

Development of methods for automating the mounting/removal operations of heat treatment jigs

Suguru FURUTANI*

Summary

JATCO aims to automate all the manual operations on the CVT pulley production line for the purpose of reducing costs. However, automation of the process of loading pulleys on heat treatment trolleys has not been accomplished yet. This process includes the work of mounting and removing heat treatment jigs that are stacked in two levels. Heat treatment jigs are repeatedly put into the heat treatment furnace during mass production; the effect of repeated heating gradually increases the amount of jig deformation and bending. This makes it extremely difficult to automate the operations of mounting and removing the jigs. This article describes the development of methods that enable automatic mounting and removal even of heat treatment jigs that are greatly deformed or bent.

1. Introduction

JATCO is promoting the automation of the CVT pulley production line for the purpose of reducing costs. Figure 1 shows the production processes of the pulley line. The processes in the blue frames have already been automated; the ones in the red frames have yet to be automated and are still performed manually at present. The unautomated processes have various issues such as detection of whether pulleys are present on the trolleys and detection of trolley position deviation. Among these processes, there is an especially strong need from an ergonomic standpoint to automate the mounting/removal of heat treatment jigs in the process indicated in the double red frames. This article describes newly developed methods that automate these operations.

2. Mounting/removal of heat treatment jigs

2.1 Heat treatment jigs and heat treatment trolleys

Heat treatment jigs are made of heat-resistant alloys, and pulleys are arranged on them for transport into the heat treatment furnace. Heat treatment jigs are put into the furnace together with the pulleys. The appearance and constituent parts of a heat treatment jig are shown in Fig. 2.

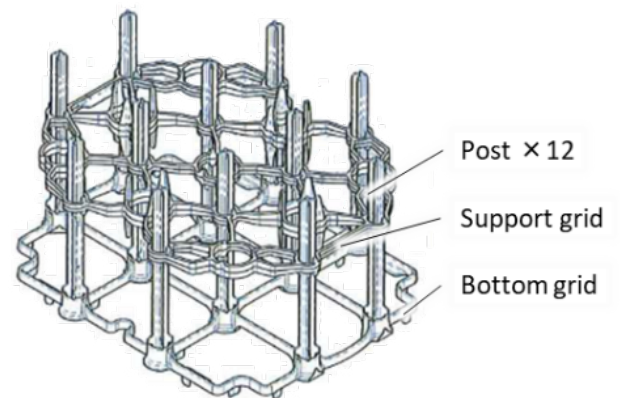


Fig. 2 Heat treatment jig



Fig. 1 Pulley production line processes

* Hardware System Development Department

A heat treatment jig consists of posts, a bottom grid and support grids. The posts are screwed to the bottom grid and the support grids are fastened to the posts. Figure 3 shows the appearance of a heat treatment trolley. The trolley is stacked with two rows and two levels of heat treatment jigs into which pulleys are loaded.

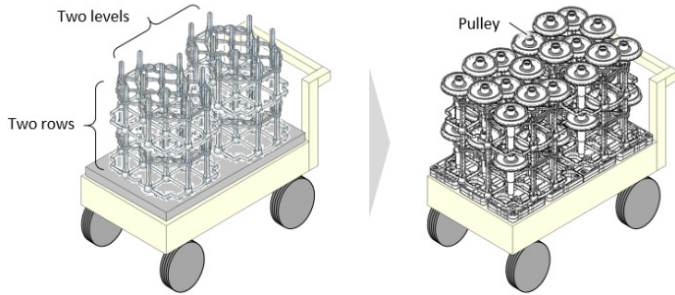


Fig. 3 Heat treatment jig trolley

2.2 Mounting/removal of heat treatment jigs

Figure 4 shows the work flow of the process for loading pulleys on a heat treatment trolley. These tasks are performed on the trolley shown in Fig. 3. A heat treatment jig has two levels stacked one above the other, so the upper level must be removed in order to load pulleys into the lower level and then remounted. These operations are repeated twice for each trolley. Because a heat treatment jig is heavy, weighing approximately 15 kg, there is a strong need to automate the work from an ergonomic perspective.

2.3 Deformation and bending of heat treatment jigs

Pulleys are heat treated to increase their surface hardness because they must function to transmit torque. Heat treatment jigs made of heat-resistant alloys also incur deformation induced by heating during the heat treatment process. The heat treatment furnace is heated to approximately 900°C in the pulley heat treatment process and then cooled. The amount of deformation induced by one heat treatment is around several tens of μm , but because heat treatment jigs are repeatedly put into the heat treatment furnace during mass production, their deformation and bending gradually become larger.

Figure 5 shows examples of heat treatment jigs that have experienced large deformation and bending. Posts show significantly large bending, with the largest bending being approximately 10 mm.



Fig. 5 Heat treatment jig

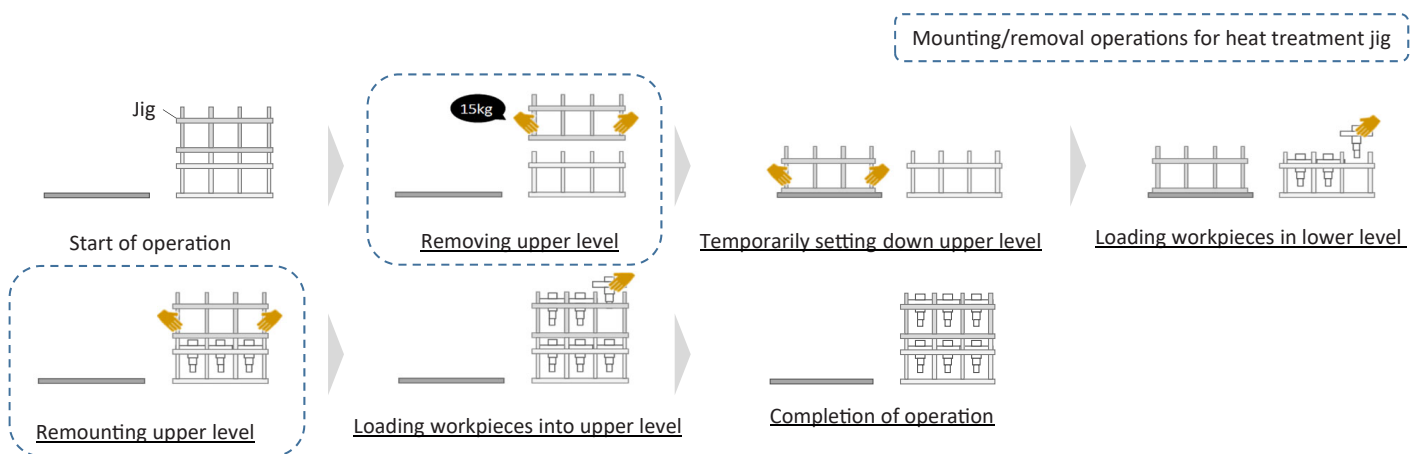


Fig. 4 Process of loading pulleys in jigs on trolleys for heat treatment

2.4 Issues in automating the work of putting pulleys into the furnace

Figure 6 shows examples of deformed and bent heat treatment jigs. Several tens of heat treatment jigs are used on the pulley production line. The amount of deformation and bending that jigs incur is not uniform for all of them.

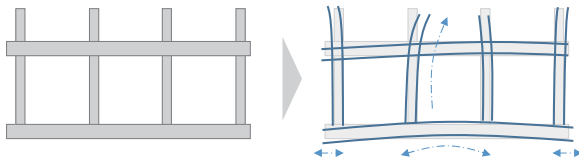


Fig. 6 Deformation/bending of heat treatment jigs

Heat treatment jigs must be clamped in order to automate the mounting/removal operations. Pneumatic cylinders are generally used to actuate clamps. Based on the configuration of the heat treatment jigs, it was assumed that the most suitable location for clamping them would be the sides of the bottom grid. However, the following problem can be cited in this regard. In case a pneumatic cylinder is used to clamp a heat treatment jig, a sensor installed in a fixed position would be used to confirm the completion of clamping. However, when the bottom grid of a greatly deformed or bent heat treatment jig is clamped, a stationary sensor would not be able to confirm the completion of clamping. It can be predicted that a clamping defect might occur (Fig. 7). This is an issue in trying to automate the work of putting pulleys into the heat treatment furnace,

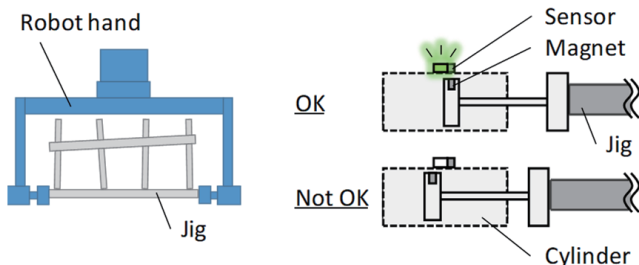


Fig. 7 General clamping system

3. Investigation of specifications

3.1 Equipment specifications

Figure 8 shows an outline of the equipment specifications.

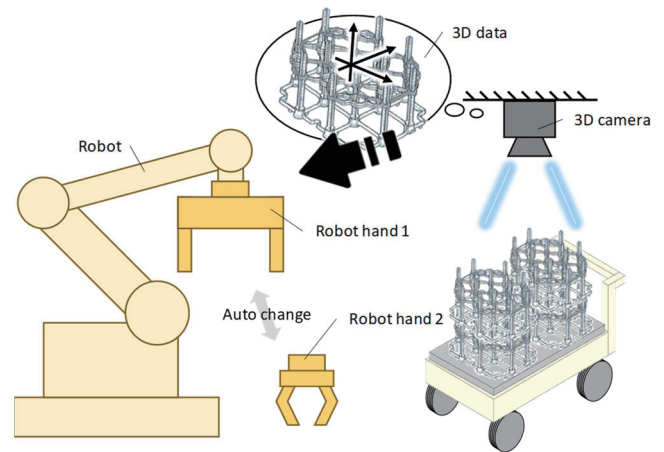


Fig. 8 Outline of equipment specifications

In this project, a study was made of equipment specifications involving the use of an articulated robot and a 3D camera. A 3D camera is capable of capturing in three dimensions the shape, position and orientation of the object being photographed. The trolley and the heat treatment jigs on it generally experience several tens of mm of positional deviation each time the trolley is changed. It was envisioned that the 3D camera would capture the positional information of the heat treatment jigs and input that information into the robot. The robot hand can approach a heat treatment jig in the space over the jig. Putting pulleys into the furnace requires a robot hand for mounting/removing heat treatment jigs and a robot hand for loading pulleys into the jigs. The equipment is fitted with a device that enables the attaching/detaching of a robot hand suitable for each task.

3.2 Investigation of a clamping system

As mentioned in section 2.4, it is obvious that general clamping systems would not be able to cope with deformed or bent heat treatment jigs. Accordingly, clamping systems were benchmarked.

Figure 9 presents the benchmarking results.

Clamping system	Flexibility	Load capacity	O :Good X :Poor	
			Cost	Durability
Suction	O	X	O	X
Spring	O	X	O	O
Interchangeable soft/hard gripper mechanism	O	X	X	X
Cooperative linkage mechanism	O	X	X	X
Locking cylinder	O	O	O	O

Fig. 9 Benchmarking of clamping systems

One function required of the clamping system in this project is flexibility for reliably clamping even deformed or bent heat treatment jigs. In addition, it must have the load capacity to transport heavy heat treatment jigs weighing 15 kg apiece. Moreover, cost and durability are also important indices for application to mass production. Based on these perspectives, it was reasoned that a locking cylinder would be best suited for the clamping system.

Figure 10 shows an outline of a locking cylinder. A locking cylinder has a mechanism for holding the rod at the position where the cylinder stops. Unlike ordinary cylinders, there is no need for a locking cylinder to stop at a pre-determined position, so it can clamp a heat treatment jig by following the jig's shape.

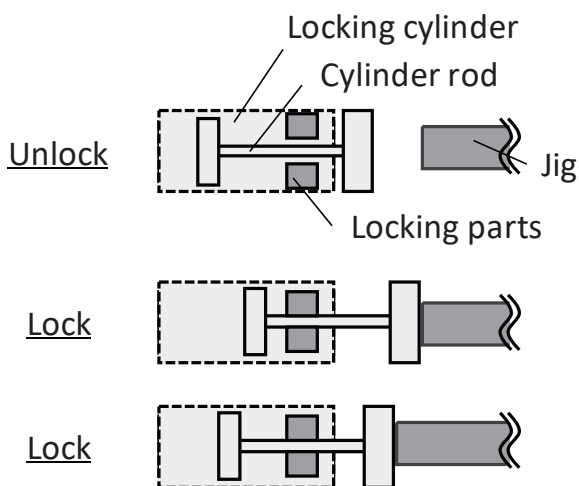


Fig. 10 Locking cylinder

3.3 Investigation of robot hand specifications

Figure 11 illustrates the concept of clamping the bottom grid of a heat treatment jig using a locking cylinder.

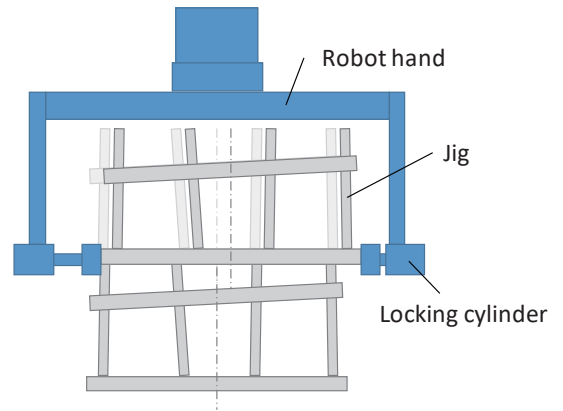


Fig. 11 Clamping system using a locking cylinder

A locking cylinder is characterized by continuing to move forward to its full-stroke position so long as a certain level of reaction force is not applied to it. Accordingly, it might shift the position of the upper level of the heat treatment jig when clamping the bottom grid. This means that it would not be able to reproduce the position for remounting the upper level. Therefore, a study was made of a clamping system capable of following the shape of the heat treatment jig while keeping the jig stationary. Figure 12 illustrates this clamping method.

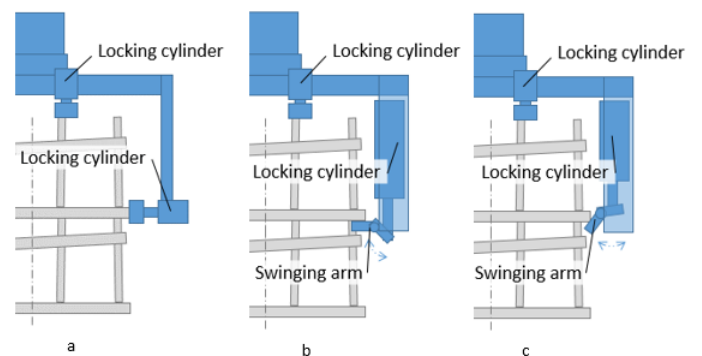


Fig. 12 Clamping method

To keep the heat treatment jig stationary, first, the upper level of the jig is pressed against the lower level. The adoption of a locking cylinder is also advantageous here because it can accommodate deformed posts. The “post holding device” attached to the front end of the cylinder was designed with a size that can handle deformed or bent posts at the time a heat treatment jig is removed.

Next, the bottom grid is clamped. There was concern that if the grid was clamped horizontally, the clamping force might be insufficient against inertial force during transport and a heat treatment jig might fall down. To prevent that, a specification was devised for sandwiching jigs from above and below by adopting a swinging arm, as shown in Fig. 12-b. However, because the swinging arm would interfere with the heat treatment jig at the lower level, clamping would be impossible. Accordingly, to avoid that interference, a method was devised for pushing the swinging arm diagonally by offsetting its fulcrum (Fig. 12-c). It was reasoned that this would not only avoid interference, it would also prevent positional deviation vertically and laterally. Figure 13 shows a 3D model of the robot hand that was designed on the basis of the proposed methods.

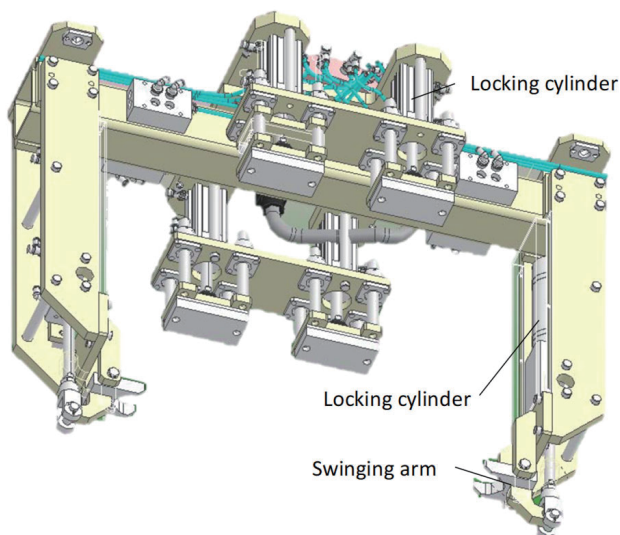


Fig. 13 Robot hand

3.4 Investigation of heat treatment jig specifications for temporary upper level removal

An investigation was made of the operation of “temporarily removing the upper level” shown in Fig. 4. In order to automate this operation, after the robot hand removes the upper level of the heat treatment jig, the hand must be switched to the robot hand for loading pulleys into the lower level of the jig. At that time, as shown in Fig. 14-a, temporarily setting down the heat treatment jig and the robot hand separately might cause their positional relationship to deviate, making it impossible to reproduce the position for remounting the upper level of the jig. Therefore, a method was devised for temporarily setting them down together in a state with the robot hand clamping the heat treatment jig (Fig. 14-b). That was accomplished by using the characteristic of the locking cylinder that it locks when the air supply is stopped. This method makes it possible to suppress any deviation in the positional relationship when temporarily removing the upper level of the jig.

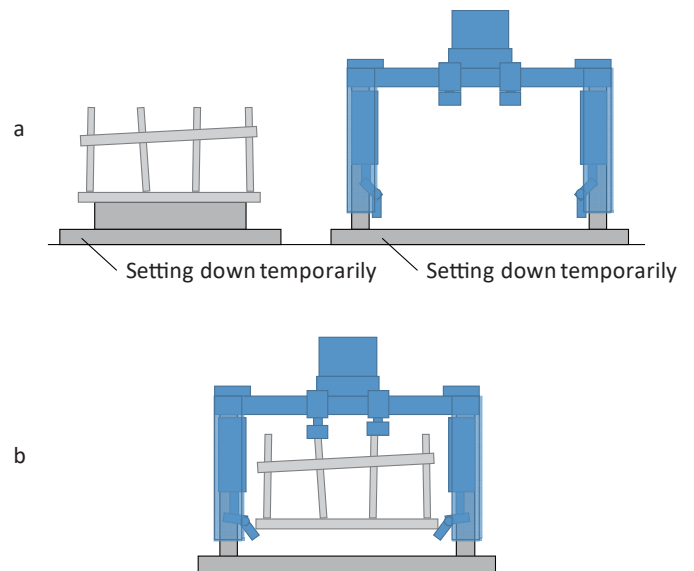


Fig. 14 Specification for temporarily setting down heat treatment jig

4. Application to mass production

Equipment was designed and built to achieve the devised methods and installed on the pulley production line to conduct a mass production trial. Figure 15 shows the appearance of the equipment installed on the pulley production line. The trial was conducted using multiple heat treatment jigs having different amounts of deformation and bending. The results confirmed that even heat treatment jigs with various amounts of deformation and bending were clamped stably. All operations of the pulley input process were automated including jig removal and remounting, thus achieving successful application to mass production.

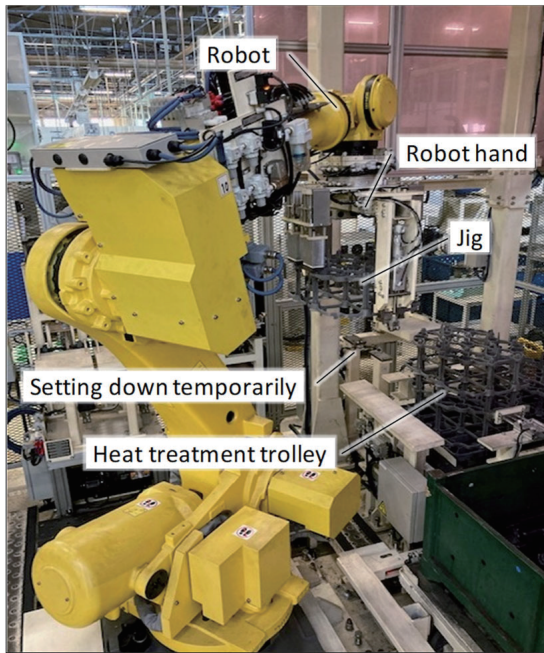


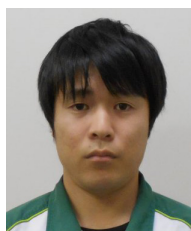
Fig. 15 Appearance of equipment

5. Conclusion

The development of the methods described here has made it possible to automate the operations of mounting/removing heat treatment jigs having large amounts of deformation or bending. As a result, this eliminates the manual work of handling heavy heat treatment jigs when putting them into the furnace, thereby reducing costs and improving the work environment.

The equipment installed in this project was developed for use on the pulley production line, but it is also applicable to the gear production line as well as to jigs. It is planned to use these methods in the future to achieve further cost reductions and work environment improvements.

■ Author ■



Suguru FURUTANI