Technical Paper

# Enhancement of Production Site Efficiency Using AI-Assisted Operation Analysis

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*To address labor shortages and decline of younger generations willing to work in manufacturing sectors in Japan, Komatsu has advanced Kom-mics to visualize and improve productivity of facilities. Improvement of worksites where manual labor are bottlenecks, however, has been slow, because visualization of workers were not achieved. This paper presents development of AI-assisted worker visualization technology for Kom-mics, and examples of production efficiency enhancement using this technology.*

***Key Words:*** *Kom-mics, Worker, Visualization, AI*

## 1. Introduction

As the machining of construction machine parts is a diversified item few quantity production process with a large variation in production volume that comes with as much variation in demand, the parts are processed on the active equipment and lines, mixed with other items. Accordingly, the machining also involves workers performing various manual work. Along with the above, in Japan, the shrinking working population and potential workers combined with younger generations increasingly hesitant to join the manufacturing sector has been raising concern about labor shortage. Komatsu shares the concern, and considers it a pressing task to increase the production value per worker through enhanced productivity.

## 2. Overview of Kom-mics

### 2.1 Entire scope of Kom-mics

To overcome the challenge, Komatsu developed Kom-mics [1]. Komatsu has various production equipment within the premises including machine tools, weld robots and heat treatment units. Kom-mics collects data from the equipment, stores it on the cloud and visualizes the data using the dedicated application (**Fig. 1**). Kom-mics now covers not just Komatsu but its suppliers to visualize the production of the entire supply chain, helping to reduce Muri (Overburdened), Muda (Waste) and Mura (Fluctuation).

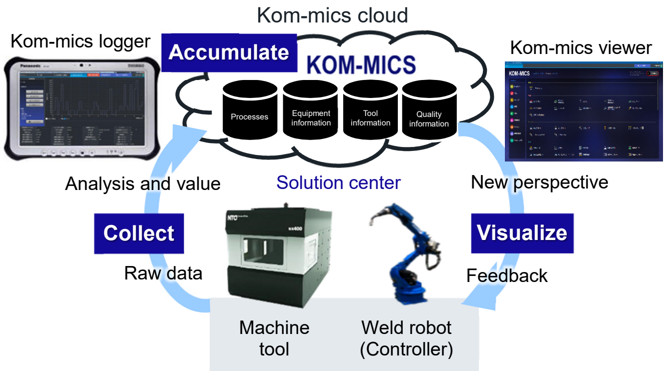



**Fig. 1** Entire scope of Kom-mics

### 2.2 Kom-mics visualization application

Kom-mics incorporates the visualization application to visualize collected data for early detection and resolution of possible issues.

#### 2.2.1 Operating ratio

Based on the equipment operation data collected in real time, the application can visualize not just the operating ratio of each piece of equipment but that of each line, workshop and plant (**Fig. 2**). Daily, weekly and monthly operating ratios are also available, making it possible to monitor for long-term change in operating ratio.

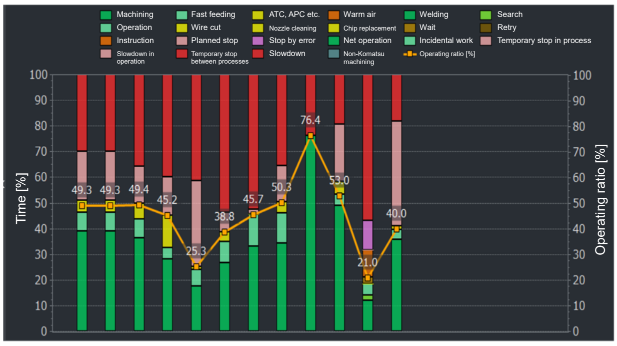



**Fig. 2** Operating ratio

### 2.2.2 Time chart

The time chart can be displayed with time on the horizontal axis and date and equipment on the vertical axis (**Fig. 3**). The time chart shows specific parts and processes that were worked on at specific time, and any stop that might have occurred together with its time and duration.

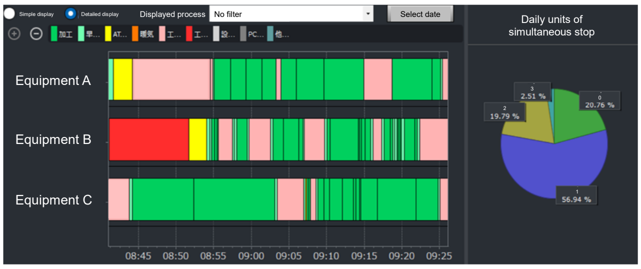



**Fig. 3** Time chart

### 2.2.3 Cutting resistance

More detailed process information can also be displayed (**Fig. 4**). Specifically, with machine tool operation, the application can visualize the cutting path a tool took, the type of force that caused the tool to take that path and the NC program that was run at that time. The information helps to identify appropriate remedial measures such as modifying machining conditions and discontinuing air cutting.

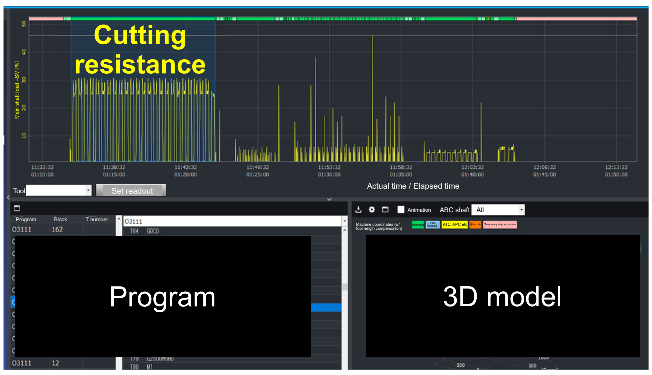



**Fig. 4** Cutting resistance

## 3. Visualization of workers

### 3.1 Overview

As discussed earlier, Komatsu employs diversified item few quantity production where part numbers produced on each piece of equipment change everyday under the production plan. On the batch production line, more than one piece of equipment is forced to stop at the same time (multiple interference) depending on the combination of part numbers being produced, pushing down the operating ratio below 50%. For worksites where multiple interference can occur, it is necessary to visualize workers' manual work, a contributing factor to line stop, to reduce downtime. To meet the need, Komatsu developed AI-assisted worker visualization technology and a system that displays the worker data together with equipment data on Kom-mics viewer.

### 3.2 Worker visualization system

Human detection AI was added into Kom-mics logger, the equipment operation data collector (**Fig. 5**). With web cameras also connected to it, the AI-assisted Kom-mics logger acquires images and detects for workers every second in real time. The AI-processed data is linked with equipment operation data, and the linked data is sent to Kom-mics cloud for data accumulation.

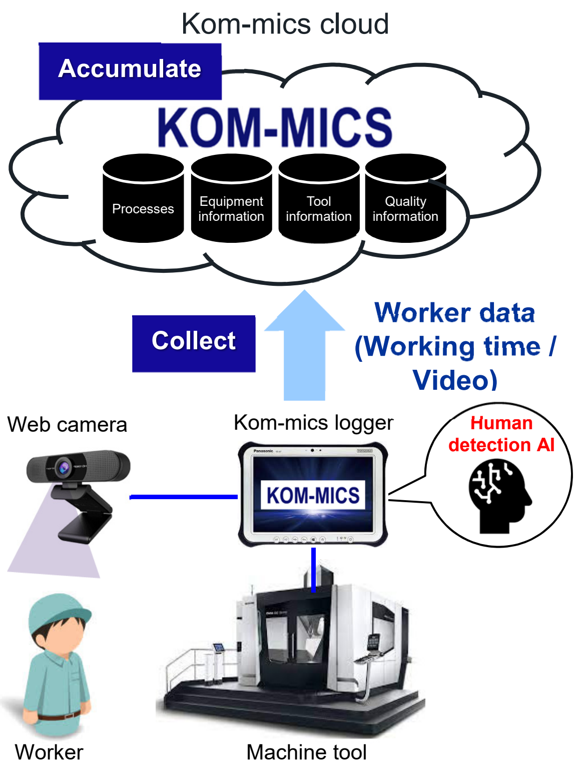



**Fig. 5** Worker visualization system configuration

**Figure 6** shows a shot of a typical production site. **Figure 6** shows work areas set by a user. AI detects workers only when they are in the set areas and outputs the working time of workers in each work area. This prevents irrelevant workers in nearby passages or working for other nearby equipment from being detected even when they are in the set work areas, and thus ensures more accurate calculation of working time.

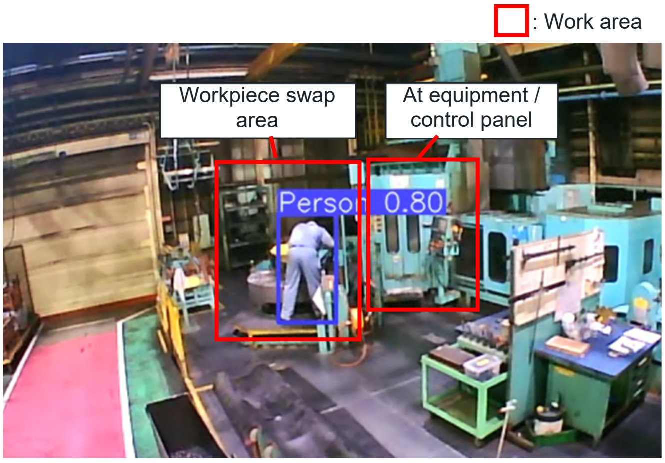



**Fig. 6** Work area setting

The worker visualization system employs lightweight, inexpensive edge AI to detect workers in real time. This, on the other hand, can generate false detection depending on the site environment. **Figures 7** and **8** show examples of false detection. There are two types of false detection: (1) an object detected as a worker that is smaller than a worker and has a relatively high AI score (**Fig. 7**) and (2) an object detected as a worker that is the same size as a worker and has a low AI score (**Fig. 8**). To prevent those two types of false detection, an option to set two thresholds was made available: (1) object size threshold and (2) AI score threshold. When those thresholds are enabled, valid worker detection is output only when the values are exceeded.

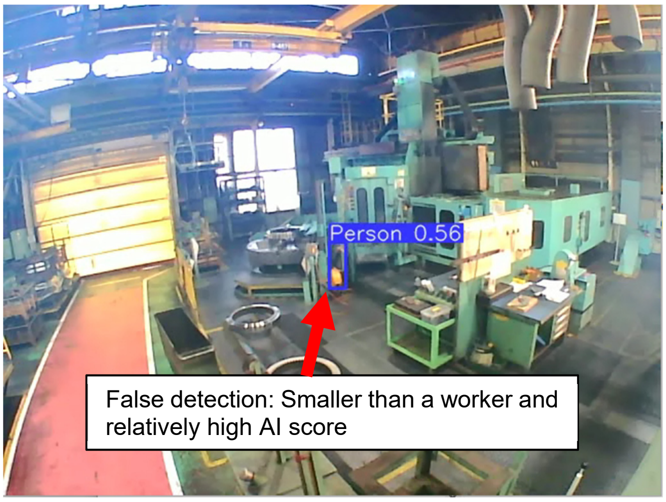



**Fig. 7** False detection example 1

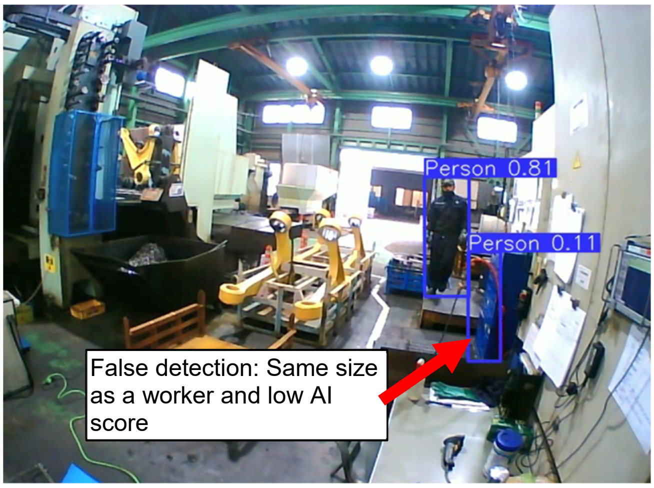



**Fig. 8** False detection example 2

### 3.3 Visualization application

Collected worker data is linked with equipment operation data and the linked data is accumulated on Kom-mics cloud. The database is then visualized as described below by the visualization application for users.

#### 3.3.1 Time chart

Equipment time chart is displayed along with worker time chart (**Fig. 9**). This arrangement enables the user to grasp operation stop, if any, the part number that is involved in the stop and the duration of the manual work during the stop. Multiple pieces of equipment can be displayed next to one another to enable the user to grasp the order in which the worker operated, what the worker was doing at the other equipment before late arrival at the next equipment, the time the worker spent outside the multi-work area, etc.

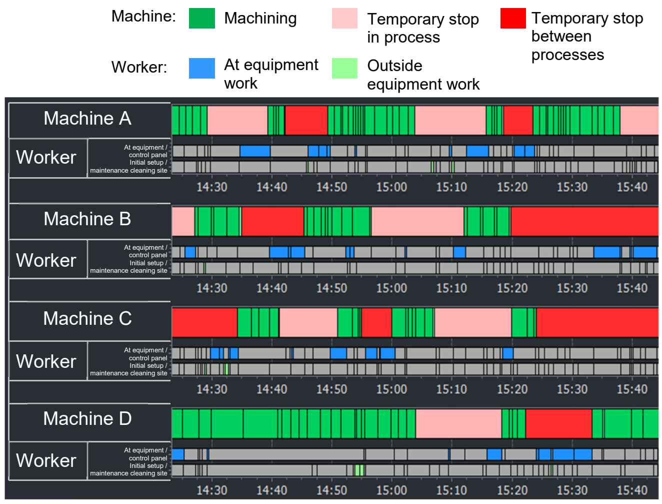


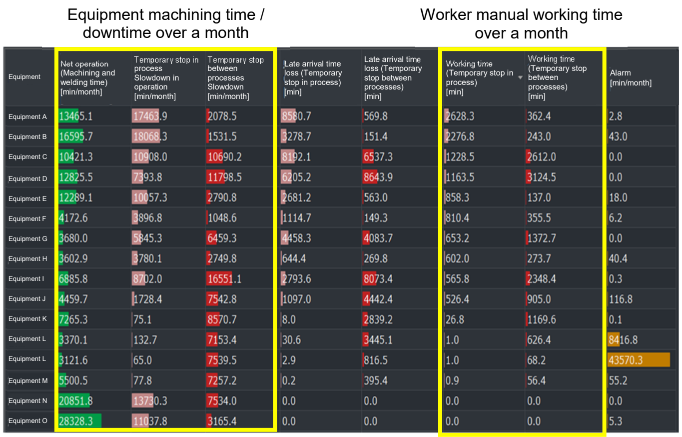

**Fig. 9** Equipment/worker time chart

### 3.3.2 Easy Improvement

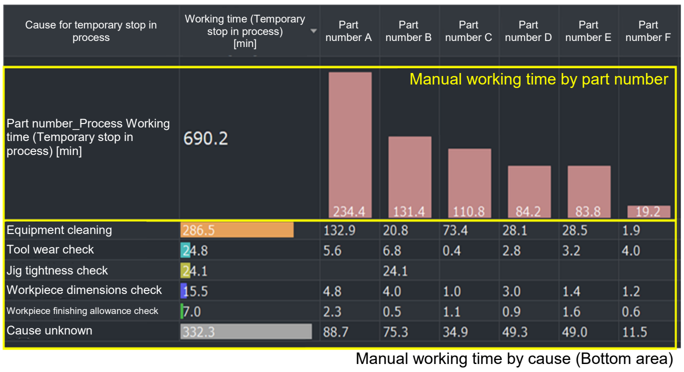
Kom-mics employs Easy Improvement, an application designed to promote improvement. Specifically, Easy Improvement collates equipment net operating time (including machining and welding time), temporary downtime in process and temporary down time between processes over a month and visualize the collated data (**Fig. 10 (a)**). The application can also visualize manual working time for each equipment by processing worker data together with the aforementioned equipment data.

More detailed data can be visualized by part number. **Figure 10 (b)** shows the manual working time during temporary stop in process by part number. The part numbers requiring more manual working time than others can be easily identified. The software can also be programmed to tally and show manual working time by cause of temporary stop, which makes it easy to monitor for improvement, i.e. which cause is tallying less manual working time than the other causes after the introduction of improvement measures.

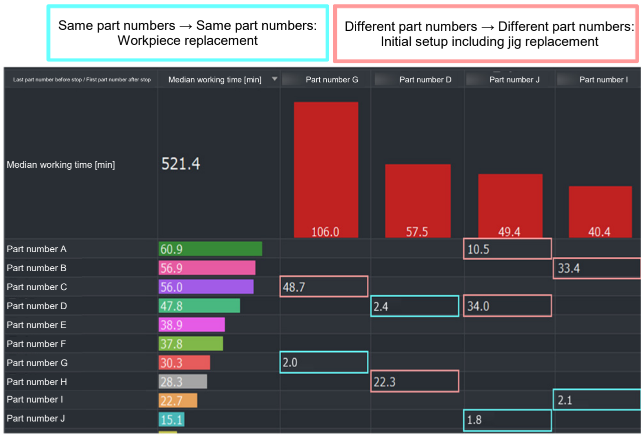
**Figure 10 (c)** shows manual working time during a stop between processes. The vertical axis shows the part number immediately before the stop while the horizontal axis shows the part number immediately after the stop. This arrangement enables the following differentiation: When the part number immediately before the stop is the same as that after the stop, the time displayed (in a blue square) was spent on replacing the workpieces while when the part numbers are different before and after the stop, the time displayed (in a red square) was spent on initial setup including jig replacement. In the example (**Fig. 10 (c)**), across the part numbers the workpiece replacement took around 2 minutes per session and the initial setup around 30 minutes per session.




(a) Entire equipment screen




(b) Manual working time during temporary stop in process by part number




(c) Manual working time during temporary stop between processes

**Fig. 10** Easy Improvement

## 4. Practical applications

The software application discussed above has been utilized at Komatsu and its suppliers to help drive improvement in overall operation.

### 4.1 Application to single equipment

The system was tried on a piece of equipment and subsequently improvement was achieved as discussed below. A camera was installed at the turning center shown in **Fig. 11** to shoot the tool area and the adjoining initial setup area, both indicated with a red square, and worker data was gathered for each of those work areas.

The operating ratio visualized by Kom-mics (**Fig. 12**) is around 30%, which is low, indicating a high ratio of temporary stop in process. Easy Improvement revealed the time spent on manual work during temporary stop in process (**Fig. 13**), together with the part number that required the longest manual working time and the types of manual work performed. It was found that the manual working time was mostly spent on workpiece dimensions check, centering and tool check.

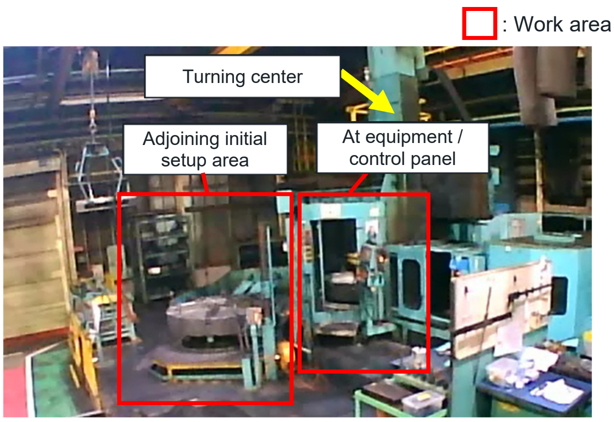



**Fig. 11** Equipment

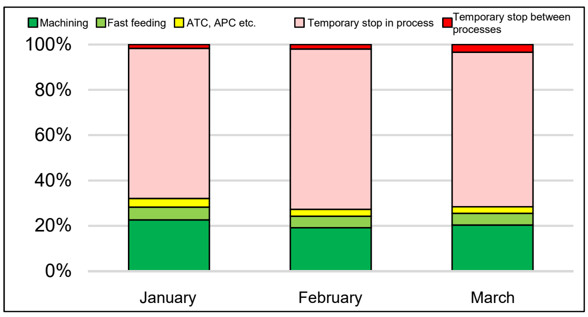



**Fig. 12** Operating ratio by month

Part number with the longest downtime for manual work

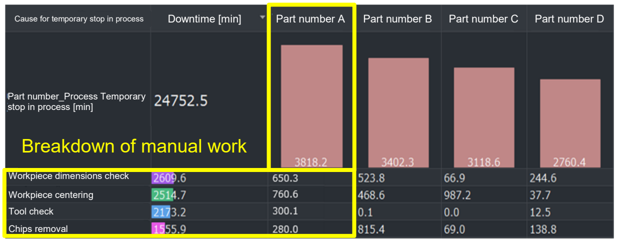



**Fig. 13** Easy Improvement (Manual working time during temporary stop in process)

The time chart for the part number with the longest downtime (**Fig. 14**) showed that the time loss was largely attributable to late arrival of the worker to the equipment. The large time loss from late arrival was due to the worker being in charge of multi-work involving a total of three pieces of equipment, creating a bottleneck. To improve the situation, the introduction of an air blow tool in the process eliminated the need to remove chips after temporarily stopping the process. As a result, the working time as well as late arrival were reduced while the cycle time was cut by 50%.

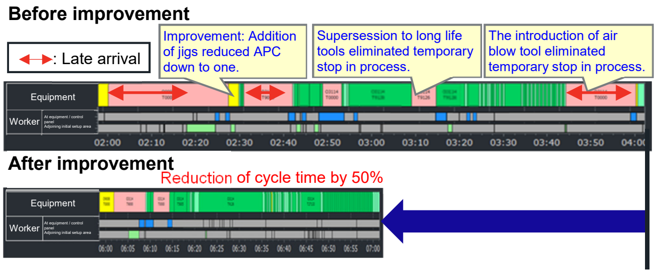



**Fig. 14** Time chart

### 4.2 Application to multi-work site

The system was tried on a machining site with four lathes grouped together (**Fig. 15**) for visualization and improvement. The site was a multi-work site with one worker machining parts using four lathes.

Kom-mics visualization revealed that every lathe had an operating ratio below 40% and that temporary stop between processes had a higher occurrence rate than temporary stop in process (**Fig. 16**).

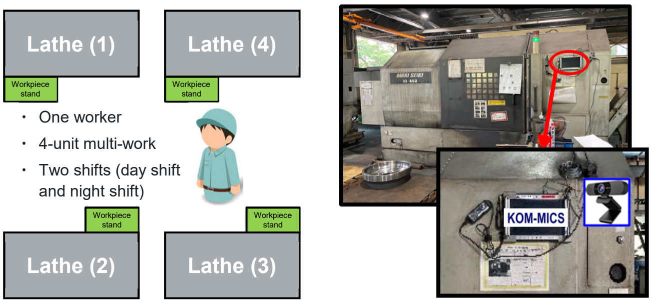



**Fig. 15** Typical multi-work site

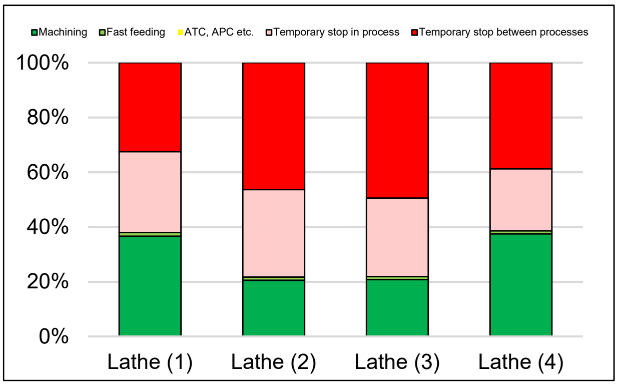



**Fig. 16** Average operating ratio

Easy Improvement visualization of working time during stop between processes (**Fig. 17**) revealed that it took the worker 8 to 9 minutes per session to remove and install workpieces with the same part number, which was longer than other worksites, thus pushing up the rate of temporary stop between processes. It took 2 minutes to remove and install workpieces at other sites, which suggested that the worker was doing something in addition to workpiece removal and installation. The relevant video showed that the worker took 2 minutes to remove and install the workpieces but spent additional time on grinding the workpiece before clamping it onto the lathe chuck, normally an unnecessary operation. There was a great variation in the dimensions of the workpiece, hence the grinding operation before machining. Calculation showed that eliminating the grinding work and just spending 2 minutes on workpiece removal and installation would cut the cycle time by 7%.

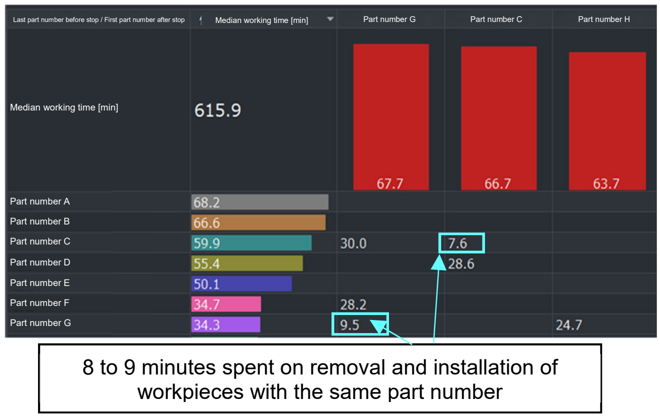



**Fig. 17** Easy Improvement (Working time during temporary stop between processes)

The time chart (**Fig. 18**) indicated that, not counting the break time, the worker was away from the group of 4 lathes for 2 hours per day. While the worker was away, the equipment stopped, resulting in the low operating ratio. The relevant video showed the worker operating a fork lift outside the work area to carry in unmachined workpieces and carry out machined workpieces. The worker and fork lift operator lacked coordination between them, with the fork lift operator failing to show up on time, forcing the worker to transport workpiece in and out. Calculation indicated that eliminating the worker's absent time of 2 hours per day would extend the equipment operating time by 2 hours, increasing the output by 10%.


**Fig. 18** Time chart

## 5. Conclusion

The research and development endeavor discussed in this paper "Enhancement of Production Site Efficiency Using AI-Assisted Operation Analysis" produced the following results.

Lightweight, inexpensive edge AI made it possible to detect workers in real time.

When used on a piece of production equipment, the system identified the part numbers with longer manual working time, helping to efficiently focus on those part numbers for effective improvement.

When used on a multi-work site, the system proved its capability to show the sequence of workers' actions, which helped to estimate the cause for process stop and low operating ratio. The system also suggested how much improvement could be expected.

Reference

[1] Naoto Saito, Keisuke Tsuboi, "KOM-MICS, a "Tsunagaruka" System for Production Sites", KOMATSU TECHNICAL REPORT, 2016, VOL.62 No.169, p.9-14

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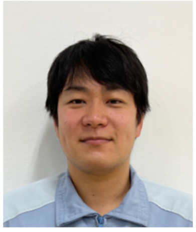

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**[A comment from the authors]**

It is hoped that AI and IoT will be utilized more actively at production sites to facilitate improvement effort. To see that happen, we will continue to keep up with the latest technology and develop systems that utilize AI and IoT.