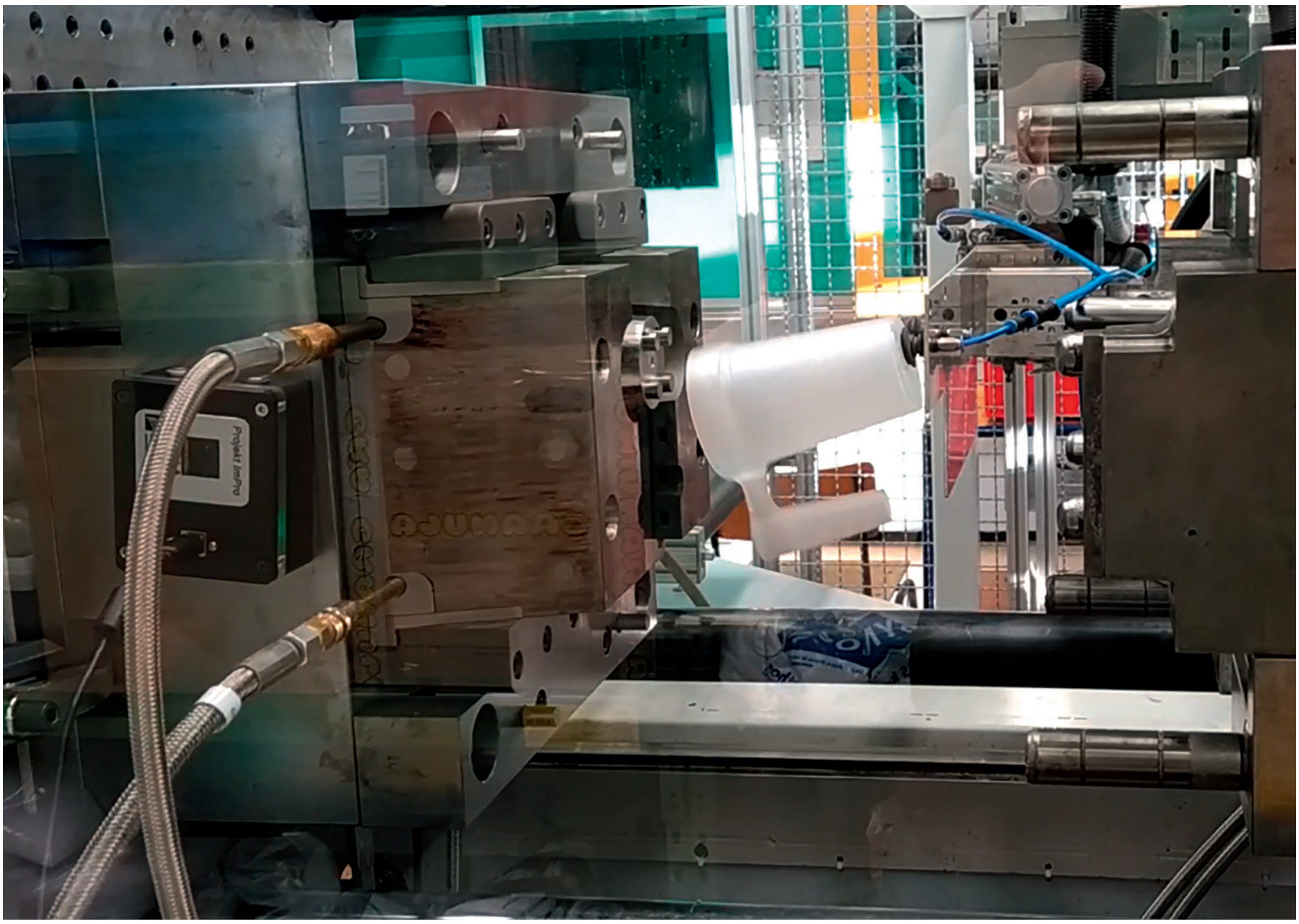
Data Management at the Tool

The Electronic Tool Logbook as a Combination of Operating Manual and Check List

A tool logbook on paper is often not to hand just when you need it most. Or it is incomplete, since it is time consuming to keep the information up to date. A cloud-independent, electronic tool log, which is directly integrated into the tool could make all the relevant data available directly. Digital access would allow authorized users to read or enter content, and, if needed, provide important operating instructions and information about the condition of the tool.



The installed ImPro module in use on a demonstrator tool under production conditions

The proven functionality and production capability of an injection molding tool always depends on the accompanying documentation. While the tool is in use, this should be at the user's fingertips, like the car manual in the glove compartment. Experience teaches us that we will need to consult the manual just when we least expect it. Predictably, this usually only occurs on the first start-up or recommissioning, or for proof of maintenance. In all cases, it is essential to know where it is stored and to rapidly locate the important content in order to quickly find the desired results and prevent damage to the tool or injuries to people.

A well-designed and maintained tool logbook contains a collection of infor- »

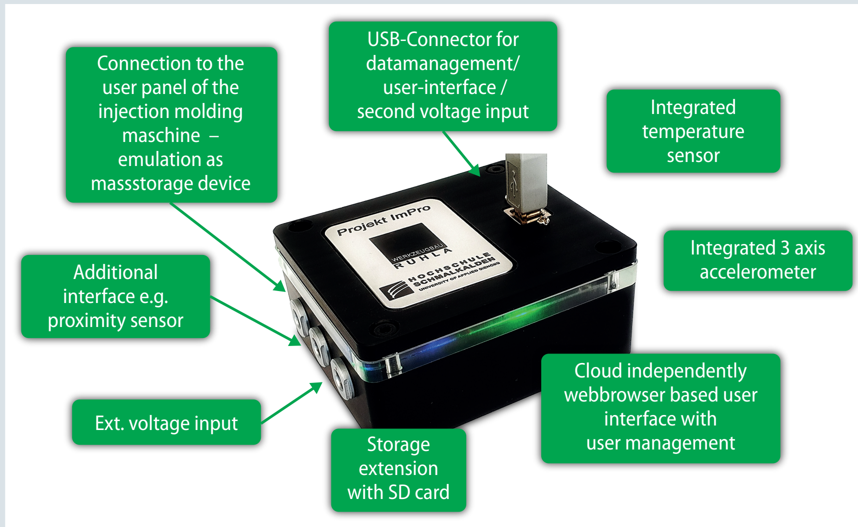


Fig. 1. The heart of the ImPro module with its diverse integrated functions, sensors and interfaces is a 1 GHz Cortex A8 processor with specially modified Linux operating system Source: University of Schmalkaden; graphic: © Hanser

mation that allows users to work safely and correctly with a tool, in a similar way to the instructions for use. The term "instructions for use" is taken from the European standard EN 82079–1, which regulates the preparation of instructions for use. In the best case, the tool logbook contains all information about the entire tool lifecycle.

This includes the basic tool description in the form of technical drawings and/or 3D data, a functional description, information for transport, storage, assembly, installation, commissioning, configuration, operation, maintenance, care, troubleshooting, disposal and other relevant technical data. It is important to know that it is not always necessary to supply a printed copy of the instructions for use, but to provide them entirely or additionally as a file on a storage medium or as web downloads.

The Obligation to Instruct Users Involves Significant Liability

The manufacturer of a tool has an obligation to provide instruction for users. He must meet this by giving them instructions for use. This is therefore a component of the tool, which regulates the use, maintenance and/or servicing, in order to provide safety and safeguard health according to the product safety law (ProdSG). Legally, it should be pointed out here that faulty, incomplete or incomprehensible instructions for use represent a material defect, and can thus lead to a claim for rectification, withdrawal from the purchase contract or reduction of the purchase price.

Within the scope of product liability, faulty instructions for use can, in the event of damage or injury, become a considerable financial liability risk for placing the product on the market. In view of the aforementioned legal aspects, it is clear that complete and well prepared tool documentation should form a natural part of an injection molding tool.

Mini-Computer at the Injection Mold

With the advances in digitalization of the production process and environment, it is clear that a system that not only contains and digitally implements the content of the conventional tool log should also meet additional functional requirements. The most important thing is that the tool log book must be easy and intuitive to create and maintain. Another goal is to prepare the content such that it is more understandable for the user and more reliable to handle.

With this goal in mind, Werkzeugbau Ruhla GmbH, Seebach, Germany, and the University of Schmalkalden, Germany, set up a research project focused on implementing digital storage solutions in production tools with the aim of audit-proof documentation (ImPro). The requirements described above were transferred to an "ImPro"

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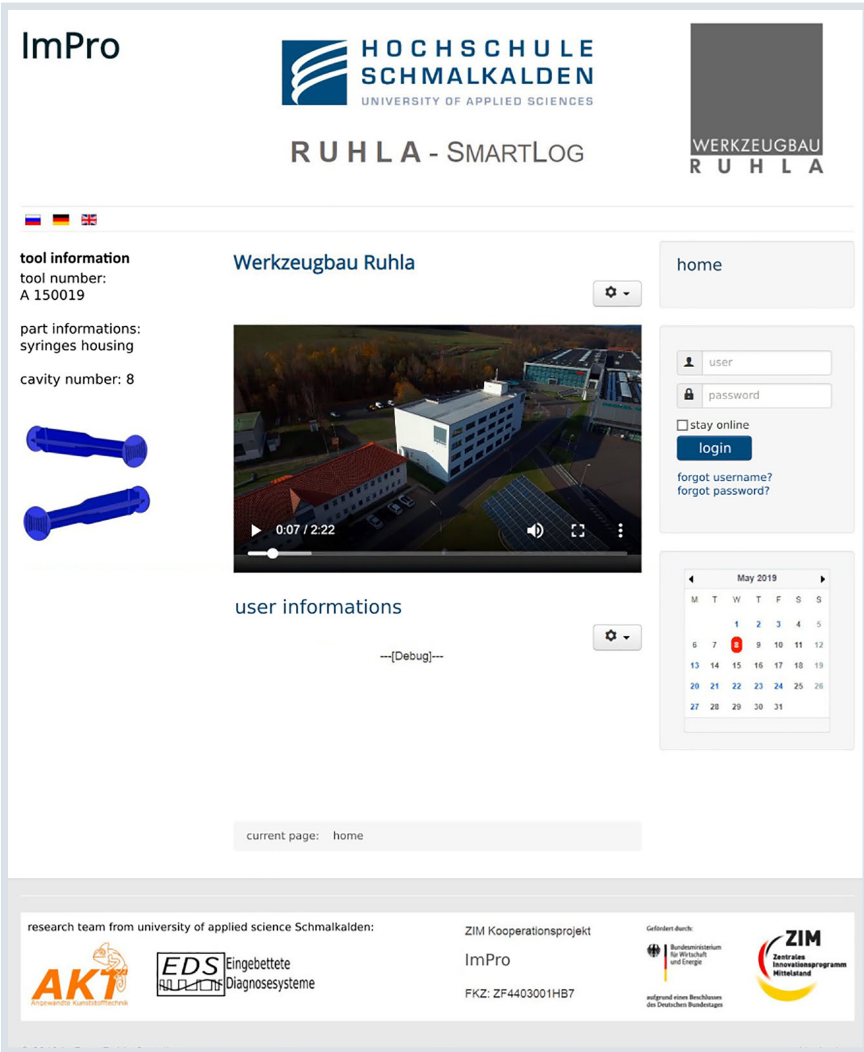

Fig. 2. Start screen of the user interface in the web browser with language selection, short overview of the manufacturer's tool data, access mask with password control and calendar overview. The illustrated QR code is used to access a video giving a short presentation of the ImPro user interface © University of Schmalkaden / Research Group of Embedded Diagnostic Systems

hardware module (**Fig. 1**). In the scope of the project, modified hardware with additional functions for use at the injection molding tool was developed. This minicomputer is equipped with a robust housing and plug contacts suitable for service at the high temperatures that are typically found in plastics processing.

In the research project, it was also possible to test the prototype under production conditions. The data stored there cannot be simply retrieved as with USB storage. Access to the data is regulated by a modified role management with access control. All the information are tamper-proofed and automatically stored in an audit-proof way at the tool. The entire life cycle (maintenance reports, error logs, etc.) can be called up at the tool without a network or Internet connection. Besides the technical specifications, aspects such as user-friendly operation, optimized size and low purchasing costs are also taken into account.

Digital Storage Solution, Integrated into the Tool in a Tamper-Proof Way

The digital tool log book is integrated into the tool independently of an electricity supply. The ImPro module's software operates independently of the particular PC platform or of the user's device (Windows, Linux, Mac). The hardware uses a specially modified Linux operating system (Linux impro kernel 4.9.82-ti-r102, ImPro-OS), taking into account the following aspects:

- Configuration of the hardware components, »

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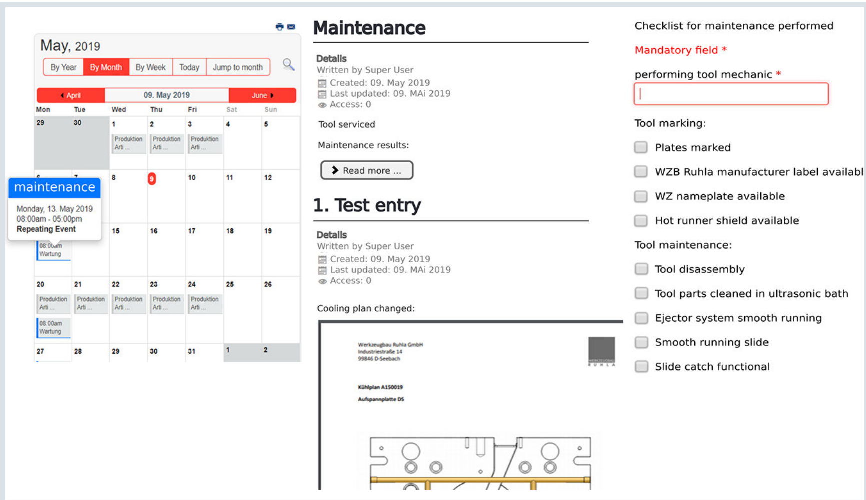

Fig. 3. User interface showing the integrated maintenance calendar (left), results of the maintenance with inserted pdf (center) and draft of a check list for planned maintenance (right). All content can only be read or captured by authorized persons © University of Schmalkaden / Embedded Diagnostic Systems research group

- embedded operating system,
- user interface,
- emulation of mass storage,
- monitoring the hardware components (sensor querying, memory),
- monitoring/protection of the data base (tamper protection, versioning/encryption, backup strategy).

The only prerequisites are a USB connection and a web browser (**Fig. 2**) on the terminal device. Tamper- and audit-proof storage was an key aspect in the implementation of the ImPro module. Both the operator and manufacturer can use it as a basis in case of a warranty claim. This basis is currently not available in practice and consequently leads to resentment in the partnership between the mold maker and injection molding processor.

The content of the ImPro module includes:

- A connection diagram for tool temperature control,
- details of the hot-runner system,
- a production flow chart for the tool,
- maintenance schedules and logs,
- assembly videos or assembly and dismantling plans.

An innovative option is thus available for the permanent tamper- and audit-proof storage of the complete documentation, directly in the injection mold under industrial service conditions in an injection molding shop and taking into account the users' different IT skills.

Videos with Assembly or Maintenance Instructions

Users and maintenance staff require a thorough understanding of the construction of a tool in order to be able to operate and maintain it correctly. A lack of knowledge – if the documentation is not present or not immediately available – can lead to suboptimal actions in operation and maintenance of the injection mold. This could result in irreparable damage to delicate structures in the tool or, in the worst case, to production downtime.

Besides technical documentation, users can also receive further documents or data, e.g. videos or animations with assembly and/or maintenance instructions. These service options were conceived on the principle of "a picture say more than a thousand words," to allow an information flow irrespective of the local language. The interactive maintenance process and its documentation by photos and videos can thus be visualized.

A typical view of the ImPro user interface shows the integrated maintenance calendar, alongside a maintenance entry with a modified drawing of the cooling channels and a draft log for maintenance with check list (**Fig. 3**). In addition to this information, the user interface is also capable of interactively displaying 3D data in STL format (**Fig. 4**).

Automatic Updating on Product and Tool Modifications

Another interesting feature of the ImPro module is the integrated 3-axis accelerometer, which permits detection of g-forces in all spatial directions (**Fig. 5**). This permits direct measurement of the tool state, e.g. in the form of a tamper-proof indirect software cycle counter or for detecting a tool crash during transportation. The machine cycle, faults and incorrect or unauthorized use can thus be indirectly recorded and stored.

The tool velocity (red curve) is shown at the left (**Fig. 5**), it was registered via the machine control unit and, the velocity calculated with the ImPro module is shown at the right. Depending on the assembly option, the ImPro module can perform an independent position determination in the XYZ direction of the Earth's gravity and calculate the acceleration vector. The acceleration values can be integrated to convert them to a velocity

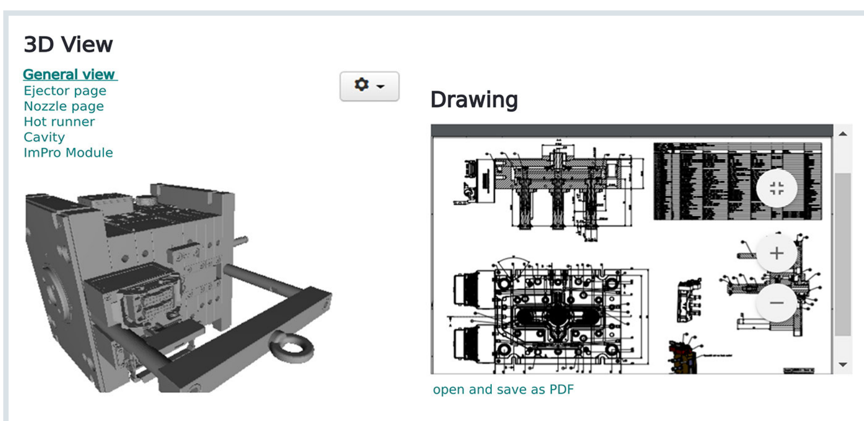

Fig. 4. Display of relevant tool data in the user interface, e.g. pdf, 3D-data, maintenance logs or assembly videos © University of Schmalkaden / Embedded Diagnostic Systems research group

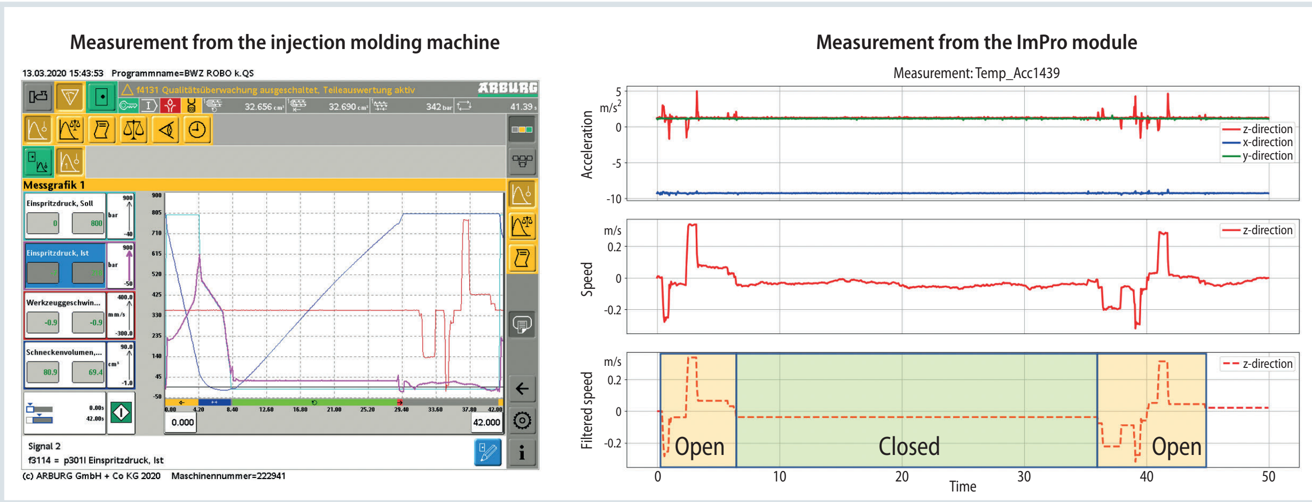

Fig. 5. Comparison of status monitoring at the machine side (left) and tool side (right) and display of the processing of the integrated 3-axis acceleration signal, which can be used as an indirect software cycle counter Source: University of Schmalkaden; graphic: © Hanser

curve. They are then filtered to obtain a curve comparable to measurement by the machine.

The complete technical documentation of the tool can be extended with a wide range of additional information, such as a detailed connection diagram for temperature control, precise and comprehensive details of the hot-runner system, a production flow chart of the tool, maintenance plans and logs as well as corresponding assembly and disassembly plans and transport instructions. It is certainly also helpful to be able to automatically save the process data of the last machine cycles via the USB interface.

They are then directly available independently of the machine for maintenance, troubleshooting and recommissioning. It is now a thing of the past to search for urgently required information in situations where time is often critical. The same is true of lost, incomplete or outdated documentation, which often generates very high costs as soon as repairs or complex maintenance are required. In this respect, documents are almost automatically updated with a visible history in the event of product and tool modifications.

Components and Integration into the Injection Mold

The ImPro module consists of two hardware components. It centers on a 10 cm x 8.5 cm x 4.3 cm box with three plug connectors on the side and a USB-A port on top (**Fig. 1**). The electricity supply of the ImPro module can be ensured in three ways, depending on the application. The first option is for operating the module at the injection molding tool (**Title figure**), using an external 230 V power supply. When the injection-molding machine is in operation, the integrated modified Linux operating system boots up.

The second supply option can be implemented via a coded connecting cable to the operator module of the injection-molding machine. This connection also serves for data transfer from the machine to the ImPro module, which logs on to the machine control unit as a USB storage.

The last variant serves for supply when the tool is decommissioned, e.g. in storage or during transport. In this case, the module can be supplied directly via the USB-A interface. Power management is ensured via an integrated power-path multiplexer and additionally protected against overvoltage by means of other safety mechanisms.

A 1 GHz Cortex-A8 AM335x processor drives the module and is specified for the service temperature range between 0 °C and 85 °C. The operating system is adapted to the IoT (Internet of Things), without any graphical user interface at all, and therefore manages with significantly reduced resources. To allow it to register the operating state even without display and PC, an RGB-LED was integrated into the module, which signals the boot state or activity by changing color. An additional interface can be used to connect an external limit switch contact or inductive proximity sensor to the ImPro module. However, this functionality does need to be preconfigured, depending on the problem.

Summary: Providing Useful Data and Overcoming Language Barriers

The ImPro module can be regarded as electronic tool documentation, a tool log book and a smart tool nameplate. The information stored here may be in the form of images, text, sound or video. The access-protected, browser-based user interface is modular and shows the product to be manufactured on the home page (**Fig. 2**). Versioning of the stored data prevents the loss of important documents throughout the tool history, which can be made accessible with the necessary authorization.

The performance of correct maintenance and handling is supported by making the necessary documentation permanently available in digital form at the tool and by allowing an interactive sequence of the individual maintenance steps to be called up. Checklists and plans are provided and can be checked off as required. This is intended to support optimum tool quality throughout the lifetime. The different documents can be saved as PDF, CAD, video or image formats in the ImPro module.

At the current state of development of the hardware and valid software, the project partner Werkzeugbau Ruhla, coordinating with the University of Schmalkaden, can equip complex injection-molding tools with the system on customers' request. The specific content of the unique tools is modified by means of a predefined software backend. ■