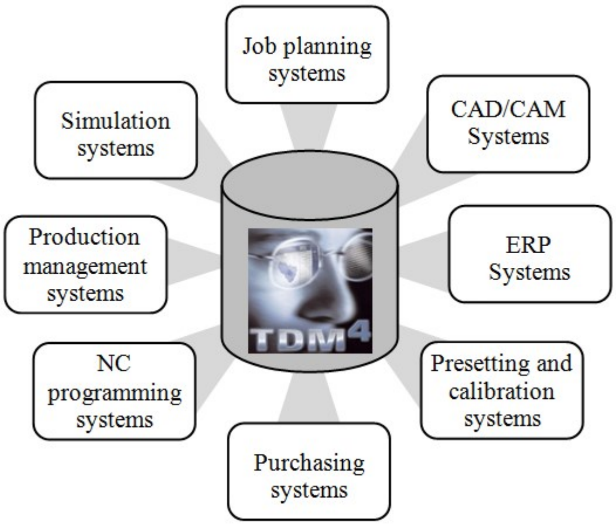


Fig. 3 TDM System's integration capabilities
Source: [14].

The main components of the TDM Systems and its key modules are shown in Figure 4.

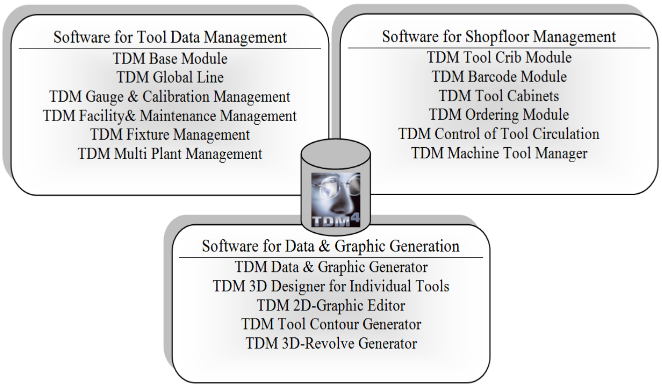
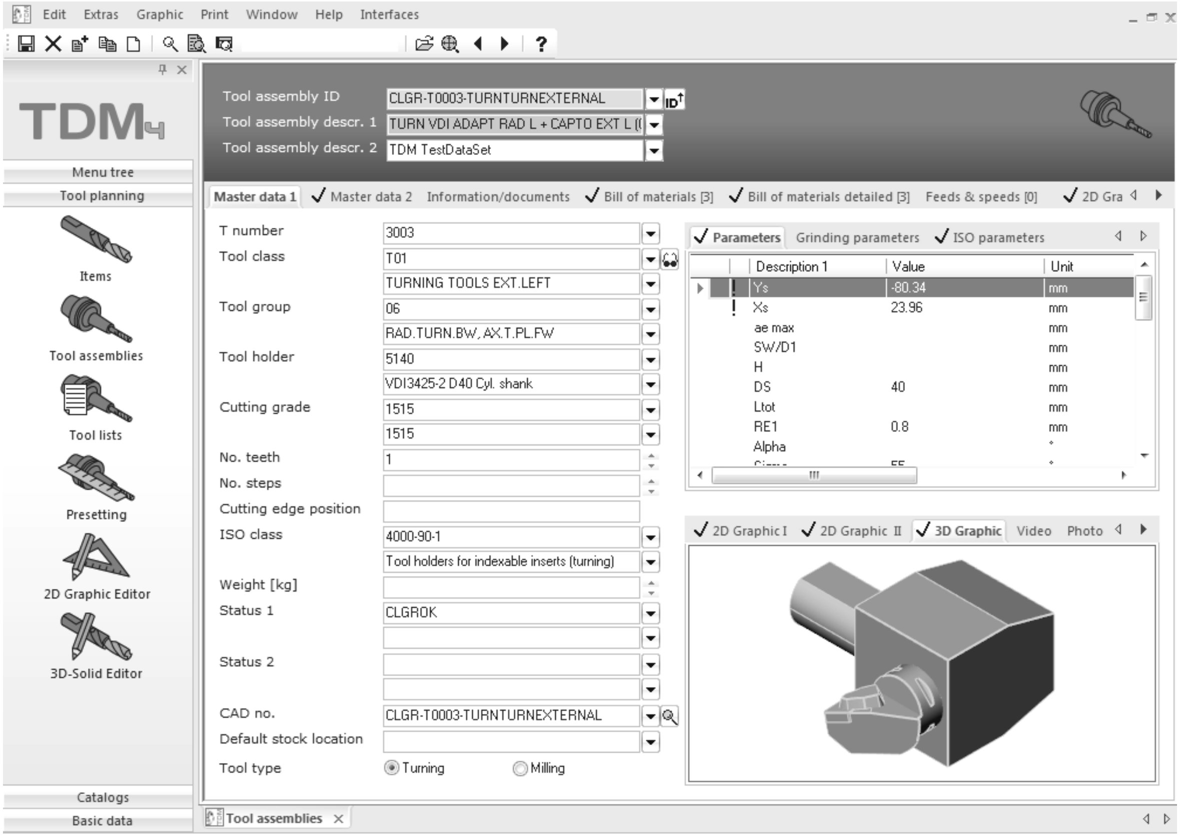


Fig. 4 Components and modules of TDM System
Source: based on [15].

Only a brief characteristic of some chosen modules of TDM Systems is presented here because of limitations on the paper's length.

The TDM Base Module enables to manage all the basic tool data. The features of this module are:

- graphic tool selection by workpiece material, machining operation, chucking devices
- automatic tool assembly with matching components,
- electronic cutting tool catalogue of more than 50 tool manufacturers with 2 and 3D graphics, machining know-how,
- automatic selection of cutting parameters and simulation of tool life,
- generating tool documentation and tool lists to changeover to define job,
- multilevel reporting.

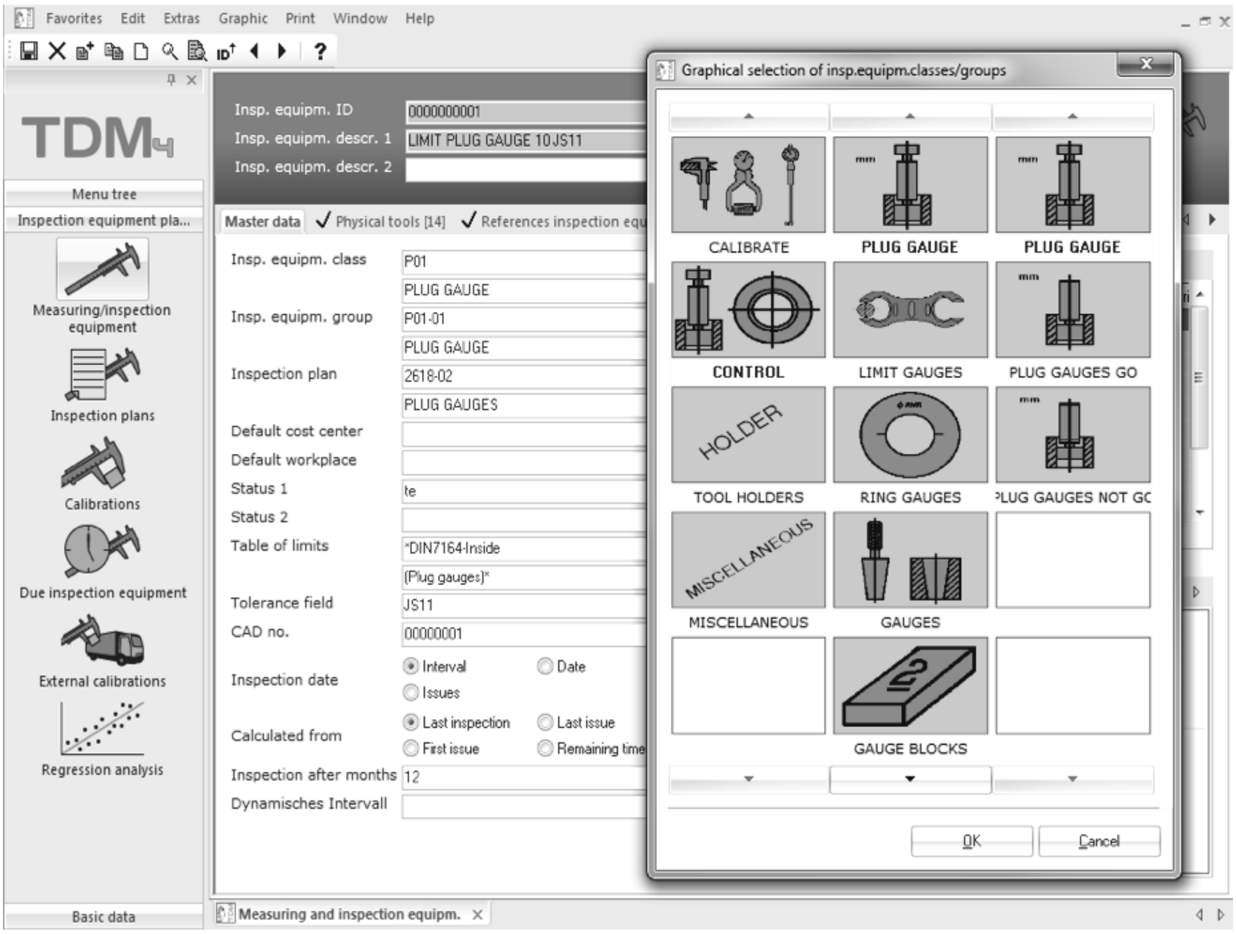


Tool assembly ID: CLGR-T0003-TURNTURNEXTERNAL
Tool assembly descr. 1: TURN VDI ADAPT RAD L + CAPTO EXT L (I
Tool assembly descr. 2: TDM TestDataSet

T number: 3003
Tool class: T01
TURNING TOOLS EXT.LEFT
Tool group: 06
RAD.TURN.BW, AX.T.PL.FW
Tool holder: 5140
VDI3425-2 D40 Cyl. shank
Cutting grade: 1515
1515
No. teeth: 1
No. steps:
Cutting edge position:
ISO class: 4000-90-1
Tool holders for indexable inserts (turning)
Weight [kg]:
Status 1: CLGROK
Status 2:
CAD no.: CLGR-T0003-TURNTURNEXTERNAL
Default stock location:
Tool type: ● Turning ○ Milling

	Description 1	Value	Unit
!	Ys	-80.34	mm
!	Xs	23.96	mm
	ae max		mm
	SW/D1		mm
	H		mm
	DS	40	mm
	Ltot		mm
	RE1	0.8	mm
	Alpha		°

Fig. 5 Window of TDM System Base Module
Source: [14].



Insp. equipm. ID	0000000001	
Insp. equipm. descr. 1	LIMIT PLUG GAUGE 10 JS11	
Insp. equipm. descr. 2		
Insp. equipm. class	P01 PLUG GAUGE	
Insp. equipm. group	P01-01 PLUG GAUGE	
Inspection plan	2618-02 PLUG GAUGES	
Default cost center		
Default workplace		
Status 1	te	
Status 2		
Table of limits	*DIN7164-Inside (Plug gauges)*	
Tolerance field	JS11	
CAD no.	00000001	
Inspection date	● Interval ○ Issues	○ Date
Calculated from	● Last inspection ○ First issue	○ Last issue ○ Remaining time
Inspection after months	12	
Dynamisches Intervall		

Fig. 6 Window of TDM System Base Module
Source: [TDM System Manual]

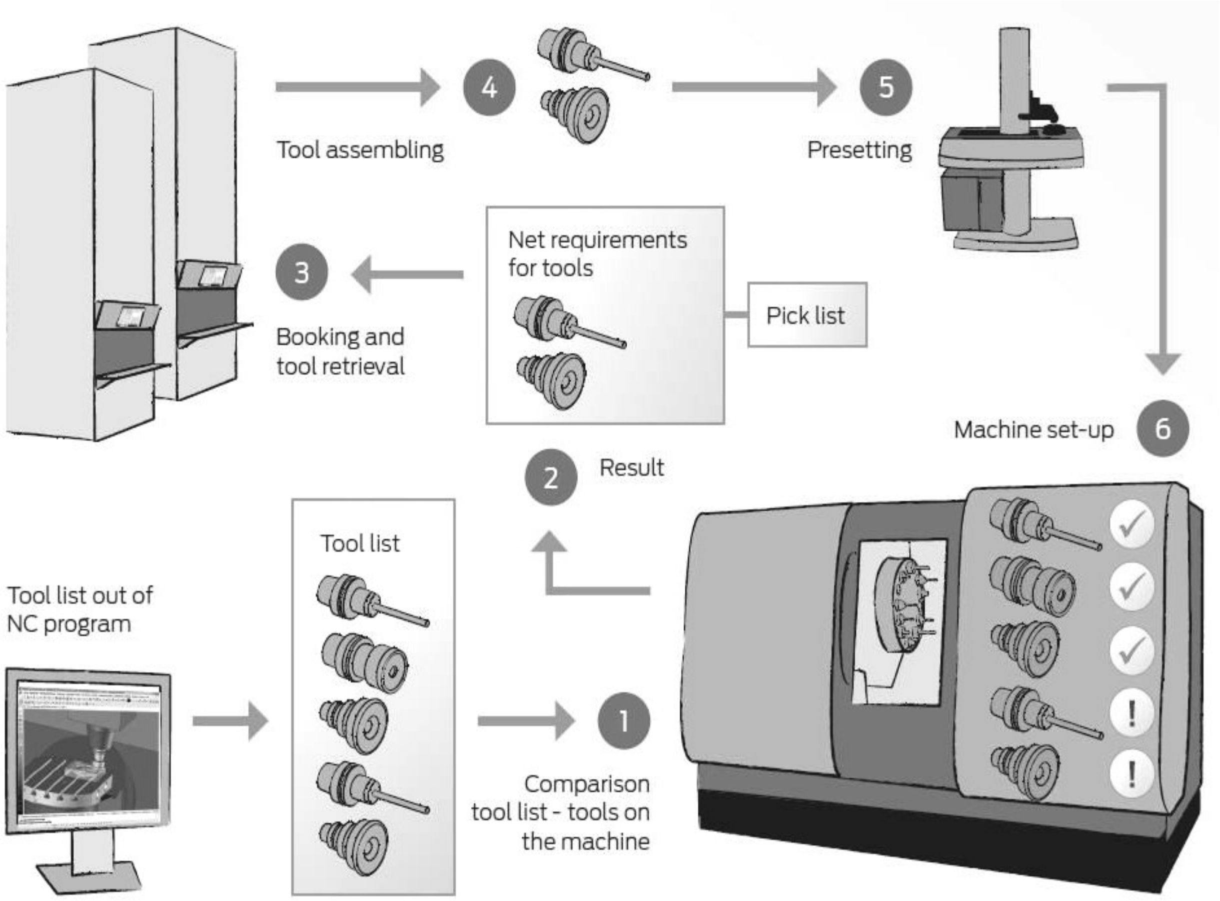


Fig. 7 Providing tool lists for production with TDM's Machine Tool Manager
Source: [16].

Table 1
Benefits from implementing Tool Data Management System

Figures / **Type of machining**	**Beading**	**Machining**
Number of machines in the company	83	22
Number of shifts per day	2	2
Average setup time	1.5 h	0.5h
Number of new jobs per shift and machine (approx.)	1	2
Reduction of setup time	15%	10%
Number of new NC-Programms per month	110	260
Average number of tools per NC-Programme	20	6
Average time required for one NC-Programm	7h	1,5h
Time required for tool data asquisition and documentation	30%	20%
Time reduction for tool data aquisition and documentation	25%	25%
Percentage of tools exchanged during setup	70%	40%
Time required for tool handling (assembling, preseting, disassembling, stocking)	10 minutes	5 minutes
Time reduction for tool handling	7%	5%

Source: own elaboration based on company data.

The window of TDM Base Module is presented in Figure 5.

TDM Gauge and Calibration Module supports the organization and supervising of calibration measurement and inspection equipment. The functions of this module are:

- predefining of inspections plans according to VDI/VDE/DGQ2618,
- management of measurement documents,
- registration of measurement uncertainties and traceability of measurement results,
- statistical analysis of measurements,
- reporting by frequency of use and inspections.

The window of TDM Gauge and Calibration Module presents Figure 6.

Providing the tools for production with TDM Machine Tool Manager is shown in Figure 7.

The NC program generates tool requirements for a new production. The tool list is compared with the current tool inventory of the machine. This provides net requirements for tools and generates a detailed pick list. The tools are booked in the tool cabinet according to the pick list. After the tool retrieval, tools are assembled . Then they are preset and the machine is setting up.

IMPLEMENTING OF THE SOFTWARE IN THE INDUSTRIAL PRACITCE

The company produces a broad range of types and sizes of steel components in four plants. The high product diversity results in high demand on different tools. The company owns over 100 CNC machines. Half of the machining is milling, and the other half is turning. The number of tools in stock exceeds 9000 items and the number of NC programs exceeds 4000 a year.

The main problem of the tool management was low efficiency of the tool purchasing process and the increasing cost of tool stocking.

The software, through the centralized data base supports tool data like geometry, cutting parameters (feeds, speeds) and supplier data for all company divisions. The TDM software modules also support the user in programming and presetting the machines.

Among the benefits of implementing Tool Data Management one needs to point out:

- the connection between previously separated areas of tool management in different plants, and the synergy effect in ordering processes,
- replacing old "registration cards" with digital data with real time access to the whole tool information,
- software integration with CAM Systems and the possibility of using the data stored in tool software (such as geometry data, feeds & speeds, cutting conditions and collisions data) in NC programming

SUMMARY

Modern tool management moves towards integration of tool management on each stage of tool lifecycle with planning, production and other company systems.

Systems based on Tool Lifecycle Management can ensure:

- time and cost savings resulting from well-organized tool storage and circulation of inventories and cutting hidden stocks,
- reduction of time required for tool selection, preparing and providing to workstation,
- process reliability by reproducible feed and speeds and operating conditions,
- reduction of machine downtimes,
- improvement of the designing process resulting from simulation of technological operations and machines collisions.

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