Douglas Knowledge Management System

Richard W. Lukanen, Jr., Principal Engineer
Douglas Machine Inc.
April 29, 2008

Douglas Machine designs and manufactures high speed packaging machinery for clients in the United States and abroad. These machines are primarily for the food and beverage industries. Founded with a five-dollar sale in 1964, Douglas continues to grow, and, since 2003 has experienced steady growth of around 30% each year.

Shrink film wrapping machines and corrugated case packing machines are the two main products offered by Douglas Machine; today, these are fully servo controlled designs. The shrink film division (known as the Contour Business Unit) typically sells its products to the beverage industry. Shrink-wrapped packages produced by these machines can be found in your local grocery aisles where spring water and sodas are kept. Douglas' Case Packers and Specials division manufactures machines that are used to package food, beverage and consumer goods into corrugated boxes. For example, the can of beans delivered to your grocery store was likely packaged using one of these machines.

In 2003, Douglas began implementing a Knowledge Management System (KMS) as part of its transition from the all-mechanical chain and line shaft era to the servo controlled machine. This paper documents Douglas' efforts and successes in implementing their KMS, and shares the ways in which mathematical modeling and utilization of a KMS has increased Douglas' client satisfaction and market share.

The Status Quo

Highly-tuned math software systems are plentiful today, so analysis methods need not be limited to ANSI standard languages such as C or BASIC. Companies typically equip their engineers with math software, but it is often the case that many engineers revert back to Excel or paper and pencils when faced with new design challenges. A study done by Maplesoft™ arrived at the same conclusion. The study found that 52% of people surveyed used hand calculations daily. 47% said they used printed reference tables in their work, while 40% of those surveyed turned to Excel for numerical computations.

The concern is that work done by hand gets lost in the desks of multiple engineers, never to be found again. Also, consider the reality of the following questions: Which reference materials were used to obtain input data? Are other engineers using different data? What about the Excel spreadsheets? How many individualized versions exist? Where are the calculations now? This is not a working KMS.

Developing the Douglas KMS

About five years ago Douglas began working with Universal Technical Systems, (UTS) based in Rockford, IL. UTS introduced Douglas to a new way of looking at programming paradigms: rule-based declarative programming.

It was through UTS that Douglas first considered a method of managing technology and information called Knowledge Management. The basic idea of a Knowledge Management System (KMS) is to keep all your information (proprietary process data, standards, and even numerical analysis programs) in a secure vault. The KMS also maintains the results of all the analyses performed, making it that much easier to reuse designs that have proven reliable.

Software life cycle maintenance issues are addressed with the KMS. Processes are easily updated because reports created in the past have a software build manager, making it possible to rebuild any program instantly. New versions of analysis codes, standards, etc. are easily managed and are kept secure in the KMS vault, with an administrator managing user access.

Douglas purchased two licenses of UTS' TK Solver in 2003. TK Solver was chosen over other math software because of its ability to backsolve for any variable, which lets users bypass all the programming. The time required to develop an analysis model in TK Solver has in many instances been up to 30 times faster than would have been possible with a procedural language.

Douglas studied the types of problems that would present themselves in the near future and developed a plan that classified groups of problems into similar schema. Managing problems in this way allowed Douglas to develop a modular programming scheme that would be applicable to many types of jobs simultaneously.

Douglas also needed a way to document the results of its TK Solver analyses that did not require any manual labor. Engineers would be more likely to accept the documentation format if the reports looked more like schematic drawings rather than a novel. Microsoft Visio was selected for this process because it is simple to work with and does not tie up needed CAD resources. The automation link between TK Solver and Visio was achieved with object link and embedding (a fancy name for "paste special"), reducing the time it took to create reports from 8 hours to just minutes.

In 2004 Douglas began developing a motion language. As with many machines, mathematically describing the motion was the first step in performing the analysis. A system to describe motion was developed in TK Solver, along with standard variable names for each variable: position would be x, speed would be v, etc. This set up standards so that as groups of engineers collaborated on a machine design project, or worked to develop the next new analysis method there would be a structure to follow – an important step in fitting all of your software building blocks together.

Next, cam application software was created using these libraries. This application would be used to study motions, make decisions about performance demands on servos, power transmission design, and conduct strength of materials studies. After developing the motion libraries and modular codes the next task was to develop software connectivity to databases of our supplier's component specifications. Douglas was on its way to developing a true KMS.

In 2005 Douglas Machine acknowledged the achievements that were made in the analysis group, and gave approval to develop the technologies to launch a formal KMS. A site license for TK Solver was obtained. A larger analysis team was created, allowing Douglas to formalize many of it's "on the fly" methods into more advanced analysis processes. One such effort was the addition of polynomial cam motions. This enhancement allowed Douglas to command motions that would move an object to a specific position in time and simultaneously specify its speed and acceleration. Douglas' strength of materials analysis also advanced in 2005 with the addition of UTS' Roark's Formulas package, which gave Douglas the ability to quickly optimize structural rigidity in the large frames used in the film wrapping machines.

In 2006 Douglas discovered that it needed to devise a way to visualize the results of motions in its machines. Early work was completed on animation development and a powerful concept was created that let the programmer work with graphic objects as if they were solids. Each object was able to interact with one another; for example, bumping into one another. These concepts were taken to a high level of sophistication in the Contour Business Unit.

Today, Douglas has modeled many of the film wrapping machinery concepts. This work, completely developed in TK Solver, could lead to an online product configuration tool for Douglas' sales teams. Currently it is used almost daily by many at Douglas to solve motion control issues. To speak of its power, Douglas now uses this work to research new machine concepts in film wrapping.

With the development of advanced numerical methods for motion analysis complete, Douglas naturally wanted to extend this capability to its machine controllers (PLC). The cam algorithms were ported to the Rockwell Allen-Bradley machine controllers, giving the machines access to the same uniform and concise motion language used by the analysis engineers. Douglas' machine performance improved significantly, but equally important, the company could now communicate between departments. The language of motion was now spoken across three departments: analysis, mechanical designers, and electrical controls. By this time, Douglas had been using TK's built-in functions to retrieve data via ODBC and found that more power was necessary to achieve some of its goals. To continue KMS development Douglas asked UTS to provide more advanced query capability within TK.

In 2007 Douglas added MathML, a symbolic algebra package. MathML is simply a standard that allows representation of math symbols and equations. The algebra system let Douglas derive equations for new machine concepts and produce some needed documentation of methods that were already in place. At this time Douglas undertook the challenge to create an expert servo linear actuator design tool, which would perform a complete analysis of bearing, belts, gearboxes, servos, etc. The modular programming developed over the past few years would be used to create this application.

Current KMS Topology

In 2008, Douglas' KMS system consists of TK Solver, a Microsoft Access database of supplier specifications, and Visio report templates. This implementation is probably considered a mid-level KMS (a full KMS, UTS' Galaxy, is slated for launch in mid-2008).

To set up the database, Douglas decided on units of measure and exactly which data was important. This format was used to obtain information from new suppliers, thus broadening Douglas' capabilities. Working with suppliers during this time was important, because they needed to understand why such highly detailed design data was required for their products.

Preferred components were a subset of this large and growing database. Douglas wanted its machine designers to be using these components as often as possible. Procurement departments were rewarded with a higher commitment from engineering that components with negotiated volume prices would be used.

A library of TK Solver libraries was created and stored in a server folder. These codes and rules are where engineers study Douglas' processes. Analysis engineers are able retrieve TK applications from the servers and enter design information, perform an analysis, and save the runtime results. Visio reports are automatically created and then routed to other engineers and the manufacturing groups.

At this time the management of these codes is not done automatically but will be when the Galaxy system is finalized.

Douglas achieved its main objective: making the transition to all servo machinery. Additionally, the analysis system works well. It is easy to develop new applications with libraries of code and Douglas continues to produce results that could not have been achieved by trial and error. The KMS efforts have also gained the attention of Douglas' customers. Their feedback has been positive and they have seen an improvement in Douglas' products.

Because the analysis systems have grown and Douglas continues to massage them, machine startup and commissioning times dropped substantially from what they were before such analysis methods were in place. Previously, Douglas worked long hours to meet its delivery dates and still missed them on occasion. In 2007 Douglas shipped 100% of its projects on time.

Douglas' KMS in Action

Time Savings 100:1

There was a machine Douglas had designed many times before, but this time the design was somewhat unique, enough so that troubles arose during early tests. Three people worked 10 hr days for 10 days to solve the problems. At the time, it seemed it was just a matter of tweaking the problem into submission. It was early in the analysis so many people were not thinking about looking for solutions via a math investigation. Once an analysis person found out about this machine he modeled it in TK Solver, animated the machine, watched it run on his computer screen, and issued a report to the shop floor. The analysis work took 3 hours. The derived solution ran perfectly when it was loaded into the machine controller. Douglas realized a 100:1 ratio of effort.

Increased Life and Speed

A new transfer table design completed by the analysis group is proving to have 12 times greater life and 6.5 times greater speed capability. This was achieved using Douglas' modular codes, rule based programming in TK Solver, and Roark's Formulas. The new design is slated for acceptance in 2008.

Leveraging Expertise to Facilitate the Design Process

In 2008 Douglas had a large proto-type project that required it to demonstrate the feasibility of using a new machine design. A successful proto-type could potentially result in a very large order.

Advanced linear actuator analysis methods were deployed to assist the design engineers. Included on the analysis team were two members who had never used the advanced linear actuator program. The two analysis team members using the linear actuator model for the first time found the program easy to use since the component data was read into the inputs via ODBC connectivity. This advanced program made it possible for the designers to complete their work early and provided the opportunity to study the types of technologies that would need to be applied during the concept phase of the project. The machine validation was performed two weeks ahead of schedule and the customer initiated the order process for more machines. This example set the standard for future engineering projects.

Case Study: Rule Based Programming with Optimization

With imperative languages (BASIC, FORTRAN, Mathcad, etc.) users have to provide instructions in code (an algorithm) to solve a problem (and it can only solve the one the user wants to solve). With declarative rule based programming, the computer can solve every possible permutation described by the user's rules (making it a solution space).

Optimization with imperative programming yields the best of what the programmer(s) could conceive, where optimization in declarative rule based programming yields the best results in a solution space – something so complicated that writing a program to do this would be very difficult to do, if not impossible.

Douglas was presented with the challenge of custom-designing guard door lift mechanisms on a tight schedule. This effort had to be right the first time and potential orders could follow. On-the-fly analysis was initiated to dodge what would have been a large amount of rework, lost profits, and a customer whose expectations would not be realized.

Rules were developed that described the lift strut's linkage, the compression spring design, and constraints for each component as well as the strut itself. The rules would make the lift strut by optimization of the spring design, linkages, and size/orientation. Optimizations of three complex systems concurrently were not trivial problems. Initially, the problem appeared too complex to solve, but in three days' time the problem was solved.

The custom spring strut was manufactured and it worked so well it remains Douglas' standard due to its compact size and performance. This design is not only small; Douglas believes it to be impossible to make it smaller. The documentation produced by TK Solver's report wizard was sent to the spring manufacturer. The springs arrived in a few days time – and they were correct. Customers have commented that Douglas has the best guard door in the industry. The guard door can be moved easily by one hand and, placed in any position, it will stay put.

Figure 1

In conclusion

Douglas Machine has made the transition that they set out to achieve; they made the change to servo based machinery. During this process Douglas also realized the benefit of KMS development. Analysis reports are now used to manage projects. Reduced startups and machine commissioning has been realized. In 2007, all projects shipped on time. The support for further KMS development continues at Douglas.

As with any survey of technologies such as this one, it is not always possible to single out one act or plan that contributes to a company's success; it often is a conglomeration of many efforts. However, everyone at Douglas Machine, and its customers, agree that the KMS has played a significant role in Douglas' success.

Douglas Machine is employee owned and has more than 7,000 machines installed with customers in over 30 countries.

Rick Lukanen is a Principal Engineer at Douglas Machine, Inc., located in Alexandria, MN, USA. Rick has 20 years of experience in software development and numerical analysis applied in machine design. He currently manages the application of analysis technologies at Douglas and oversees a five-member analysis team.