Construction of a One-by-one Production System for Resistance Welding Electrodes

抵抗溶接電極の 1 個流し生産体制構築

Tatsuro YAMAGUCHI

山口　達郎

Taro KUROKI

黒木　太郎

Yasunari TANAKA

田中　泰成

Kazutomi NAGANO

長野　和臣

Yousuke SAKURAI

櫻井　陽介

Yuuki OHTA

大田　祐樹

Key words: TK Electrode, Toyota Production System (TPS), lead time, one-by-one production system

キーワード；TK 電極、トヨタ生産方式 (TPS)、リードタイム、1 個流し生産方式

Abstract

The number of electrical components in automobile parts has increased in recent years, and demand is increasing for our products, especially "TK Electrode", our representative resistance welding electrode. Owing to large fluctuations in demand for such electrodes, a production system that can flexibly respond to demand was urgently required. We constructed a production system adopting concepts from the Toyota Production System. As a result, we could shorten the production lead time of TK Electrode by constructing one-by-one production system, and cope with increased demand and respond flexibly to demand fluctuations.

近年、自動車部品における電装品の増加に伴い、当社の抵抗溶接電極の需要が増加している。抵抗溶接電極は需要変動も大きいため、需要量に対し柔軟に対応できる生産体制の構築が急務であった。我々は、当社の抵抗溶接電極の代表製品である「TK 電極」に対し、TPS の考え方を取り入れた生産体制構築に取り組んだ。取り組みの結果、1 個流し生産方式を適用することにより TK 電極の製造リードタイムを短縮し、需要増加及び需要変動に柔軟に対応することができた。

1. Introduction

1.1 Background

Our resistance welding electrodes belong to a group of products mainly used in the automobile industry. Recently, demand for TK Electrode, our representative product, has increased rapidly. Considering future increases in demand, we expected that, using our conventional production system, it would be difficult to meet to customers' desired delivery dates. Our company typically employed the lot production system, in which products move between processes in lots (batches). For the TK Electrode, each lot contained several hundred units. Thus, we were unable to respond flexibly to large fluctuations in demand for the TK Electrode. Therefore, it was urgently required to shorten production lead times (the duration required from the start of manufacturing until all processes are completed), to cope with increased demand and to establish a production system that can flexibly respond to demand fluctuations.

1.2 About resistance welding electrode

Resistance welding electrodes are used for welding of insulated coated copper wires, metal terminals and wire harnesses (copper wire bundles). Such electrodes are indispensable for welding electrical components for use in automobiles.

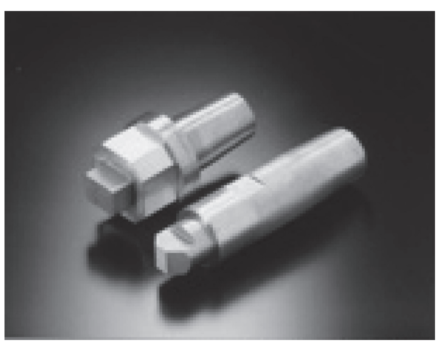


Fig.1 Resistance welding electrode

1.3 Purpose of the study

In this study, we changed the production system of TK Electrode from a lot production system to a one-by-one production system in which products move between processes one at a time. This eliminated the residence time between each process. The aim of the study was to shorten production lead time and to build a production system that can flexibly respond to demand fluctuations.

1.4 Production lead time

Production lead time is the sum of working time and residence time. Working time can be divided into net working time (processing time) that adds value and incidental working time (setup time) without adding value. Residence time is the time spent waiting for processing.

1.5 Toyota Production System and the seven types of waste

In this study, we conducted activities based on the Toyota Production System (TPS). TPS is a production method proposed by Toyota Motor Corporation. Its purpose is to meet customer demand in the shortest time and most efficiently. The basic idea of TPS is to thoroughly eliminate overburden, inconsistency and waste.

Table 1 shows the seven types of waste that form a key part of TPS. The present study focused on these seven types of waste. We analyzed the TK Electrode production line and implemented improvements.

In addition, TPS utilizes a one-by-one production system. In the lot production system, setup and processing are carried out on a lot basis. Thus, the process is intermittent, and long residence times occur when the processing equipment has insufficient capacity. In contrast, in the one-by-one production system, setup and processing are carried out on a one-by-one basis and all processes are continuously carried out. Therefore, residence time between the processes is minimized or eliminated. In addition, it is a flexible production system that can respond to demand in increments a single unit. Therefore, even if the per-unit working time (setup time + processing time) is the same for each production system, the production lead time will be shorter for one-by-one production owing to the shorter residence time.

Table 1 Seven types of waste in the Toyota Production System

Seven wastes	Contents
Waste due to unnecessary processing (Described in 2.3)	It refers to finishing work more than necessary since the standard is not decided, and originally unnecessary inspection etc.
Waste due to unnecessary inventory (Described in 2.5)	It refers to an inventory that cannot explain why it is there now. Inventory objects are all materials, parts, work-in-progress, finished products, etc.
Waste due to over-production	It means to produce unnecessary things unnecessarily at unnecessary timing.
Waste due to waiting	It refers to a state where there is no work to do.
Waste due to unnecessary motion	It refers to unnecessary movements that do not produce added value of products within the movement of workers such as searching, squatting, changing, and checking.
Waste due to unnecessary transportation (Described in 2.4)	It refers to movement of products, temporary placement, and transshipment more than necessary.
Waste due to making defects	It refers to the rework of products and discard of defective products.

2. Improvement method

2.1 Identification of waste

Considering the seven types of waste mentioned above, we analyzed the production process of TK Electrode and identified areas of waste. Fig. 2 shows the outline of the TK Electrode production process and the lead time. To identify waste, we analyzed lead times, focusing on the residence time between each process. We also analyzed the actual work process, using video footage. As a result of the two analyses, we identified waste in unnecessary processing, unnecessary transport and unnecessary inventory in the TK Electrode production process. To eliminate these types of waste, it was necessary to change from the lot production system to the one-by-one production system.

2.2 Setting of target

We set a target production lead time to produce the required quantity of TK Electrode and meet the customer's requested delivery date. Table 2 shows the current and target lead times. To achieve the target lead times for the material process and for the product process, we attempted to reduce the waste identified in each process.

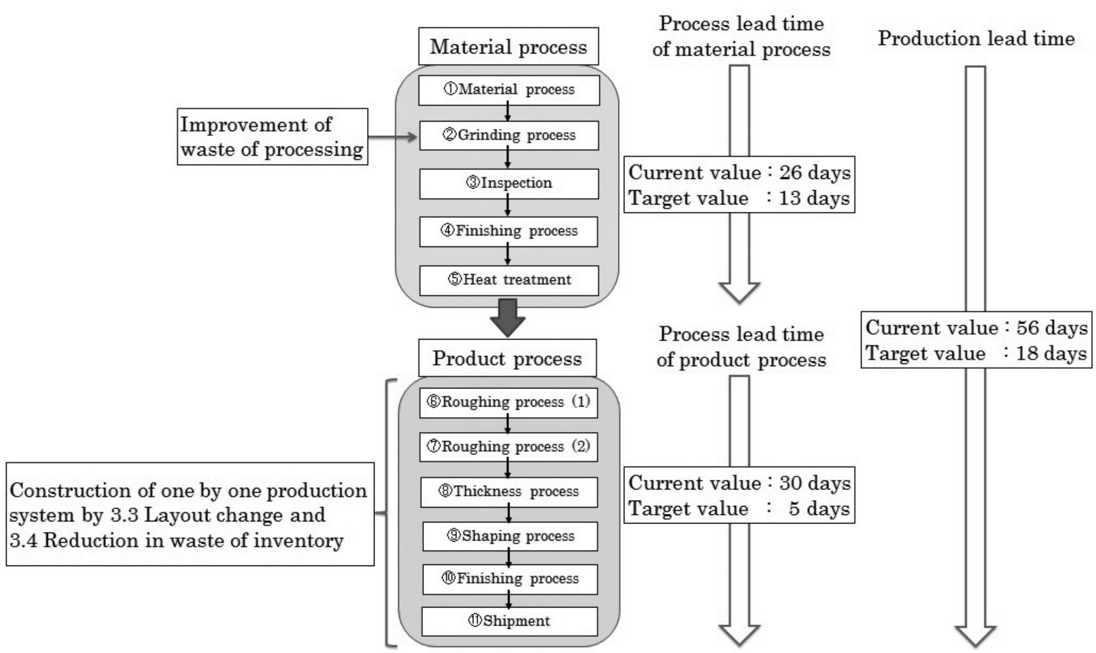

Fig.2 Outline of the TK Electrode production process

Table 2 Current and target lead times

	Process lead time of material process [day]	Process lead time of product process [day]	Production lead time [day]
Current value	26	30	56
Target value	13	5	18

2.3 Lead time analysis of the material process (waste due to unnecessary processing)

Fig. 3 shows the current and target material process lead times. The current material process lead time is 26 days. Among the parts of this process, the lead time of the grinding process (② in Fig.2) was the longest, at 16 days, accounting for 62% of the lead time. Therefore, by shortening the lead time of grinding process, we aimed to shorten the lead time of the material process by 13 days. As a result of analyzing work during the grinding process (② in Fig.2), we found that the processing efficiency was low. To shorten the lead time of the material process, we implemented measures to improve the efficiency of the grinding process.

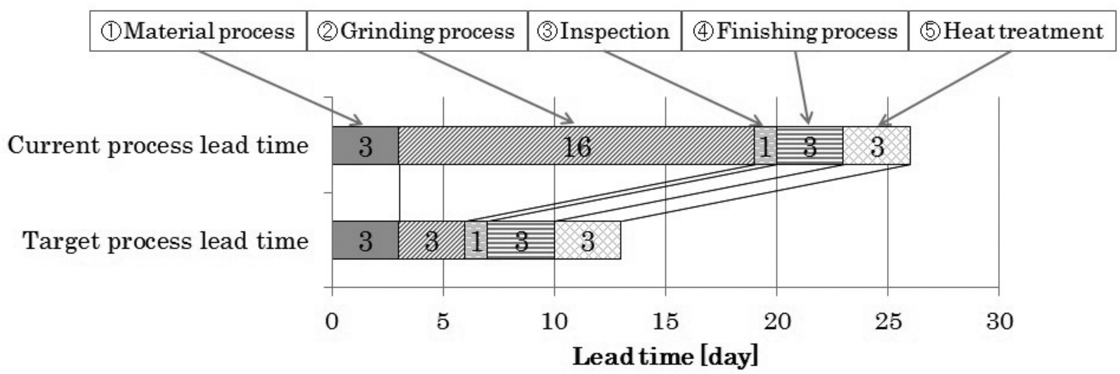

Fig.3 Material process lead time

2.4 Analysis of carrying distance during the product process (waste due to unnecessary transport)

After analysis of the product process, we found large distances between the processing equipment, leading to the product being carried for unnecessarily long distances. Fig. 4 shows the layout of the current product process. We aimed to minimize the carrying distance by aggregating equipment for the one-by-one production system.

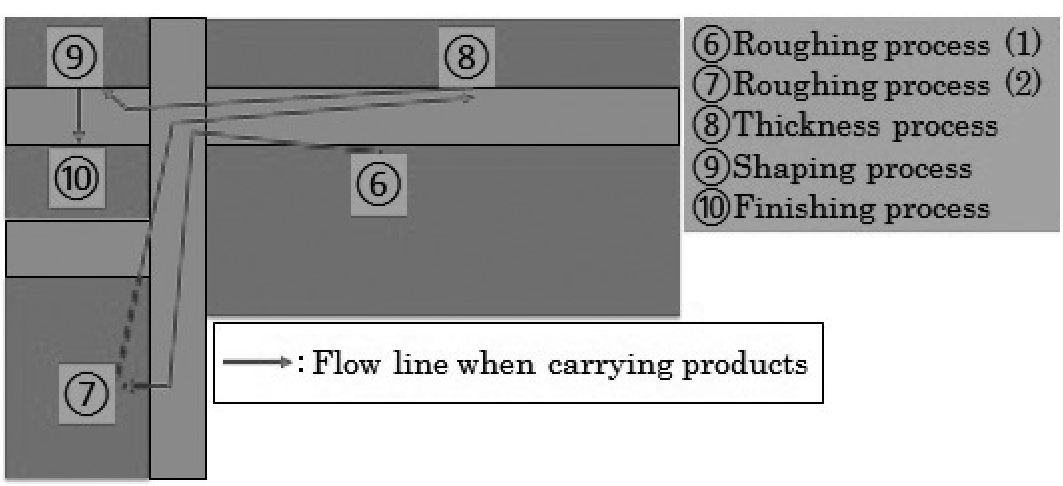

Fig.4 Layout of the current product process

2.5 Analysis of residence time of product process (waste due to unnecessary inventory)

In the current lot production system, setup and processing are carried out intermittently, and long residence times occur when the processing equipment has insufficient capacity. Fig. 5 shows the current product process lead time. The residence time accounted for most of the lead time (83%). We set a target of 5 days, to eliminate residence time. To achieve this we worked to construct a one-by-one production system with increased capacity.

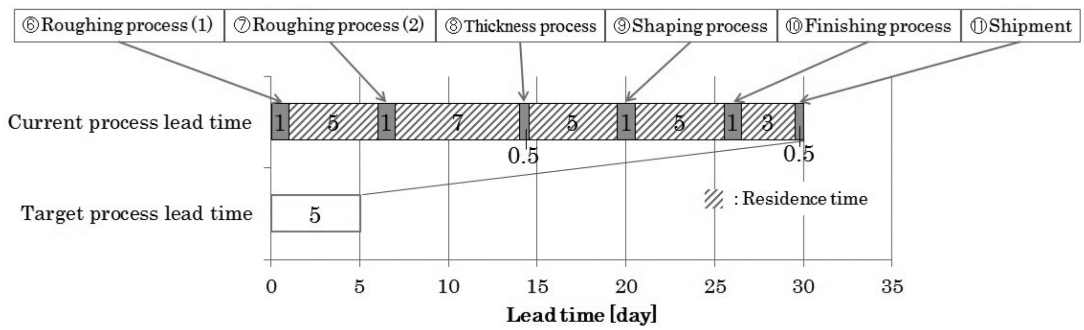

Fig.5 Product process lead time

3. Improvement results

3.1 Overview of improvement

By solving the waste problems outlined in sections 2.3, 2.4 and 2.5, and by constructing a one-by-one production system, the production lead time was greatly shortened. Each improvement is described below.

3.2 Improvement of the grinding processing method (reduction of waste due to unnecessary processing)

The grinding process (② in Fig.2) part of the material process was conventionally processed by only grinding. To improve this, we divided the processing method into two stages: cutting and grinding. Processing efficiency of cutting is higher than that of grinding; thus, the lead time can be greatly shortened. However, in ordinary cutting work, the tool life is short and there is a problem of increased tooling costs. Therefore, we selected tools to prolong the tool life and set a target life based on the number of machining processes and the amount of tool wear. Fig. 6 shows the test results. Table 3 shows a matrix evaluation of each processing method. From the matrix evaluation, it was confirmed that the improved combined cutting and grinding process has better processing and lead times than the other methods, for a small increase in tooling cost. We shortened the material process lead time by 15 days (58%) by changing the processing method. Fig.7 shows the improvement in the material process lead time.

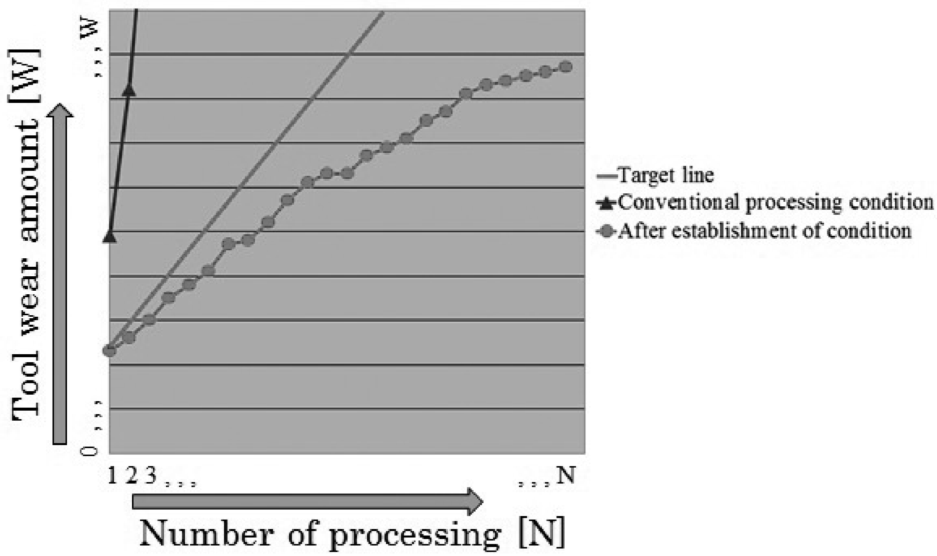

Fig.6 Cutting test result

Table 3 Matrix evaluation by processing condition

	Tool cost	Processing time	Lead time
Only grinding	◎	×	×
Conventional cutting	×	△	△
Cutting after condition establishment	△	◎	◎

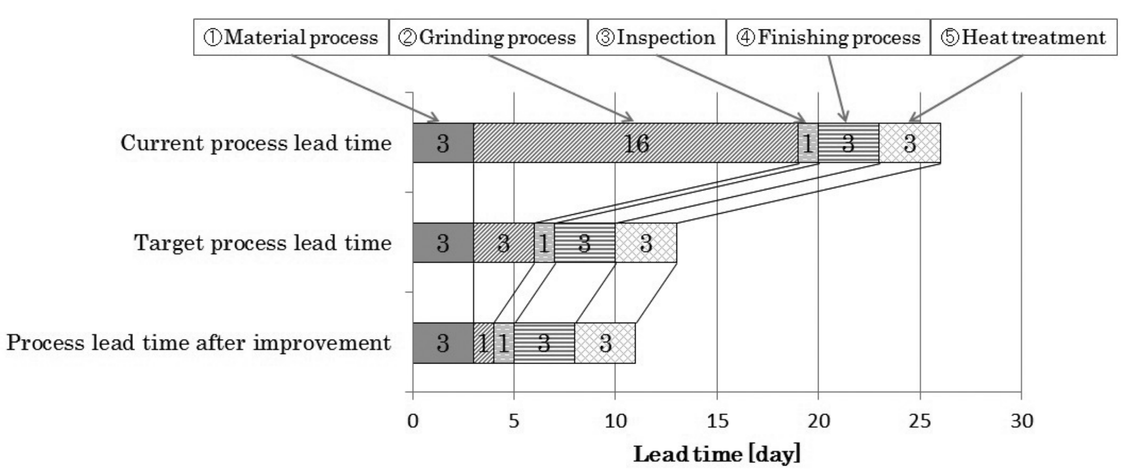

Fig.7 Improvements in material process lead time

3.3 Layout change (reduction of waste due to unnecessary transport)

In the conventional product process, products were carried for long distances between processing equipment stations. Although it was desirable to move processing equipment into a smaller area to reduce unnecessary transport, there were problems implementing this:

The processing equipment used in roughing process (2) (⑦ in Fig.2) was large and heavy, making it impossible to change the layout. Therefore, we constructed smaller processing equipment to allow the equipment to be rearranged and moved closer together.

Processing equipment used for roughing process (1) (⑥ in Fig.2), the thickness process (⑧ in Fig.2), the shaping process (⑨ in Fig.2), and the finishing process (⑩ in Fig.2) were easily moved, but were unsuitable for a small working area, owing to their large size. Therefore, new smaller processing equipment was selected and introduced.

As shown in Fig. 8, by arranging the smaller processing equipment in a U shape, the distance walked by the worker while transporting products was shortened by 80% compared with that for the conventional layout.

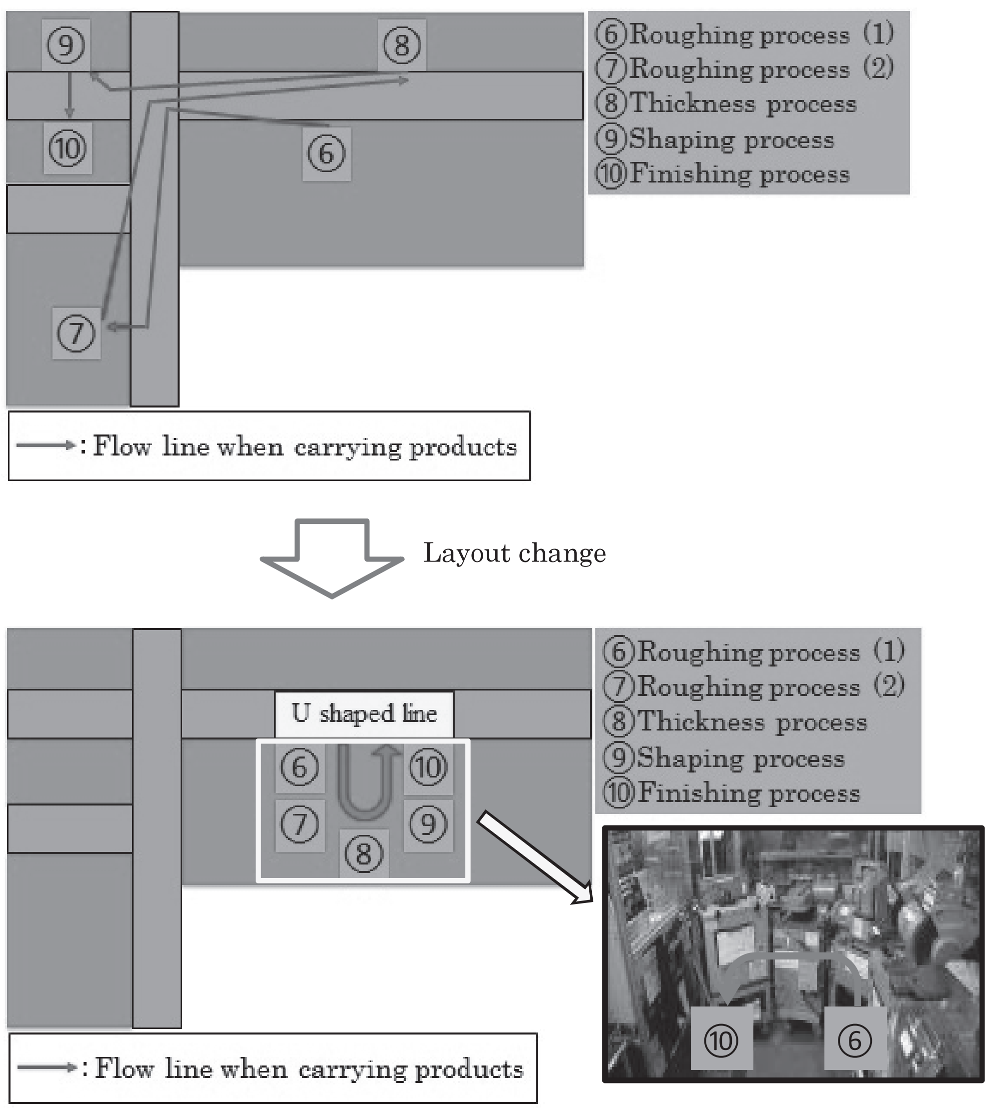

Fig.8 Facility layout before and after the layout change to the new U-shaped line

3.4 Reduction in residence time (reduction of waste due to unnecessary inventory)

To reduce the types of waste identified in sections 3.2 and 3.3, we greatly shortened the residence time by constructing a one-by-one production system. (Fig. 9)

By reducing the residence time, we achieved a process lead time of 5 days. Moreover, we have been able to further reduce the processing time, to just 2 days, by improving the setup method and optimizing the processing conditions. As a result, we shortened the product process lead time by 28 days (93%). Including the reduction in the material process lead time, we shortened the total TK Electrode production lead time by 43 days (77%). (Fig. 10 and Table 4)

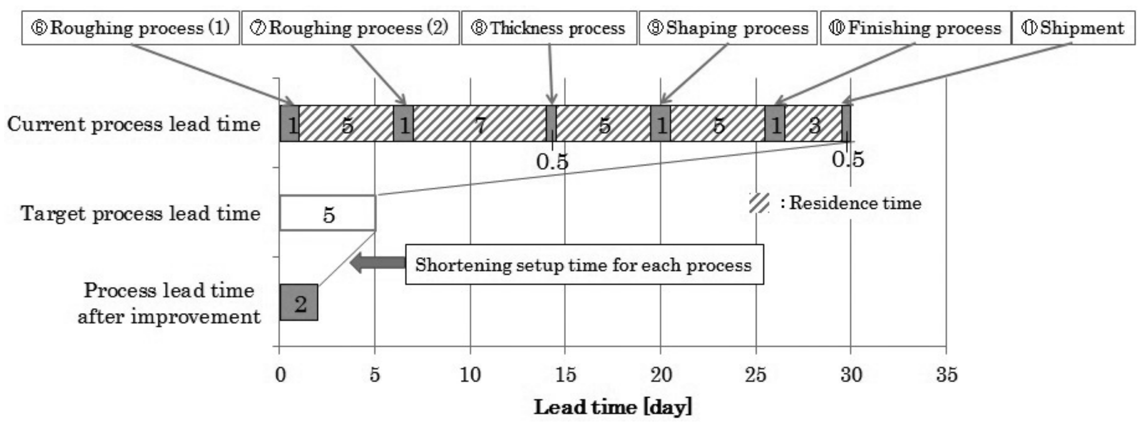

Fig.9 Improvements in production process lead time

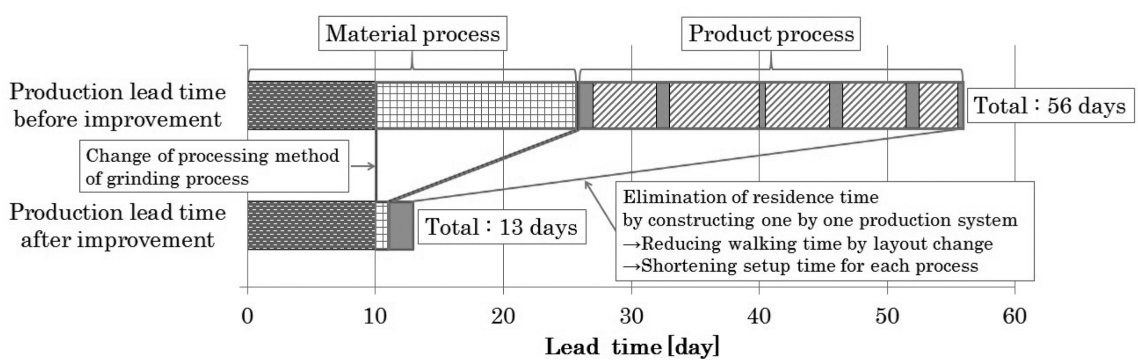

Fig.10 Production lead time after improvement

Table 4 Lead time after improvement

	Process lead time of material process [day]	Process lead time of product process [day]	Production lead time [day]
Current value	26	30	56
Target value	13	5	18
After improvement	11	2	13

4. Conclusions

The aim of the present study was to shorten the production process lead time of our TK Electrode. We constructed a new production system, adopting concepts from TPS and eliminating waste.

The main results are as follows:

1) In the material process, we reduced the lead time by 58% by dividing the grinding process into two processes: a cutting process and a grinding process, and by choosing appropriate processing conditions.

2) In the product process, we shortened the lead time by 93% by adopting a one-by-one production system with an improved layout and dedicated equipment.

3) In total, we shortened the production lead time of the TK Electrode by 77%.

These improvements allow us to meet to customer's short delivery dates and to cope with demand fluctuation. This production system can be adapted for other products, and we will continue to shorten production lead times and improve productivity.