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THE UNICONTROL HARDWARE, SOFTWARE AND SYSTEM CONCEPT

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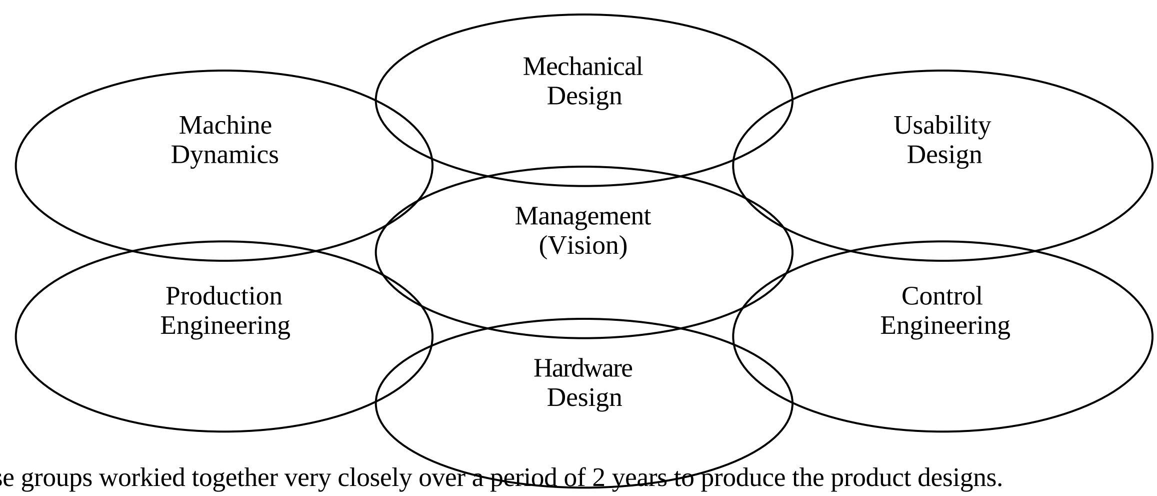
Abstract: This paper describes the introduction of new concepts into a tin can manufacturing line and its re-engineering with the aim of doubling the production speed. The design of the hardware and control system played an important part in matching the dynamics of the machinery to the production processes, and also in reducing costs and improving reliability.

Introduction

Automated machinery for the continuous manufacture of welded tin cans has been available for about 50 years, gradually increasing in production speed and product reliability. In 1994 the Swiss company Soudronic decided to re-engineer their family of production machinery. The re-engineering brief for the design and production team was

- simplify where possible, particularly wiring, configuration and mechanics
- adapt existing machine concepts and experience
- reuse only relevant parts and knowledge from the 'old' designs
- use creativity to provide new ideas, understandings and solutions

The principle team organisation was



All these groups workied together very closely over a period of 2 years to produce the product designs.

Business Objectives

The project was business driven based on a radical vision of business needs in a global marketplace. The project objectives were

- create a single hardware, software and system concept for all Soudronic products
- double the speed of the machinery
- improve operational reliability
- lower the cost of manufacture
- lower the cost of servicing and spares
- reduce training needs
- reduce variation in designs, concepts, hardware and software

This paper focuses on the Unicontrol system which is a completely new distributed control system which animates the mechanical hardware whilst presenting information to the production line users (managers, operators, service engineers, cleaners) in ways which match their level of education and experience.

Metamorphosis to a System Concept

The original machine consisted of a series of mechanical processes, such as

- get the next metal sheet
- round it
- weld it
- check it, maybe reject it
- spray it with lacquer
- cure it

All these processes were driven by one motor via a series of clutches and gear boxes, consequently their dynamics were fixed. This reduced the production speed range for reliable operation. A single control system with a text based user interface was used to monitor and partially control the machinery.

The new machine concept uses the same series of mechanical processes but each one has been revisited to study its simplicity, dynamics and reliability. As a result each process is controlled separately and optimally, and has its own Unicontrol computer controlled drive. This makes it possible to tune the dynamics of each process and the whole machine over a wide range of production speeds (from just a single can to 1000 cans per minute) whilst producing consistent quality. The role of the new control system is to orchestrate the machines production performance.

The Unicontrol System

An overview of the Unicontrol system is shown in Figure 1. This shows a distributed control system with each part of the production process being controlled by its own local Motorola 68332 processor. All the processing nodes are identical, this has led to several benefits

- reduced design time
- minimised spares holding
- optimised production
- simplified buying of parts and lower inventory
- less variation in production

A small percentage of each node is unused in each application, however overall there is a huge saving by meeting the criteria mentioned above.

To simplify software installation in the factory and on-site (world-wide) the Unicontrol system automatically configuration are held in a database. Only a single set of software exists for all machines in the range, for all languages and for all production configurations.

To improve maintainability the system continually monitors its own performance. If a node fails it can be replaced by a new 'empty' node, its software is automatically loaded and configured when the machine is next started up. The system includes a maintenance schedule for all wearing parts and keeps a log of maintenance activity.

The CAN Bus

All the control nodes communicate using the Controller Area Network bus. This was originally developed by Bosch for use in the automotive industry[1]. The CAN bus provides for deterministic communication over a two wire network with extreme reliability under extreme EMC conditions. A set of system wide protocols have been designed as part of the project to

- auto configure the software
- provide distributed health monitoring
- continuous performance logging
- software tuneable by database
- truly parallel operation

The CAN bus protocols are designed using State Transaction Protocol diagrams, an example is shown in Figure 3. In this way the software is explicitly designed to serve the desired behaviour and dynamics of the whole system. The technique is naturally extensible [2] and very easy to prototype even when the actual production machinery is not yet available. All the software was written in Borland Object Pascal (for the PC Windows interface) or Modula-2 for the Unicontrol embedded system controllers and the digital signal processors.

The Unicontrol Node

The Unicontrol node is a standard piece of hardware housed in an IP65 environmental housing. All nodes contain a Motorola 68332 processor and are connected together via a 4 wire cable which carries the two CAN signals and raw DC power supply. Each node has one or more daughter boards to support digital and/or analogue input and output signals. One specific node required a digital signal processor (DSP) to support weld quality monitoring sampling at 50 KHz. This was achieved by adapting the existing 68332 board design to make a 68332 daughter board as a DSP. As a result the same development tools could be used for DSP and normal control and application software saving on development time and equipment cost.

The software in each node consists of a fixed part and a ‘node application’ part. The fixed part includes CAN bus handling and buffering, health monitoring, software download, diagnostics and a simple real time scheduler. The node application part is designed as state machines and complements peer to peer protocols in other nodes, it performs control algorithms based on I/O signals. Each node has a single 7 segment LED which continuously indicates the state and activity of the node. This makes it very easy to locate problems in practice.

Unicontrol Emulators

Whilst the tin can production machinery was being designed and prototyped the Unicontrol system was created and tested by itself. This was achieved by creating the Unicontrol emulation system shown in Figures 4 and 5. This makes it possible to

(a) log CAN messages, fully or selectively

(b) emulate nodes which do not yet physically exist

(c) provide symbolic traces of CAN messages for debugging and timing analysis

Figure 4 shows a block diagram of the main development system. This includes the CAN ‘SPY’ which provides a symbolic trace of CAN bus activity and also some additional Unicontrol nodes which are specially programmed to emulate the behaviour of the actual machinery input output interface. The real machinery costs well over $100,000 and so is not available as a permanent test system, however the emulated machine costs less than a tenth cost and fits on a desk top (the actual machine is about 20 x 4 x 4 metres!).

Figure 5 shows a block diagram of the Windows software environment and the machine emulator which are used to support testing of the user interface software on a standalone PC.

By using the software emulator, and also hardware emulators to represent the machine being developed, it was possible to test most Unicontrol functions before the production machinery became available. The benefit was that

User Interfacing

The requirements for the user interface were

- simple and graphic
- minimal text to translate
- European, Cyrillic and Eastern languages
- easy for each kind of user, including operators with poor education
- language selectable during production to support global markets

Wherever possible a pictorial approach was taken with a 1:1 relationship between real world and on screen objects. An example is shown in Figure 3.

In order to simplify the organisation of the user interface it is partitioned by kind of user (line manager, operator, service engineer, cleaner, maintainer). For each user the sequence of normal operation for their view of the production process is presented to them as a sequence of pictures.

Conclusions

This brief paper has described a project involving the radical redesign of a high speed production line system. Its successful completion within 2 years has been due to a combination of vision, enthusiasm, innovation, taking a fresh approach and sheer hard work. The Unicontrol system has provided the dynamic backbone for the production line and its machinery. The objectives have been met with the first deliveries to the German and Japanese markets. Already we are looking at how to make the production line run even faster than one million cans per machine per day, every day ...

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Diagrams