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A NEW CONTROL- AND FEEDBACK-CONTROL-SYSTEM FOR FORCE AND TORQUE STANDARD MACHINES

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Abstract – A new control- and feedback-control-system for Force and Torque Standard Machines was developed in order to fulfil metrological and functional requirements. Different functionalities were programmed as independent modules, e.g. software modules for deadweight machines with sequential or exchange stack can be linked with modules for lever or hydraulic amplification. During the realisation of the concept, a strict requirement was that the application of the control system is possible to older, existing Standard Machines as well as to new Standard Machines, in order to allow retro-fits and upgrades. New features of the user interface allow easy connection of external devices like temperature chambers and the implementation of their functions in a calibration process without changing the software.

This paper outlines the concept of the system and gives details of how it was developed to become a universally applicable part in the GTM range of machines. Furthermore, some successful examples are given where more operational reliability and for this reason more measurement certainty has been reached by fitting the new system to older Standard Machines in the process of an upgrade.

Keywords: Control System, Standard Machines.

1. INTRODUCTION

Constant refinement of the control and operating systems of force and torque standard machines over the years has produced two major results:

Machines designed and built today have a functionality, reliability and serviceability similar to other kinds of modern industrial machinery and process equipment, paired with an enormous level of flexibility.

The second result concerns older existing machines. Their control systems have become entirely outdated, leading to poor reliability, expensive maintenance, and even decommissioning as their hardware is no longer serviceable.

This has prompted GTM to draw up a concept which makes the most possible use of up-to-date technology, providing operators of standard machines with one common user interface, whilst at the same time allowing the highest amount of flexibility in terms of machine design and type, optional fixtures and external components.

Taking this concept one step further, it is also possible to retro-fit it to existing standard machines of almost any kind.

2. DESIGN CONCEPT

The new control system would have to handle every type and capacity of standard machine available from GTM, as well as capacities and designs of other manufacturers. The appearance of the controller to the operator would have to be identical throughout. Hence, if a person can operate one kind of machine, he or she can in principle operate any other kind with very little training, a significant advantage for laboratories with more than one standard.

There are several optional devices for standard machines, such as temperature chambers, magazines, indicators and measuring amplifiers. For all of these, the system needed to be adaptable.

GTM's proven dual philosophy of control systems, i.e. a programmable logic controller (PLC) operating the machine hardware whilst the operator enters his commands through a PC-based graphic user interface, was expanded to allow the inclusion of fast closed-loop controllers.

Analogue devices were eliminated as much as possible. Fully digital closed-loop control is achieved through specially developed software. Measuring amplifiers, motor drives and many other devices rely entirely on digital signal processing, leading to higher reliability and making changes and modifications easier.

Figure 1 shows some of the hardware systems which may be encountered.

3. PRINCIPAL COMPONENTS

Figure 2 shows a block diagram with the major devices, the signal flow and interfaces provided to the various kinds of hardware components.

Central point of all GTM control systems is the operator software, or graphic user interface, appropriately called "ForceManager" or "TorqueManager", as the case may be. It runs on a PC, which is positioned conveniently as a workstation where the operator normally works, under MS-Windows™. It also handles the entire data management and interfaces with strain-gauge amplifiers through RS232.

The universal control rack (UCR) forms the heart of every GTM feedback control system, i.e. it takes responsibility for all processes requiring closed-loop load control. It is based on an independent industrial PC and is freely programmable for a wire variety of tasks.

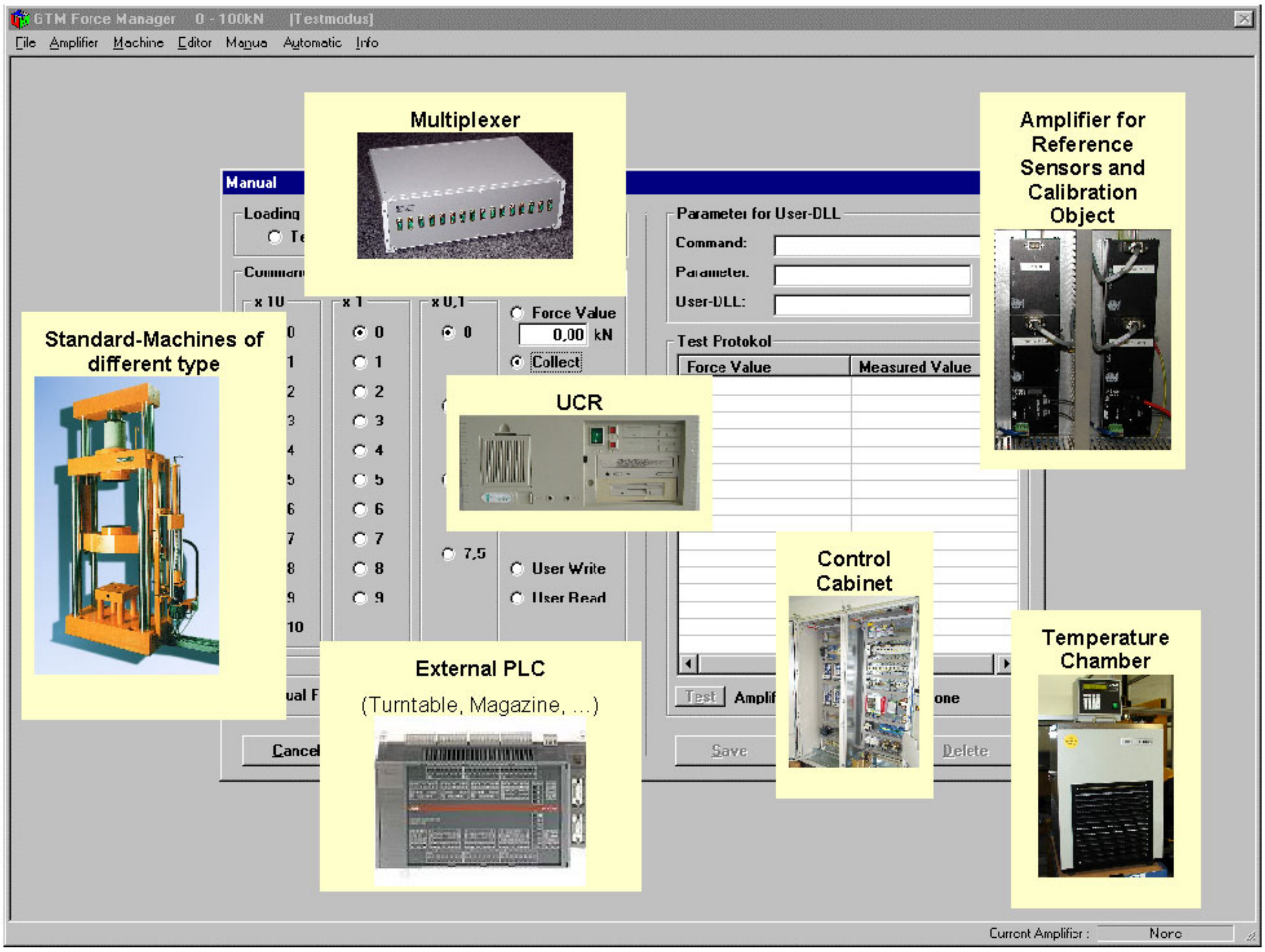

Figure 1: Some hardware systems

For machines having a very large quantity of sensors and actuators, or for such that do not require closed-loop control, a PLC is used. It also stores the actual operating program.

For machines relying in one way or another on signal processing from a strain gauge sensor, measuring amplifiers of the type LWL-DMS are used to condition the signals required, and pass them on to the UCR. The digital interface provided uses fibre-optic connection. Any number of such amplifier modules and other devices can be connected, with synchronous readout to within a few microseconds.

Other additional components that may be fitted are input-output devices, such as to operate temperature chambers, turntables, magazines or multiplexers.

4. SOFTWARE STRUCTURE

The software required for the whole range of machines can be split into the following parts:

- the user interface software for the operating PC (ForceManager or TorqueManager)
- the UCR program including
- the closed-loop feedback controller, if required
- the PLC program, if required
- evaluation software, if required.

The user interface software is written in Visual Basic™ and runs on the operating PC. It consists of a number of modules linked together as needed. Thereby, the operating software is tailored to the individual requirement. This method lends itself to retro-fitting to existing machines, since these fall normally into similar design categories, and the software does not depend on a particular make or manufacturer of hardware components.

The UCR program is written in Visual C++™ and forms the backbone of the actual system. If a closed-loop controller is required, a corresponding software module is included and adjusted. It runs on the UCR processor, again being in Visual C++™ code. It is activated by the UCR when required, e.g. in a lever machine to continuously balance the lever according to the signal of the strain controlled lever bearings.

Certain types of machine rely on a PLC for the actual operation of the hardware components. In such cases, a PLC program is written in the appropriate language and stored in the memory of the PLC controller. Depending on commands sent through the user interface, the PLC will acquire and evaluate digital and analogue inputs, and generate the corresponding outputs to operate motors and other devices.

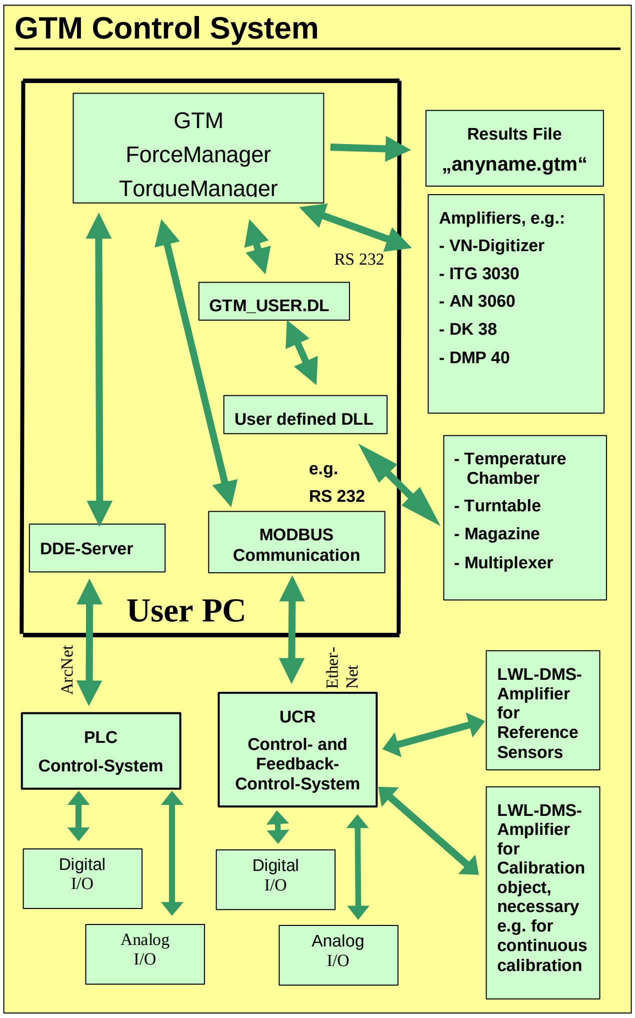

Figure 2: Block diagram of the Control System

A DataManager software module is available which takes a stored results file and evaluates the readings. The DataManager is based on an MS Access™dat a-base and handles both the measured data and the user data. The data from the results files of previous calibrations are read in and stored safely in the data-base, from where they can be called up at any time by means of comfortable search functions, e.g. using an attached calibration number or serial number. The DataManager also administrates templates for the evaluation of test results and for the generation of certificates, which are based on MS Excel™ and MS Word™, and takes care of the data transfer between the programs. Using special DataManager templates, the generation of new certificates is simplified, since the difficult handling of the measured readings is solved by the software. The various additional data from the results file can be conveniently pasted into MS Word™ as text by selection from the menu. There is no longer any requirement for detailed knowledge of word processing and spread sheets, and no more macro programming is necessary. Pre-programmed evaluation routines according to ISO 376, OIML R60 and other standards are optionally available as MS-Excel™work sheet s. Figure 3 shows the principle of data input and transfer, Figure 4 shows the general advantages of the Control system.

5. APPLICATION TO VARIOUS MACHINE TYPES

The standard range of GTM machines is equipped with controller modules as indicated in Table 1. Further extensions for particular requirements are possible.

TABLE I. Controller components applied to the various machine types

Controller component / Machine type	Operating PC + ForceManager	Operating PC + TorqueManager	UCR + software	Feedback controller + software	PLC + software	DataManager	Temperature chamber interface	Magazine interface
D/W (Force) with sequential stack	yes	no	no	no	yes	optional	optional	optional
D/W (Force) with exchange stack	yes	no	yes	yes	yes	optional	optional	optional
D/W (Force) + lever amplification	yes	no	yes	yes	yes	optional	optional	optional
Hydraulic (Force)	yes	no	yes	yes	no	optional	optional	optional
Jockey weight (Force)	yes	no	yes	yes	no	optional	optional	optional
D/W (Torque) with exch. stack	no	yes	yes	yes	yes	optional	optional	no
Jockey weight (Torque)	no	yes	yes	yes	no	optional	optional	no

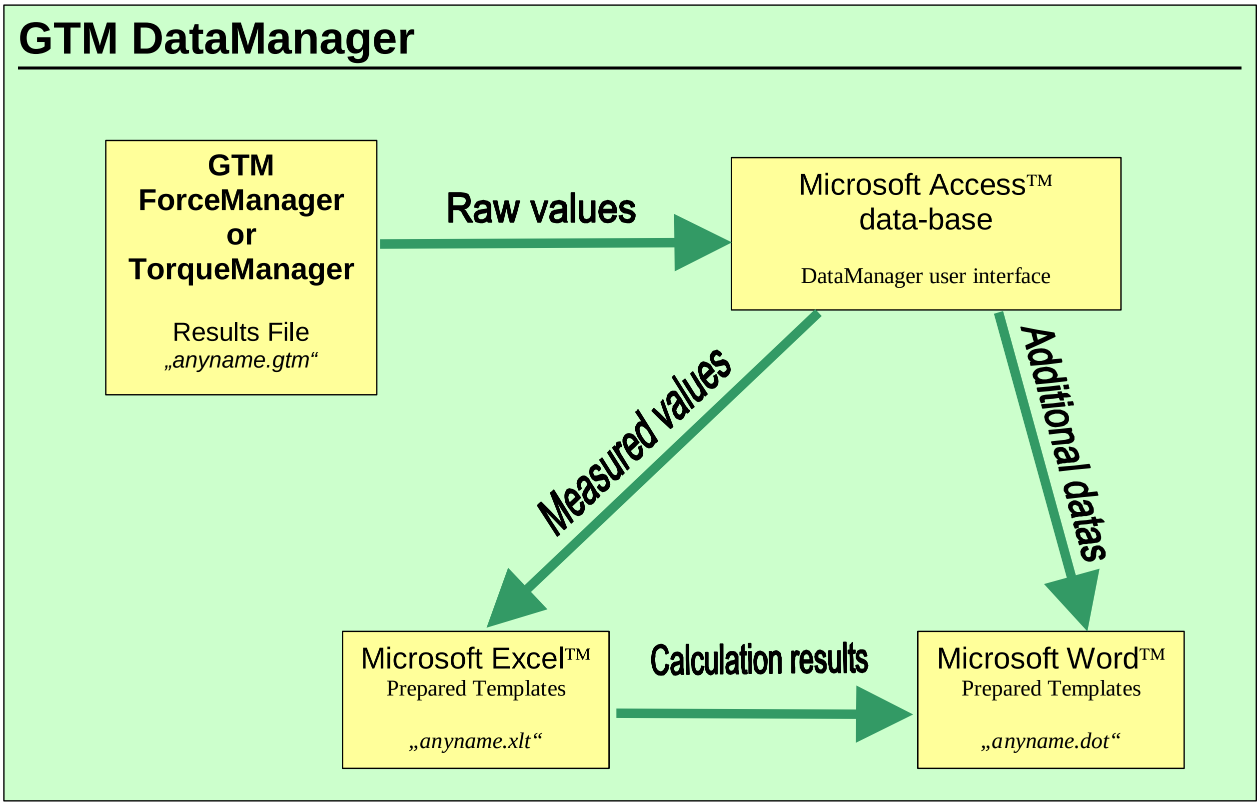

Figure 3: Data Input and Transfer using the DataManager

Advantages of the GTM Control System:

- **Modular solutions for all types of force and torque standard machines**
- **Special feedback control system for force and torque requirements**
- **Easy integration of various accessories at any time by adding small user- defined software modules**
- **Automatic mode of operation with self-explanatory macro programming**
- **Data management system for calibration certificates based on Microsoft ™ products**

Figure 4: Advantages of the Control System

6. ADAPTATION TO EXISTING MACHINES

The application of the new system to an existing machine is outlined along the example of the 100 kN / 1 MN force standard machine built by Schenck for Statens Proveningsanstalt (SP) in Sweden. This machine consists of a 100 kN deadweight part with a total of 62 mass disks and a 10:1 lever amplification system, based on knife-edge lever bearings. Originally, the machine was equipped with a relay-based control system, the repair and maintenance of which had become uneconomic and very difficult.

During a visit to SP, the main components, functions and interfaces of the machine were identified. This allowed the tailoring of the GTM control system design to this specific application. Additional requirements by the machine operator, such as the interfacing with a temperature chamber and a turntable, were implemented at this stage. Although none of the existing components involved were of a design normally used or specified by GTM, the extensive flexibility of the control structure allowed easy communication with every hardware device.

In a second step, the control software was generated. Using the modular design of the ForceManager software as well as the flexible programming facilities of the PLC language, both operating and control software were written so that the full functionality and metrological characteristics of the machine, as specified at the beginning of the project, were achieved.

It should be noted here that the control philosophy of this Schenck machine is quite different from that usually applied to GTM lever machines. The force control relies on the maintenance of a horizontal lever position, the latter being indicated by a LVDT-type position sensor (Linear Variable Differential Transformer). Nevertheless, there were no difficulties in adapting the control hardware to utilise this and other sensors, and also no major problems in the programming of the control algorithm, although this is naturally quite different to software used for GTM lever machines.

Similar retro-fit control systems were designed and supplied to a number of other machines at various companies and institutes (e.g. PTB Braunschweig, METAS in Switzerland, Revere Transducers Europe). Although these included greatly different designs of machines (deadweight, hydraulic, lever amplification), the basic components of the control structure and the user interface software are the same for all of them. This has the benefits of being able to quickly and economically re-fit virtually any existing hardware with a new control system, and also means that a person who is able to operate one type of standard machine which uses this system would be able to quickly learn how to use another, quite different, type.

The metrological benefits should also not be overlooked: Since an upgrade of this kind leads to a great increase in functionality and reliability, calibrations carried out on machines thus modernised depend to a lesser extend on operator skills and are less prone to data-loss or corrupted readings. In many cases, results obtained in this way are equivalent in precision and measuring uncertainty to those taken using brand new standard machines.

7. CONCLUSIONS

Recent developments in commercially available components for control applications have allowed to achieve significant improvements of control systems for force and torque standard machines.

By identifying the requirements, metrological and otherwise, a philosophy for suitable control systems has been realised which will be applicable to machines of almost any design, both for such built in the past, present and in years to come.

The philosophy is both transparent and modular, so that cost effective, functional and reliable solutions are available for almost any standard machine application. This applies in particular for existing machines whose control system needs replacing.

The concept and its realisation appear to be well capable of handling further developments in standard machine design and hardware, since they have already proven invaluable for machines of the jockey-weight design, the latter leading the way towards standards for the future.

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