Cambashi

Industry Knowledge for Business Advantage

52 Mawson Road
Cambridge CB1 2HY
United Kingdom

Tel: +44 (0) 1223 460 439
Fax: +44 (0) 1223 461 055
www.cambashi.com
info@cambashi.com

Connecting manufacturing engineering and the shop floor

- a manufacturer's signature of efficiency

Author: Peter Thorne, Cambashi

Registered in England and Wales No. 1360554. Registered office as above. VAT No. GB 393 1001 82

Introduction

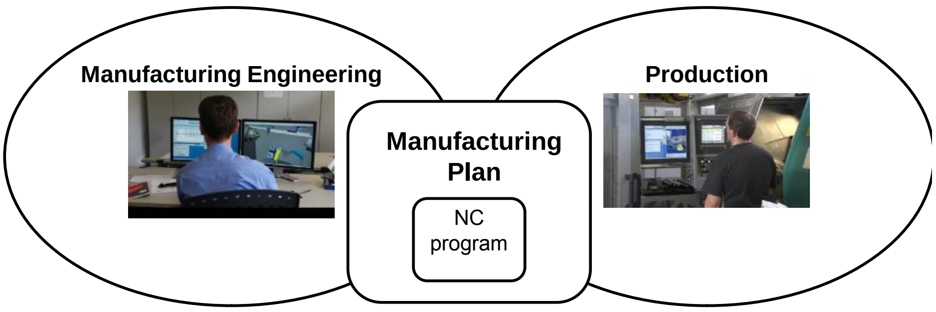
This paper is written for engineers and managers working with components and parts in design and manufacturing environments. It examines the potential of product lifecycle management (PLM) technology (see note) for the management of shop floor data.

In the virtual world of design and manufacturing engineering, PLM has successfully delivered information management including managed workflows, flexible configuration handling, change management, and robust version and access control. For companies involved in global operations, this capability can extend across multiple sites, supporting partner firms and tens of thousands of users by delivering consistent datasets with status information that can be trusted. A successful deployment replaces the costs and delays of uncertainty with confidence the right information is available for every task and decision.

However, as information progresses to the physical world of the shop floor, in many organizations the information management regime becomes more fragmented. Somehow, the complexity of information, the effect of point solutions on the shop floor and other business system connections, such as ERP or other bill-of-materials and scheduling systems, have combined so that smooth operations depend on constant interventions to solve data consistency issues.

Could a PLM system be configured with a manufacturing data model to create a single source of information that eliminated these problems? In this document, the complete set of information used on the shop floor to define every action and resource needed to make a product will be called the 'manufacturing plan'. An NC (numerical control) program - the software to control automated production machines - is one component of the manufacturing plan, and, as one of the most challenging items to manage, will be used as a central example (see fig. 1).

Figure 1: Numerical control (NC) programs are a critical part of the 'manufacturing plan'.



photographs source: Siemens

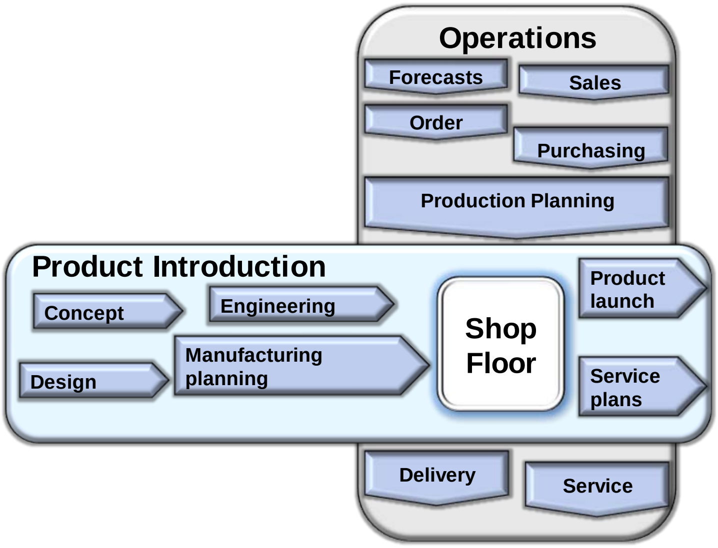
note: The phrase „Product Lifecycle Management' is sometimes used in a limited way to describe workflow and version management functions surrounding engineering information. Here it is used to describe not only these management functions, but also an extended vision including integrated creation and use of technical information.

Every manufacturer needs to manage information

Efficiency and flexibility

The shop floor is at the intersection of two of the most important processes of a manufacturing business (see figure 2). 'Product Introduction' is the process that starts with market needs and ideas, and progresses these to a product launch. 'Operations' is the process that converts orders into products and services delivered to customers.

Figure 2: Two major business processes intersect on the shop floor



Manufacturers must constantly find the optimum trade-offs between competing objectives. Lowest shop floor unit costs can be achieved in an environment of minimum change, with long runs of large batch sizes, stable product mixes, and product-specific automation. However, market competitiveness demands new products, customization and rapid response, which together require short runs of small batches, unpredictable product mixes and flexible assets rather than hard-wired automation.

As a result, most shop floors are places of continuing change. Existing production assets are upgraded, reconfigured and adjusted to improve efficiency, enhance flexibility and meet new manufacturing demands. New assets are acquired and commissioned to increase or change capacity and capabilities. New relationships with suppliers, partners and customers lead to new shop floor procedures. Multiple sites may be geographically distributed, and the business may need to change the product set being manufactured at each site.

> "Development of an nc program for a new machine tool is not easy. The part-programmer needs knowledge of the behaviour of the machine tool and its controller. A programmer might learn characteristics such as acceleration and deceleration as well as details of timing and relative movement of cutter and workpiece by watching the machine tool – but not if it is at a remote factory."
>
> **Extract from Cambashi research interviews**

So it is not only new products that trigger new or revised manufacturing plans (see panel 'A manufacturing plan....'). Every change of machinery, tooling, standards, or arrangements with suppliers and customers may require adjustment of manufacturing plans. Each new or revised manufacturing plan must be reviewed and tested before being released for use on the shop floor.

A manufacturing plan.....

... defines everything needed to make a component, part or assembly. Process development engineers must understand, and perhaps extend, the factory's physical manufacturing capabilities. Then they must apply their skills to assemble the information, including, for example:

An operations list identifying every process step in sequence and referencing standard operations

The planned routing through the factory

A tool schedule of the tools required at each work cell

The manufacturing bill of materials, identifying all parts and materials required

Work instructions, to be available to the operators responsible for each process step

Stage drawings

Setup sheets, defining, for example, a tool set, kit list, clamping arrangements and calibration procedures

Inspection and test instructions and data

This information must be structured, formatted and communicated in a way that enables the people and systems in the factory to follow the instructions. The full set of documents and other data, including NC programs, form the 'manufacturing plan'.

This flow of updated manufacturing information is relentless. The component elements of a manufacturing plan are released to the shop floor from multiple sources using different systems. Version numbers embedded in the data, perhaps combined with separate documents, identify what goes with what. An agile, responsive production facility must be able to absorb and use the information. Yet, all too often, there is uncertainty and sometimes error. Is the new clamp setup intended to be used with all the same parts as the old setup, or just some of them? Additional ad-hoc communications are needed to solve ambiguities, and this leads to cost and delay.

Production people at all levels from management teams to operators must always be able to find full and consistent information for present, past and future production. If managed according to a manufacturing data model, the manufacturing plan will provide up-to-date, consistent, complete sets of information that can be queried to provide clear context such as where the data came from, and what it applies to.

Direct/Distributed Numerical Control

In the early days of NC machine controllers, memory was often a constraint - the controller did not have enough memory to handle big NC programs. Use of a separate computer to feed the program to the controller one block at a time achieved better automation than operators loading paper tapes. This was 'direct numerical control', DNC. But the source computer was often capable of driving more than one controller in this way. The resulting network was also known as DNC, now meaning 'distributed numerical control'.

"We store nc programs on the DNC systems at our factories. We allow operators to make changes – especially to feeds and speeds – to solve problems such as surface finish. This is good for quality but creates challenges to capture feedback and integrate version control with other CAD and CAM files."

Extract from Cambashi research interviews

From these technology-driven beginnings, DNC systems developed NC program storage and management capabilities. Many DNC systems also allow storage of additional types of file, but synchronization of DNC with other systems, and maintaining consistency with information flowing through other channels, is not always easy, and discrepancies cause problems. For example, while NC programs may be delivered to the factory as data files, related tool setup information may be printed and sent to a tool store. Fixtures may be referenced or defined in stage drawings held with production plans.

Version management of all of this information is vital. Yet in the case of NC programs there are additional points to consider. NC programs are created or changed by a manufacturing engineering team. This usually involves taking data from a computer aided design (CAD) system and moving it into computer aided manufacturing (CAM) software, which is used to design and generate the NC program. NC programs can also be created or changed in the factory using facilities of machine controllers. Intermediate forms of each NC program may be maintained for later 'post-processing', a translation which converts a controller-neutral form of the program into the exact form needed by a specific controller. So there may be multiple 'formats' of each version of an NC program. In addition, a complete NC program for a machining centre may be structured into multiple files, and some changes will not affect all the files - so the working program consists of a mixture of file versions.

Distributed Production

The engineers who develop the manufacturing plan must use existing assets or justify investment in new assets to optimise the cost-performance of production according to expected production volumes. With remote sites, and production assets that are becoming more integrated, fewer

> "The „design-anywhere, build-anywhere' strategy offers competitiveness through flexibility and load balancing across production units. But small details can cause big challenges. For example, differences in the available fixtures and tooling at different locations can create the need for completely different sets of manufacturing documentation at each location."
>
> **Extract from Cambashi research interviews**

issues can be resolved on the shop floor. Therefore the manufacturing plan must foresee all possibilities, cater for alternatives (such as different batch sizes and alternative parts) and provide instructions on what to do if, say, a work cell or the first choice material is not available.

The need for information management

Shop floor management teams invest in systems and tools for efficient, flexible production. In the area of data management, DNC systems are widely used to provide a basic level of capability. However, the DNC solution may have to work in parallel with other filing systems. This can force complex working practices, since any inconsistency is likely to cause delays, downtime and rework.

A more complete information management capability could simplify working practices by providing automatic, built-in support for data access control and workflows. If it is structured as a single data source, then the difficulties of keeping multiple data sources in step are immediately resolved.

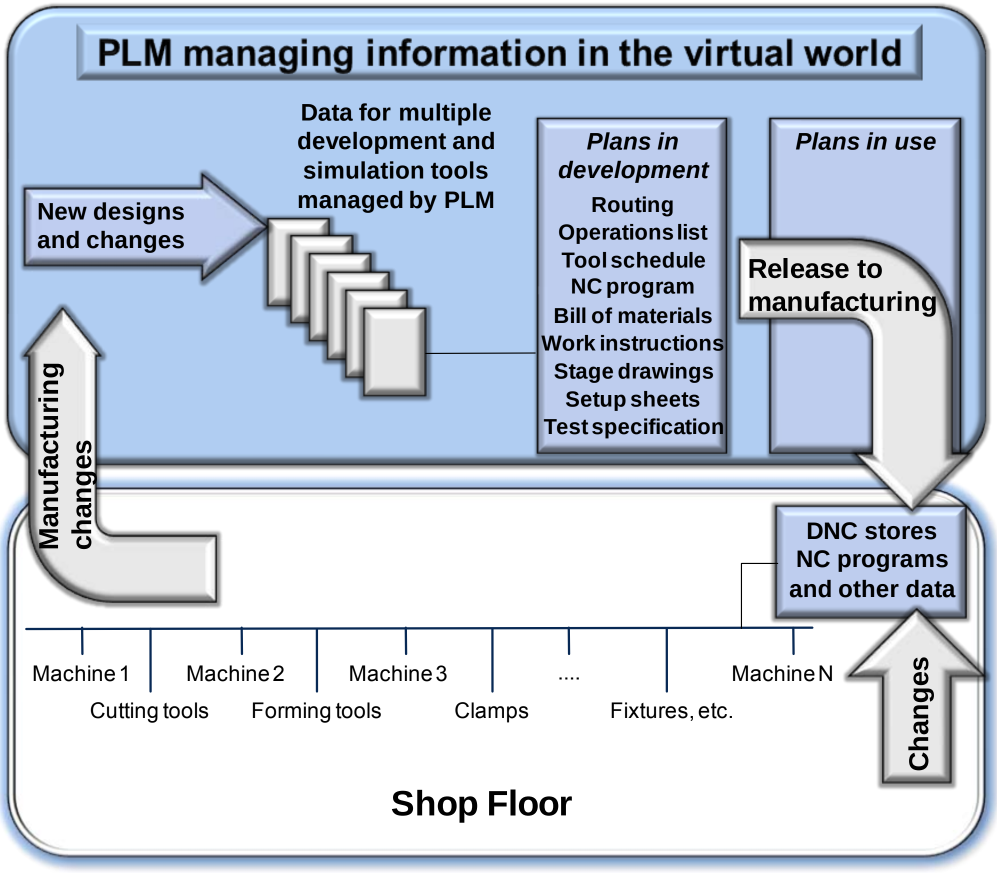
PLM provides these capabilities in the virtual world of design and manufacturing engineering. Is it able to support the needs of production?

PLM in design and manufacturing engineering

Figure 3 shows a typical example of the role of PLM for management of the information in a manufacturing plan. The PLM environment manages versions, maintains consistent datasets, supports workflows, and provides secure, managed access to the information in the virtual world, up to and including release of information to manufacturing.

Here, the shop floor has separate, independent information management. But why? PLM solutions have evolved into flexible toolkits providing controlled access to consistent datasets by potentially large populations of users who may be in geographically distributed locations. Surely this capability can be adapted to meet the needs of users in the physical world of production?

Figure 3: PLM in design and manufacturing engineering



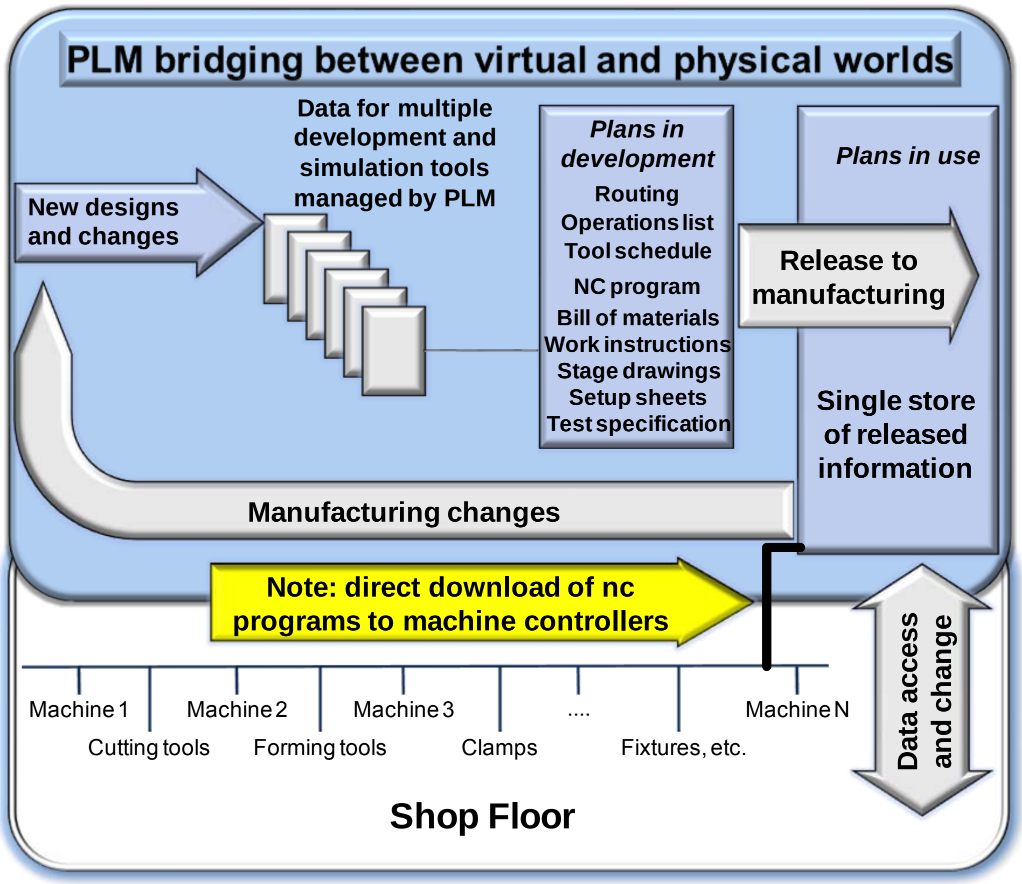
PLM for the shop floor

On almost every shop floor, there are standalone, manually operated machines which are being upgraded and replaced to create networked, automated, integrated work cells. Even a 'manually-operated' machine may have an electronic control system capable of allowing an operator to use a web-browser to access the webpages it maintains to report status, and support remote monitoring and control.

A DNC system in a factory provides basic information management, especially for NC programs, in this environment. However, it is possible to extend PLM technology to cover this function. A PLM based approach will be based on a manufacturing data model that defines the particular relationships and procedures needed by the user organization, and will help deliver a broader range of managed information to operators, enabling faster response and better decision making.

The extension of PLM to the shop floor opens up new possibilities, for example, elimination of duplicate data, and better workflow management from design through to manufacturing. The integration of 'manufacturing changes' into the managed environment used for design and manufacturing engineering potentially enables a tighter feedback loop, and faster, more effective communication between shop floor people and the design and manufacturing engineers working

Figure 4: PLM for the shop floor



on the products and processes. Regulated environments may need PLM capabilities to implement the required levels of access control, security, logs of changes and so on that are needed for an audit trail. In a business initiative aiming to link orders to production, the integrated environment may allow the order-processing side to ignore revision numbers, since this information can be gathered automatically from the PLM system.

This vision is easy to describe and draw, as in figure 4. However, the extension of PLM to the shop floor can be held back by both big-picture and practical details.

Questions to ask

Management teams have to be very careful about the big-picture of all technology used to support production. Is it 24/7? Does it depend on external communications or equipment, or can it be configured to maintain a local copy of the data needed for production? Is there enough local control to be able to handle problems? These issues are fundamental to the resilience of production operations.

Practical details are also crucial. The advantages of a single source of data are well understood. But the exact details of access to this data may be very significant. Many factories will contain a range of machine and controller types, some new, some old. Implementation flexibility is required. For example, many modern machine controllers have 'browser' capabilities, and it should be possible to use these built-in browsers to access the database. At the same time, it must be possible to choose to control other machines via a nearby PC. In both cases, it is essential the range and style of interaction are suitable for shop-floor use. For the PLM vision of integrated, managed, consistent information to reach the physical world of production, its screens, concepts, commands and performance must match the culture, capability and expectations of shop floor people.

Conclusion

Every user or buyer of DNC technology should consider PLM technology for use on the shop floor. Not all PLM suppliers will pass the 'big-picture' and 'detail' tests indicated above. But if the technology is 'shop-floor' ready, then PLM offers the remarkable combination of simplification - a single system to handle design and manufacturing information, and flexibility - configurable and customizable workflows and interfaces. This combination can position PLM as the technology base for more advanced manufacturing initiatives.

About Siemens PLM Software

Siemens PLM Software, a business unit of the Siemens Industry Automation Division, is a leading global provider of product lifecycle management (PLM) software and services with 6.7 million licensed seats and more than 69,500 customers worldwide. Headquartered in Plano, Texas, Siemens PLM Software works collaboratively with companies to deliver open solutions that help them turn more ideas into successful products. For more information on Siemens PLM Software products and services, visit www.siemens.com/plm.

About Cambashi

Cambashi, based in Cambridge UK and Cummaquid MA, USA provides independent research and analysis of the business reasons to use of IT in industry world-wide. Its specialist fields include Engineering, Enterprise, Plant, and Supply Chain applications and the infrastructure to enable industrial firms to use IT effectively. Cambashi publishes market size estimates in its Market Observatory and multi-client studies in Cambashi Reports Industry Directions. Its clients vary in size from small to large and include most of the leading software vendors and many pioneering IT users. www.cambashi.com