Development of SFC Control Systems

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Conventionally, Programmable Logic Controller (PLC) programs used for equipment control in plants, etc., were written in ladder language, decipherable only by trained or fully experienced control engineers or electrical maintenance personnel. However, by introducing Sequential Function Chart (SFC) which display the entire cycle of a production process in a flowchart-like format, even operators with basic operation skills can comprehend equipment operation flow and stopped states, allowing them to easily pinpoint problem areas. JTEKT will use SFC not only on our existing in-house equipment, but also on that of Toyota group companies, other vehicle manufacturers, components manufacturers and so on. The adoption of this method on JTEKT machine tools will also be proactively promoted.

***Key Words**: programmable logic controller, PLC, sequential function chart, SFC, NC program*

1. Introduction

In recent years, equipment control has become more complex, and many companies are faced with a shortage of experienced control engineers and plant electric maintenance personnel. This has created a situation where production creation and modification work often takes an extremely long time and the finished quality is poor. Subsequently, many problems arise during equipment operation, which maintenance personnel are incapable of rectifying, thus leaving no other option but to request the manufacturer carry out repairs. Another issue is the amount of time required to train local staff in overseas plants. To respond to these issues, JTEKT has developed a control system which offers visualization and standardization and is applying this to a wide range of equipment.

2. About SFC

Conventionally, Programmable Logic Controller (PLC) programs used for equipment control in plants, etc., were written in ladder language, decipherable only by trained or experienced control engineers or electrical maintenance personnel. However, by introducing Sequential Function Chart (SFC) which displays the entire cycle of a production process in a flowchart-like format, even operators with basic operation skills can comprehend equipment operation flow and stopped states, allowing them to easily pinpoint problems areas.

SFC, like ladder language, is one of the program languages for PLCs defined by standard IEC61131-3 published by the International Electrotechnical Commission (IEC).

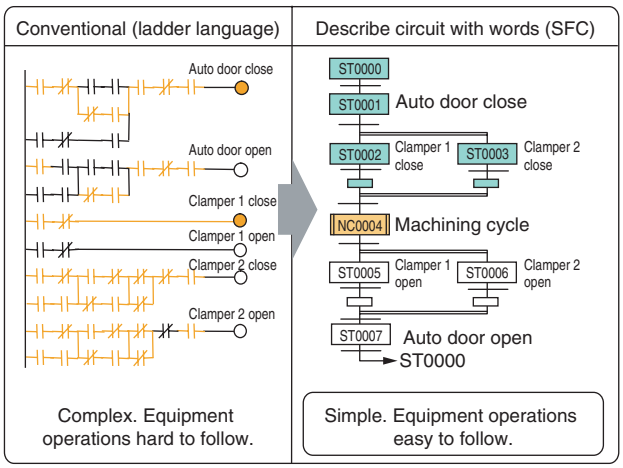

Fig. 1 Ladder language and SFC

3. SFC Special Features and Advantages

3. 1 Reduction in Design and Trial Run Time

In the design of equipment control, cycle diagrams must first be created so that the mechanical designer can decide the order of equipment operations. Conventionally, the control designer creates the ladder circuit based on this cycle diagram. When SFC is used, cycle diagrams can be written into SFC as is. The mechanical designer is capable of doing this task as it is simple and can be done with a PC tool (PCwin). The control designer then sets the necessary conditions and designs the ladder circuit using standard function blocks (FB) based on the

SFC. Standard FBs are standardized by actuator type, recently popular communication monitoring, ID, QR code readers, laser markers and so on, and are used repeatedly, significantly reducing design time and improving quality. Trial runs and debugging can be completed in a short time also as a result of the visualization brought about by the introduction of SFC and the high level of quality of FBs.

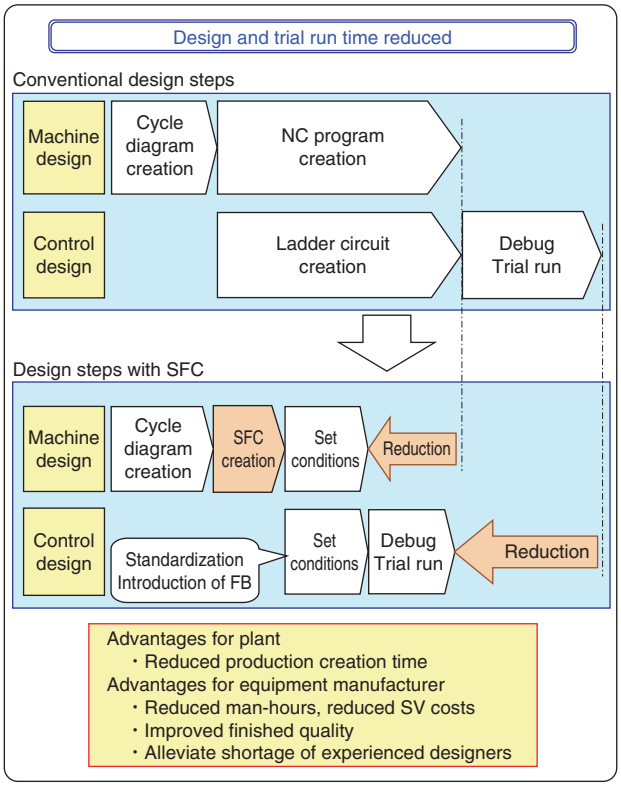

Fig. 2 Reduction in design and trial run time

3. 2 Reduced Maintenance Time

SFC monitors significantly reduce the amount of time taken to investigate the cause of equipment stoppage.

In SFC's automatic cycle, the steps of each operation appear in orange while they are executing, then turn green upon completion. When the equipment stops on a fault, the step that appears in orange indicates the equipment's stop state. When the operator touches this orange portion, the screen will jump to the circuit monitor of the stopped step and the operator can decipher the cause of the stoppage from a ladder circuit monitor with comments. It is also possible to jump to an I/O diagram display from the input contacts or output coils in the ladder circuit and, once there, identify devices, confirm wire numbers, etc. Moreover, using the SFC monitor eliminates the need to search through endless pages of circuit drawings, meaning that the cause can be pinpointed in less time.

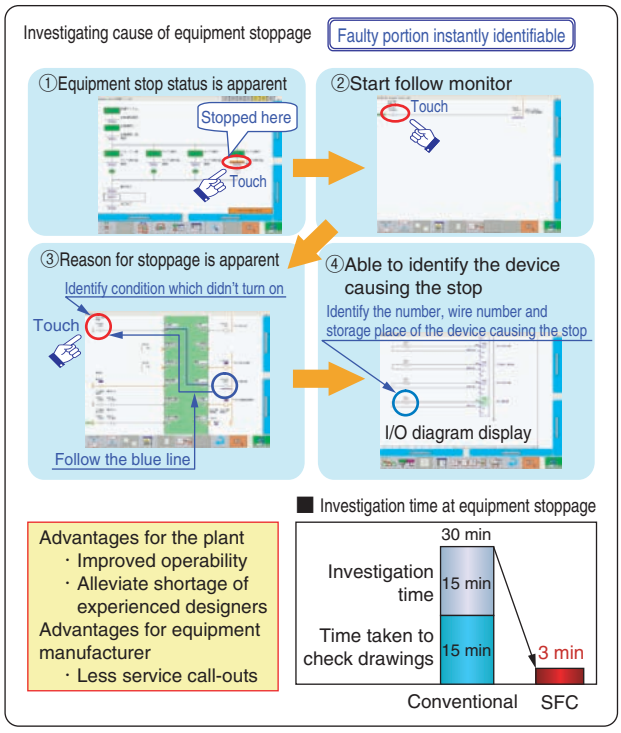

Fig. 3 Reduction in maintenance time

3. 3 Reduced Modification Time

If the modification involves a simple cycle change, then it can be achieved by merely changing around the relevant SFC steps. However, if there is a change to an interlock for interference prevention, the FB setting circuit must also be revised. Because changes to running conditions are clearly apparent in FBs, interlock change is also easy, with plant personnel being able to do many more modifications than in the past, reducing dependency on the equipment manufacturer.

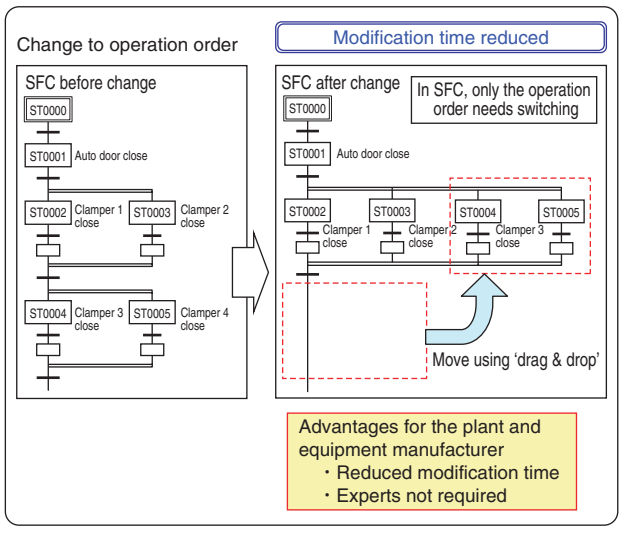

Fig. 4 Reduction in modification time

4. Introduction of SFC to NC Programs

JTEKT introduced the SFC technology cultivated on TOYOPUC to MC50 CNC models. This has made it possible for even operators unfamiliar with conventional NC program language such as G code program, to create machining programs and enter spindle speed, feedrate, positioning coordinates, etc., into a list with comments. Once the program is complete, individual SFC steps can be copied and moved easily, reducing modification time. There is seamless operability between the NC SFC monitor and the PLC SFC monitor. Operations start up from the machining cycle steps of the overall cycle SFC controlled by the PLC and, in the same way as the SFC, individual machining steps being executed are displayed in orange and turn green upon completion, thus visualization of the machining cycle is achieved.

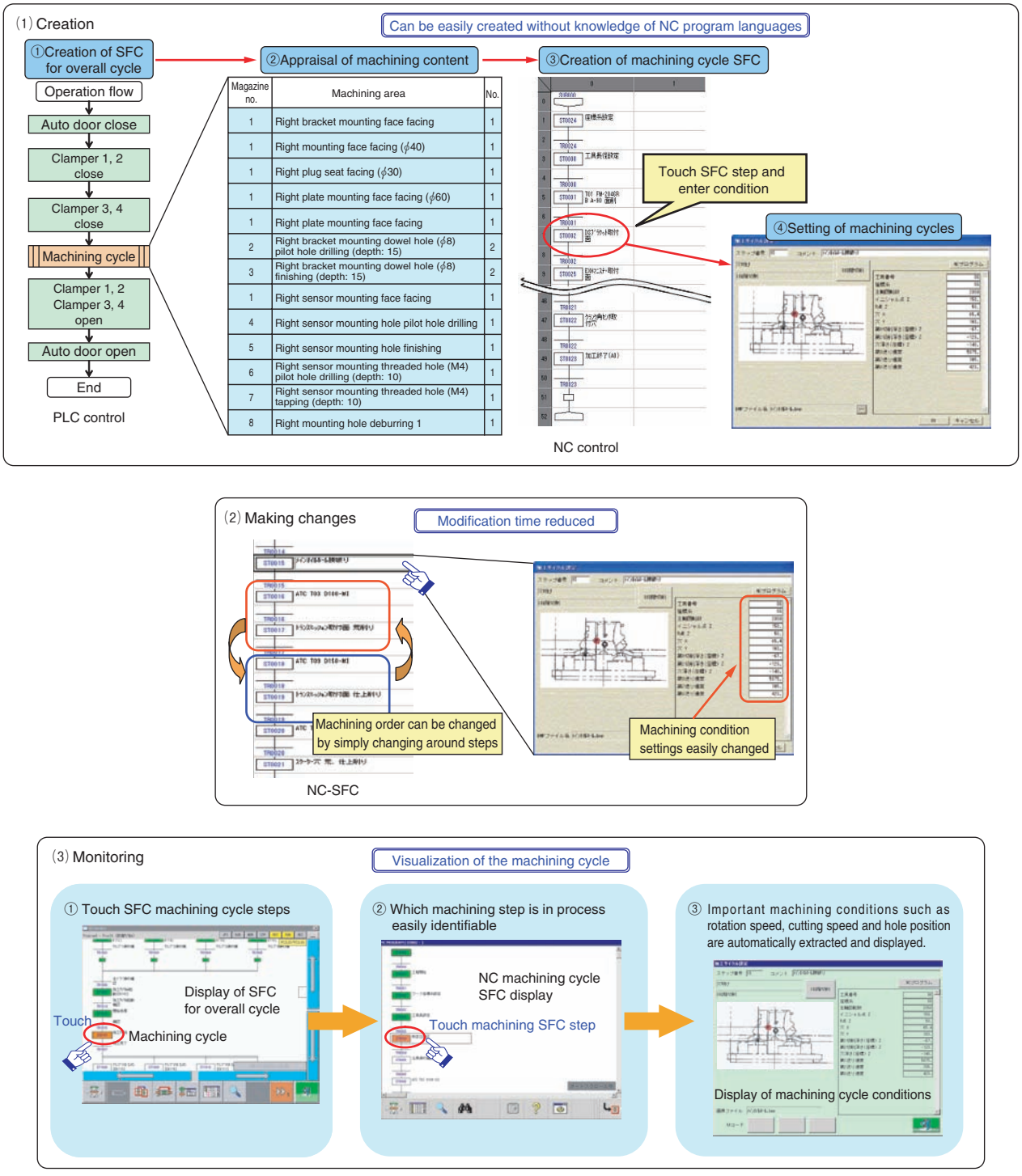

Fig. 5 Introduction of SFC to an NC machining program

5. Hardware and Software Needed for SFC

All hardware and software required to achieve visualization of control using SFC are supplied by JTEKT.

5. 1 SFC Monitoring

The Direct Circuit Monitor and SFC monitor built in to Multi-purpose operation panels allow for easy maintenance of equipment without the use of computers or drawings, thus improving operability of production equipment.

5. 2 PLC Device - TOYOPUC

SFC is supported on the PC10 series, PC3JG and the PCDL models of PLC device TOYOPUC. From these, the customer may choose the model most suited to their production scale. SFC can be used throughout all stages, from plant management and line control to small scale equipment.

5. 3 CNC Device - MC50

The MC50, a CNC device JTEKT developed for cutting machines, has a built-in TOYOPUC PC10P and supports SFC. Moreover, SFC has been introduced to the NC program achieving visualization of the overall cycle and individual machining cycles of fabrication equipment.

5. 4 Programming Tool - PCwin

PCwin is a tool for PCs which supports everything from SFC and ladder design to maintenance. With PCwin, I/O diagrams can be created and print-outs with drawing frames can be made, tasks previously only achievable using CAD.

6. Conclusion

SFC introduction began from around 2001, focusing mainly on the body production plants of Toyota Motor Corporation. Since then, SFC has contributed towards significantly reducing Mean Time To Recovery (MTTR). JTEKT will continue to proactively promote the adoption of SFC in all Toyota group companies, other vehicle manufacturers, parts manufacturers and our own company's machine tool and equipment lines.

＊1 TOYOPUC and PCwin are registered trademarks of JTEKT Corporation.

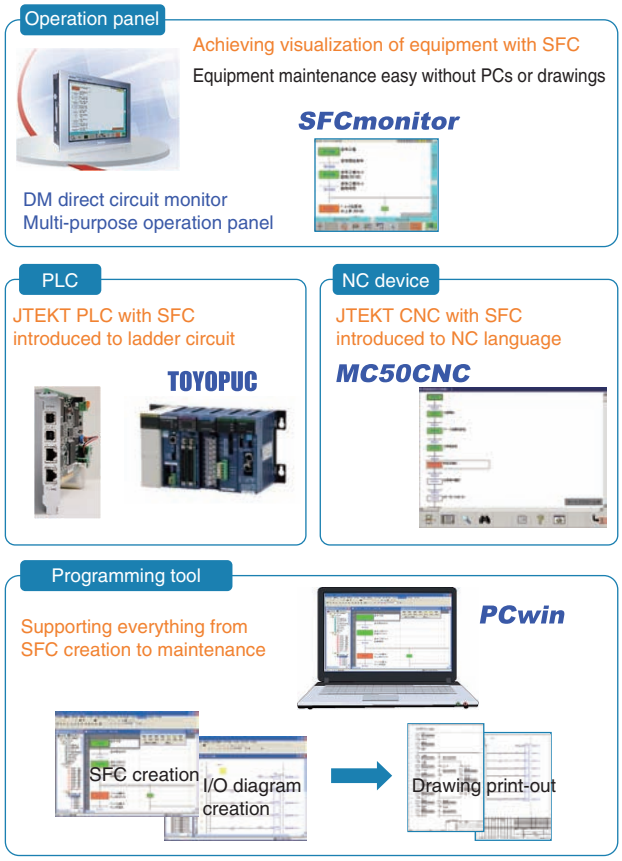

Fig. 6 Hardware and software needed for SFC

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