EuroForth 2019
Forth returns to the automotive industry

Abstract

A stretch bending machine for producing automotive components is described, on which the automation system is programmed in Forth.

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1. Introduction

A wide variety of processes are used to produce bodywork parts for vehicles. One of those processes is called stretch bending. A formed metal section (typically a U section) is bent into a complex shape while being simultaneously stretched so as to retain its sectional form without distortion. A typical usage might be the surrounding frame of a car window. The parts have tight tolerances and must be produced in high volumes. The control system of a machine that produces such parts is quite sophisticated.

2. Historical notes

The Euroforth 2003 conference included a visit to a company that made stretch bending machines. The machines at that time used hydraulic proportional valves, each controlled by a dedicated circuit with an IX1 single chip microcontroller. This communicated with a virtual programmable logic controller (VPLC), installed within a personal computer. The PC, VPLC and IX1 were all programmed in Forth.

The mechanical engineering company that made the stretch bending machines had enjoyed a great deal of success, creating machines that were used to produce numerous popular European cars, for all the main manufacturers.

Unfortunately, it was taken over by a much larger company which, a short time later, went bankrupt.

Some of the engineers from the original company went on to form a new company, though it took them some years before they accumulated the resources to offer a complex machine. Finally in 2019 they obtained a contract from Jaguar Land Rover, to build a machine for a new model. In turn, our company was called on to automate the machine. Forth returns to the automotive industry!

3. A truly international industry

Jaguar and Land Rover are historical British companies, and all design work is still carried out in the U.K. However, the owner of JLR is the Indian company Tata Motors. The final assembly of the new model will take place in Slovakia. The engines will be built in the U.K. However, the part that we are concerned with is to be made in Turkey. This means that the automation system must be usable in both English and Turkish.

4. Overview of a stretch bending machine

The material is presented to the stretch forming machine as a continuous strip of preformed steel or aluminium alloy section. The machine cuts a piece to the required length, grasps and then bends it in several planes, simultaneously stretching the section in order to avoid irregularities in the curved surfaces.

Some sections are formed in quite heavy material, and considerable forces are required to perform the stretching and bending actions. This means that the axes cannot be driven by stepper motors which are commonly used on industrial robots. In the past, hydraulic cylinders were used to obtain the necessary force. These days, d.c. servomotors combined with linear actuators are sufficiently powerful. The axes positions are measured by encoders.

In order that the finished parts fit precisely into their assemblies, considerable accuracy is required – the current specification calls for a positional tolerance of 0.01mm over a total axis length of up to 2m. To obtain the correct shape, the stretching and bending must take place over up to seven axes simultaneously, all moving in a co-ordinated manner.

The machines must operate quite rapidly, for example a high volume car might require around 1,000,000 parts per year. Even a company like JLR, which is a relatively low volume luxury manufacturer, produces almost half a million vehicles a year. The machines must be extremely reliable because they form part of a just-in-time production system with no parts storage. Downtime of less than 24 hours can stop a major car plant, with thousands of workers laid off.

5. Some design decisions of the control system hardware and software

a) The machine must be able to produce a variety of different parts, for different varieties of the same basic car - for example, long and short wheelbase models. This is achieved by having a standard machine base, to which are attached different tooling modules. The base, and each item of tooling has different sensor and actuator requirements, and therefore each has its own control panel with PLC I/O modules and servo drives as necessary.

b) To connect the various PLC and servo modules together, a fieldbus is necessary. A decision had been made to use Bosch servo drives, and this determined that the Sercos fieldbus system had to be used.

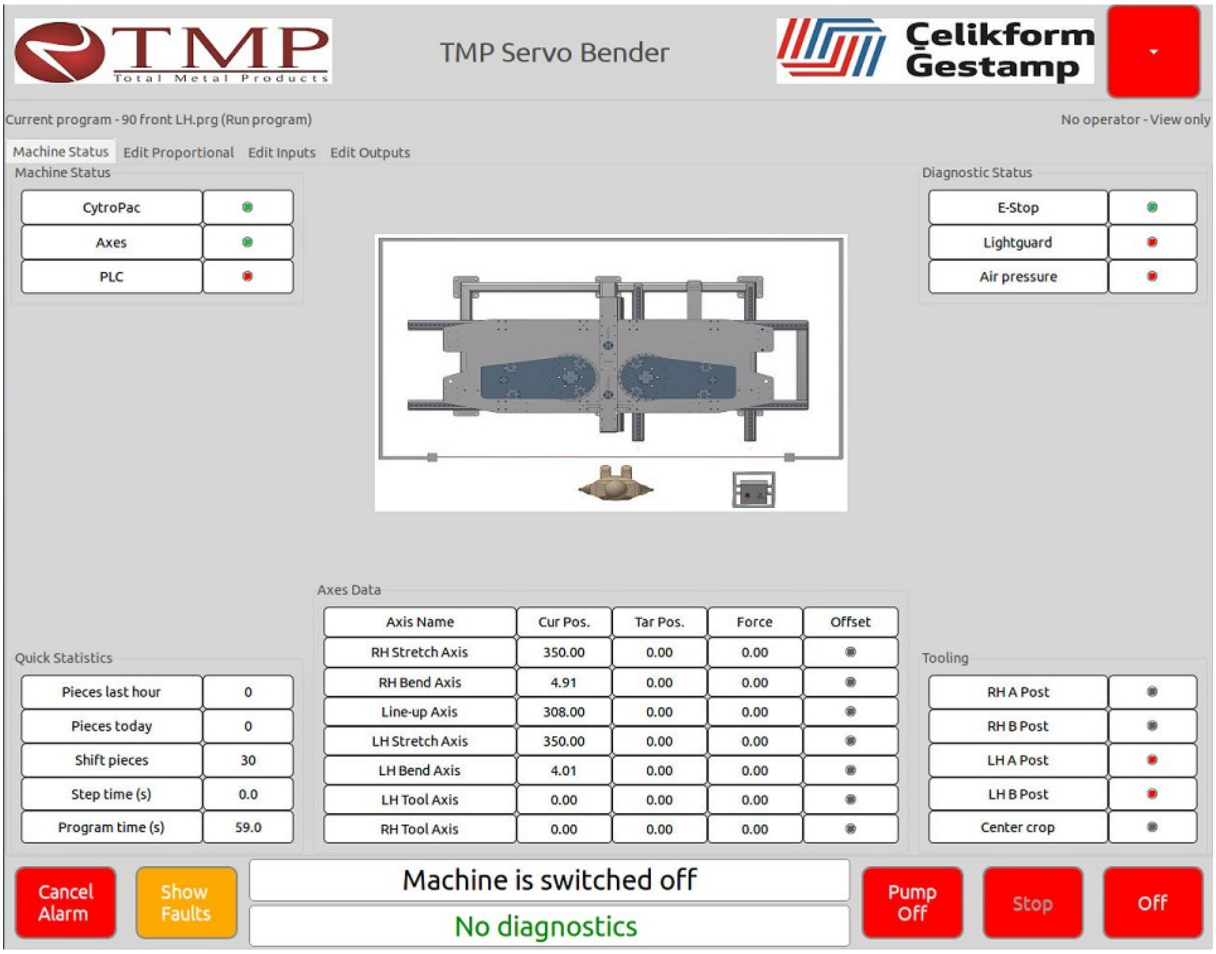
c) In turn, for ease of integration, the Bosch PLC had to be used. This unfortunately meant that IEC61131 had to be used for programming the PLC.

d) Supervisory control, diagnostics, visualisation, performance monitoring reports and statistics, and part profile programming and storage are done by an industrial PC running Ubuntu Linux and programmed in Forth using MPE VFX.

e) In a previous paper at Euroforth, I compared the benefits of programming in Forth, with IEC61131. These remarks still stand, therefore when dividing the control responsibilities between the PLC and the PC, as much of the work as possible is carried out by the PC.

6. Some key features of the software

a) The main visualisation



This is a live display showing the machine status, with an animated plan view of the bending process.

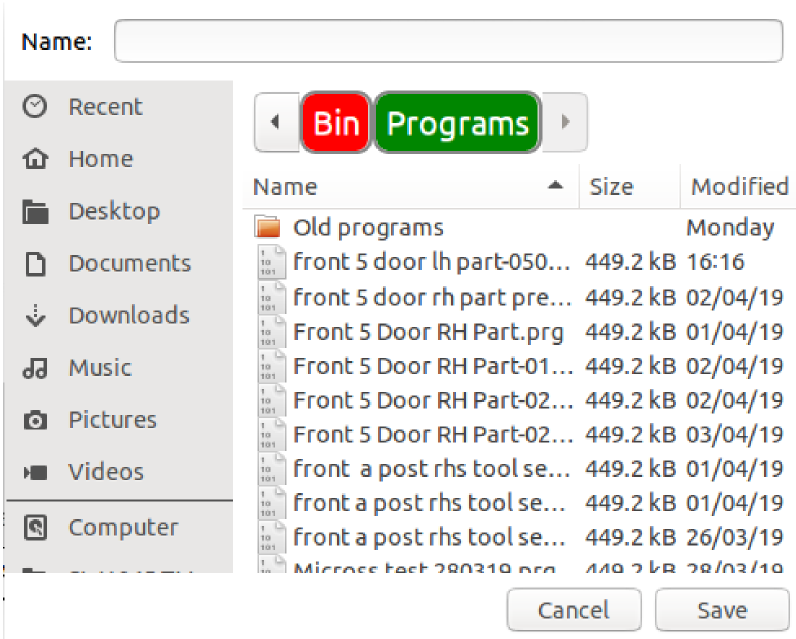
b) High speed communication with PLC

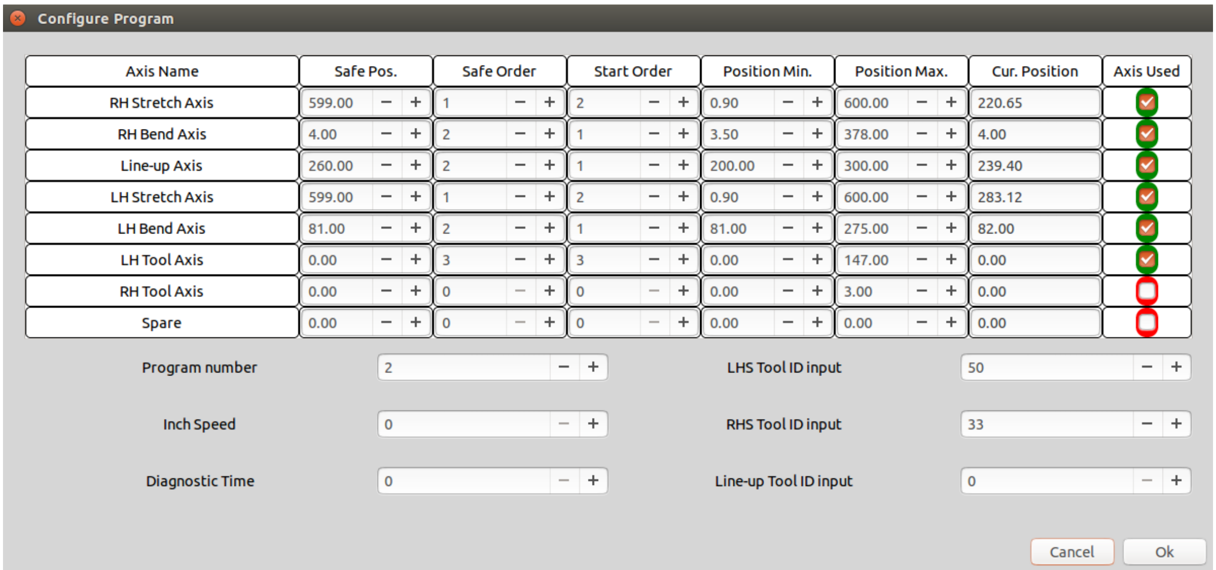
We use our standard method of data exchange from PC to PLC, using fixed format UDP messages over a dedicated Ethernet connection, on a 50ms tick.

c) Diagnostics

As well as the status of the safety system and the air and hydraulic supplies, the correct position of each axis is constantly monitored for tolerances.

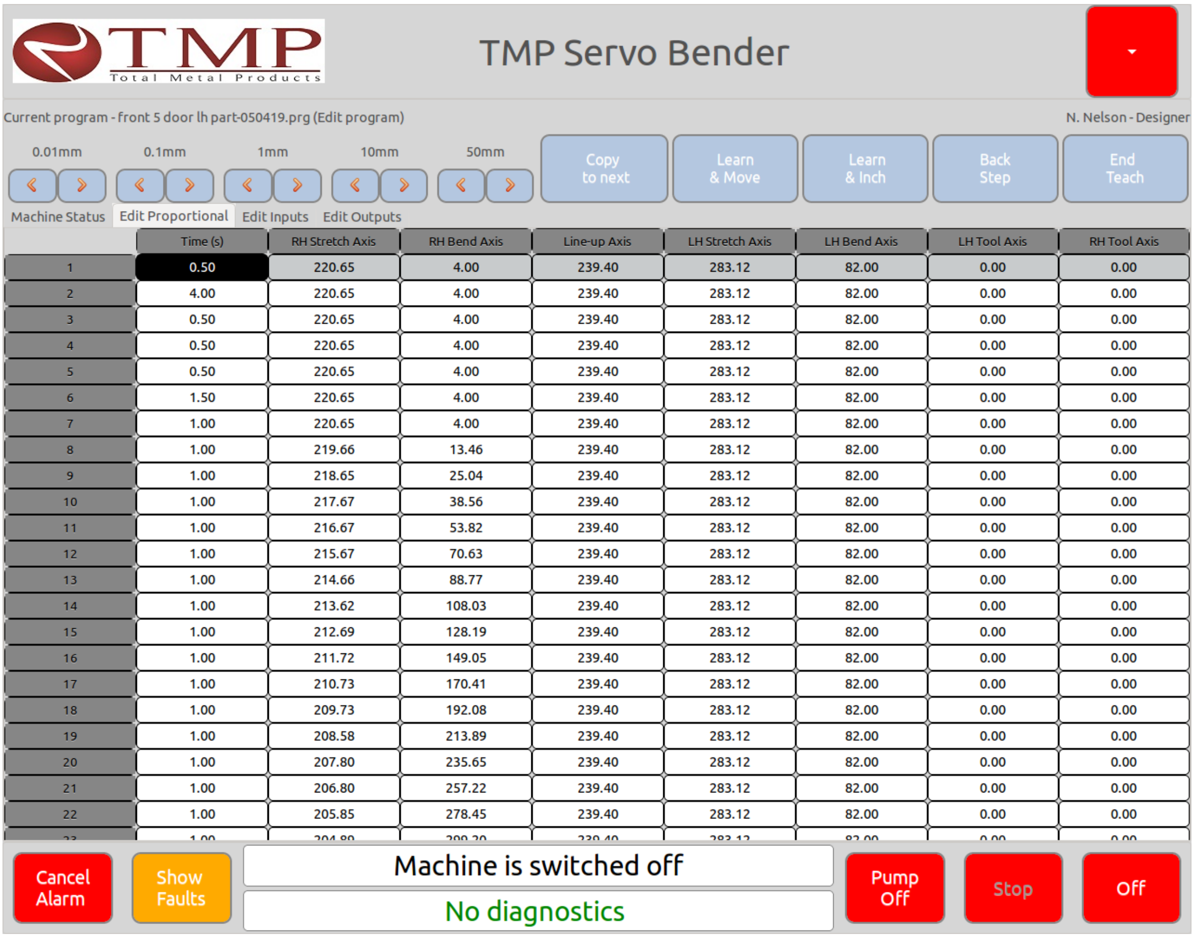
d) Program change





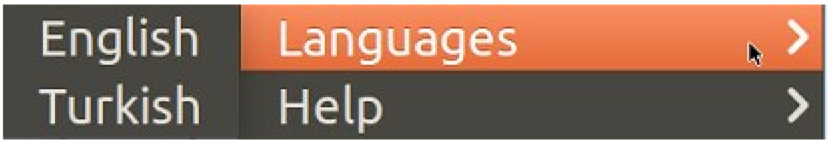
When the tooling needs to be changed, to suit a different model of the vehicle, the fieldbus configuration of the PLC and servo drive network changes, because some elements of the PLC are installed on the changeable tooling. So the system validates that the PLC configuration matches the selected bending program. This was one of the most difficult things to achieve, because the hardware application engineers had not encountered this requirement before.

e) Programming and teach mode



When designing the bending program for a new part, the procedure is to inch each axis step by step to a new desired position, using a "teach mode". This gets the basic shape right, but the bending program still needs fine tuning to account for dynamic operation.

f) Multilanguage support



The machine is installed in a factory just outside Istanbul! So all the on screen functions need to be in Turkish as well as English. See the previous paper "Internationalisation - a new approach in Forth".

7. Some major lessons learned from the project

a) Never overestimate the capabilities of major suppliers.

We were offered a lot of assistance by a team of application engineers from the hardware suppliers, particularly in getting the servo drives to function as required. It took about a week before we realised that by then we knew more about drives than they did!

b) Never underestimate your own engineering capabilities.

Although we had no experience of this type of drive before, we did have a lot of experience in multi-access positioning systems. Sufficient, in fact to realise after a while, that the advice offered by the hardware suppliers might not be the best.

c) Beware of newly introduced products.

The machine included two highly integrated hydraulic compressor packs, which were being used for the first time in the UK. These were fieldbus controlled. You would have thought that a hydraulic compressor was a fairly simple piece of equipment, but it's amazing how complex you can make them with a bit of imagination.

8. If we did it again, we would…

Not go for a new hardware supplier when starting a major new project. The double learning curve was a severe challenge.

9. Conclusion

Once again, Forth has shown its capabilities as an outstanding tool for automating industrial control equipment.

10. References

Industrial control languages: Forth vs IEC61131
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