Commentary

Construction of Silent Chain Sprocket Production Line

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Abstract

Application of silent chains in automobile engines has increased recently. Because high contact fatigue strength is required in silent chain sprockets, Hitachi Powdered Metals Co., Ltd. produces these sprockets by a process which includes compacting, high temperature sintering, gear rolling, etc.

In order to respond to increased unit production, a production line was constructed and productivity was increased. In the construction of the production line, the number of pieces packed in sintering cases was increased, and the production capacities of the presses and sintering furnace were set to be consistent with each other. As part of this project, the transportation of green compacts, sintering case packing work, and the process of charging to the sintering furnace were automated. The processing method used in gear rolling was also studied, and the gear rolling process was synchronized with the following repressing process, thereby realizing increased productivity. As a result, the productivity of the line as a whole was improved to 250% in comparison with that before improvements to realize line production.

Keywords: Silent chain, sprocket, line production, automatic sintering case packing, 1-process/2-gear rolling

1. Product specification

Fig. 1 shows a drawing of the sprocket which was the object of this project. The material is a high strength Fe-Ni-Mo-C based material, and the product configuration is a 2-step sprocket shape.

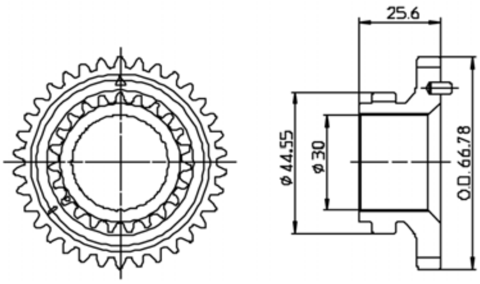

Fig.1 Product figure.

Fig. 2 shows the manufacturing process. In order to secure the contact fatigue strength of the sprocket tooth surface, the basic manufacturing process for this product comprises compaction and high temperature sintering, followed by rolling to increase the tooth density to 7.6Mg/m^3 or higher, and heat treatment by super carburizing and tempering.

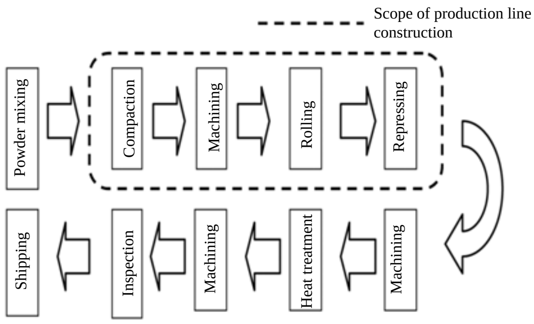

Fig. 2 Scope of production line construction project.

2. Conventional production process

Fig. 3 shows the production process which had been used since the start of mass production. Because the original production process used dispersed, general-purpose equipment, the production mode was “group control” production for each process. For this reason, the process required a considerable amount of manual work in charging and extraction, as well as much work related to in-process product/transportation between processes, resulting in low productivity.

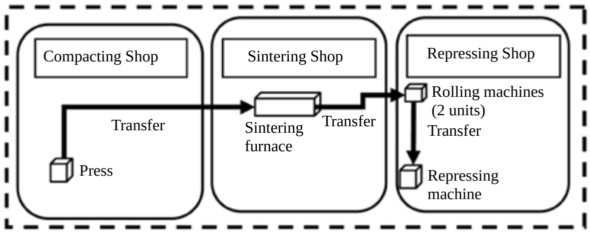

Fig. 3 Conventional production process.

Table 1 shows the number of machines used for production of this product and their load factors. Because all of this equipment was used in common with the production of other products, the load factors of all the equipment except the rolling machines exceeded 100% from the start of mass production, and also exceeded 100% with the rolling machines after production was increased. Therefore, an adequate response to production requirements was considered impossible.

Table 1 Equipment available for silent chain sprocket production and load factors.

	No. of object machines	Load factor at start of mass production	Load factor after improvement
Compacting press	7	116%	124%
Sintering furnace	5	128%	148%
Rolling machine	4	86%	143%
Repressing press	3	121%	146%

3. Concept for realizing line production

3.1 Study of composition of production line equipment

Table 2 shows the production capacity of each unit of equipment assuming the treatment capacity index of the presses is 100, and the number of units of other equipment necessary, as calculated based on press capacity. If a production line is constructed using the existing equipment, the expected unit output after increasing production will not exceed the capacity of the presses. As the capacity index of the sintering furnaces and rolling machines are 53 and 33, respectively, 2 sintering furnaces and 3 rolling machine are necessary to cope with the capacity of the presses.

Therefore, it was planned to increase the capacities of the sintering furnaces and rolling machines, having small capacities,, and construction of the production line was carried out preconditioned on eliminating the existing unbalances in treatment capacity.

Table 2 Treatment capacity (index) of existing equipment and necessary units of equipment.

	Treatment capacity (index)	No. of machines
Compacting press	100	1
Sintering furnace	53	2
Rolling machine	33	3
Repressing press	100	1

Fig. 4 shows a conceptual diagram of the production line. This new line consists of one automated compacting-sintering line, and two automated rolling-repressing lines. Details regarding the increases in the capacities of the sintering furnaces and rolling machines, which were a precondition for this line, will be discussed separately.

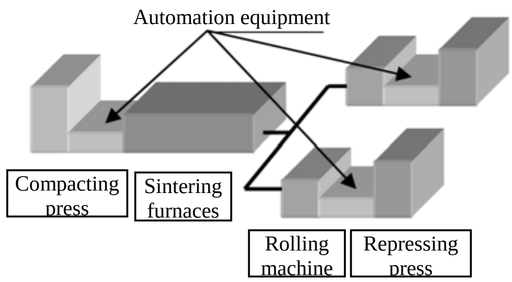

Fig. 4 Concept of the new production line.

3.2 Target values of production line

The target values of the various items in the development of the production line, including productivity, labor-saving, lead time, and rejection ratio, were set as shown in Table 3.

Table 3 Target values.

	Before improvement (%)	After improvement (%)	Concrete study items
Productivity (capacity)	100	180	Increase of sintering furnace capacity Arrangement of compacts Automatic sintering case packing Increase of rolling machine capacity Construction of inline rolling-repressing line
Labor-saving	100	50	
Lead time	100	50	
Rejection ratio	100	10	

4. Study of compacting-sintering production line

4.1 Increase in sintering furnace capacity

Although adoption of a large-scale sintering furnace is effective for securing the required capacity in sintering furnaces, in the present project, installation space, energy saving, etc. were problems. Therefore, in the new sintering furnace, line tact was secured by increasing the height of the sintering case, making it possible to stack multiple layers of sintering plates in the sintering case while using a furnace of the same scale as the existing unit.

An automation device was developed to set multiple layers of green compacts in the sintering case, and ingenuity was also applied to the arrangement of the green compacts.

4.2 Arrangement of green compacts

Fig. 5 and Fig. 6 show the original arrangement of the green compacts on the sintering plate and the arrangement after improvement, respectively. Originally, all green compacts were arranged in the same direction (i.e., with the same side of the work facing upward). Therefore, considering the relationship between the plate dimensions and green compact dimensions, the spacing between the compacts was approximately 5mm. In manual arrangement work, this resulted in defects such as missing gear teeth due to contact between the green compacts, and sticking defects after sintering also occurred due to vibration during sintering case transportation.

These missing tooth and sticking defects were reduced to zero by adopting automatic arrangement of the green compacts with a spacing of approximately 16mm, in a new arrangement in which alternating compacts are turned face up and face down.

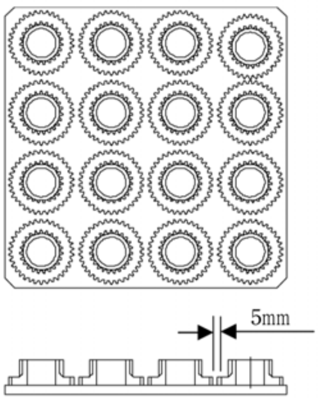

Fig. 5 Arrangement of compacts at conventional line (manual work).

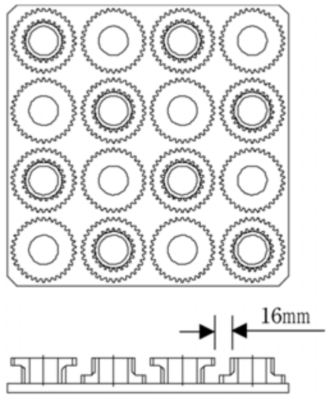

Fig. 6 Improved arrangement (automated arrangement, alternating sprockets face up/down).

4.3 Automatic sintering case packing device for green compacts

Fig. 7 shows a schematic diagram of the automatic sintering case packing device for green compacts. The device comprises 3 units, a green compact transportation section, a stacking arrangement section, and a sintering case exchange section.

The green compact transportation section includes a weight checker, NG rejection device, deburring device, and compact inverting device. The stacking arrangement section consists of a 3-axis orthogonal robot, a triple hand for the work, jigs, and plates, and a jig/plate supply device. The sintering case exchange section consists of a supply conveyor, lifting conveyor, and case cover/frame lifting device.

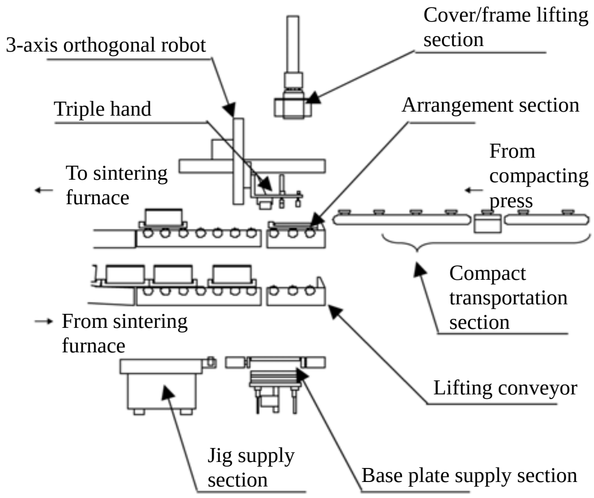

Fig. 7 Outline of automatic sintering case packing system.

4.4 Automatic arrangement method for green compacts in sintering case

Fig. 8 shows the automatic sintering case packing method for green compacts. Considering the function of the object product, high temperature sintering is necessary in the sintering furnace. Therefore, a pusher-type sintering furnace which uses a deep box-shaped sintering case was adopted.

First, the green compacts are automatically arranged on the plate, as illustrated in Fig. 6. Next, multi-layer stacking jigs are arranged between the green compacts, as shown in Fig. 8, and the base plate on which the green compacts are arranged is placed on the sintering tray. Next, another base plate on which compacts are arranged is placed on the stacking jigs on the previous plate. This process is repeated until the necessary number of layers have been stacked on the tray. The case frame and case cover are the assembled. This case packing work was automated using the 3-axis orthogonal robot.

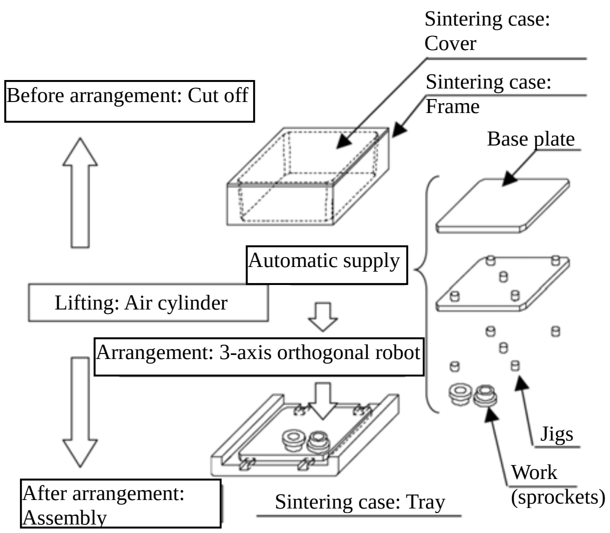

Fig. 8 Method of packing green compacts into sintering case by automatic operation.

5. Study of rolling-repressing production line

5.1 Increase of rolling machine capacity

Because the object product has a 2-step sprocket shape, it is necessary to roll two gears. However, the existing rolling machine required one work transport process for each gear rolling operation. Therefore, use of this machine in the new production line would result in loss due to exchange of the roll die used in machining the large gear and the small gear and loss due to double transportation of the work. To secure the capacity required in the line, three rolling machines would be necessary. However, considering inline production with the repressing machines, 4 rolling machines would be necessary. That is, it would be necessary to install two sets of rolling equipment, each consisting of two rolling machines (one each for the large gear and small gear), for the two repressing machines.

Therefore, a rolling machine that enables rolling of two gears with one transport process was designed. The required capacity was secured with two of these machines, and inline production with the repressing machine was realized.

5.2 Method of rolling 2 gears with 1 transport process

Fig. 9 shows an outline of the rolling method in which two gears are rolled with one transport process. In the specification of the conventional equipment, one gear was machined with one pair of roll dies. However, with the equipment studied in this project, one set of a large gear roll die and a small gear roll die is mounted on each shaft (two sets on two shafts), and rolling of two gears is realized by moving the work to the large gear machining section with the center stand, and next moving it to the small gear machining section.

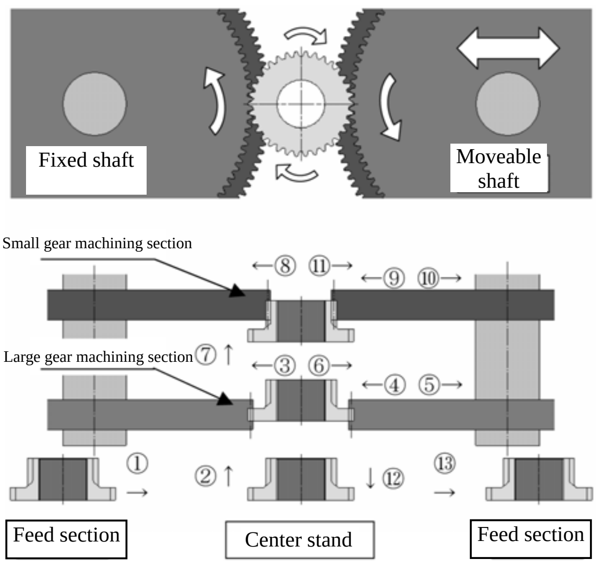

Fig. 9 Method of rolling 2 gears with 1 transportation process.

5.3 Construction of inline rolling-repressing production line

Fig. 10 shows an outline of the rolling-repressing line. The work is fed from the feed device to the center stand of the rolling machine, the large gear and small gear are machined, and the work is discharged from the machine.

After rolling, the phase of the work is aligned, and the work is coating with lubricating oil. The work is then fed to the repressing machine and repressed. After repressing, the work is discharged to the discharge stocker by the discharge device.

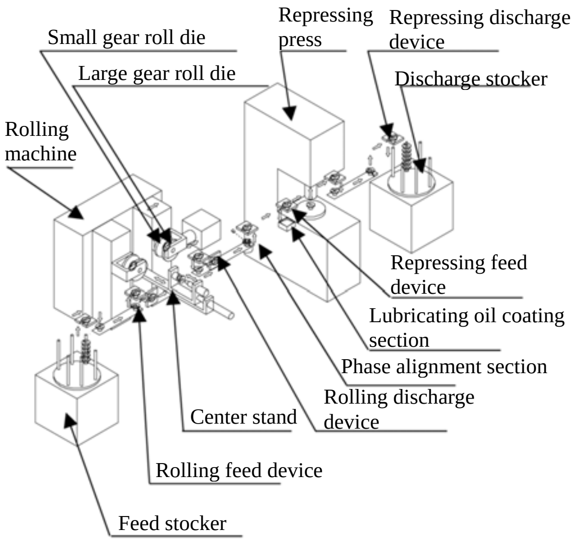

Fig. 10 Outline of inline rolling-repressing production line.

6. Implementation of inline production

Fig. 11 shows the layout of the equipment after construction of the integrated production line. The equipment comprises one compacting-sintering line and two rolling-repressing lines. The total length of the line is approximately 40m.

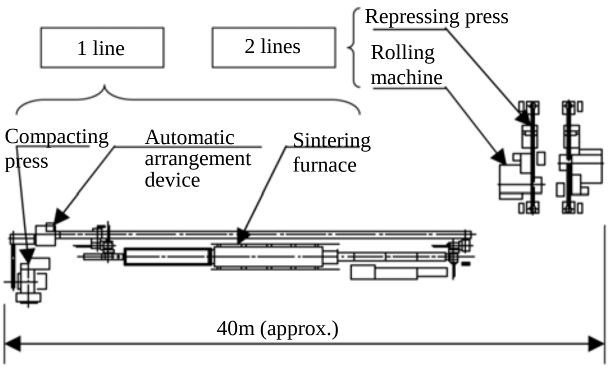

Fig. 11 Layout of equipment.

7. Conclusions

An integrated production line for silent chain sprockets was constructed. The following may be mentioned as results of this modernization project.

Table 4 shows the various results, assuming the level before improvement is 100. Production capacity has increased to 180, while manual work has been reduced to 40. Including labor-saving, productivity has increased to 250. Lead time has been cut by half, and the rejection ratio has been reduced to only 1/7 the previous level.

Table 4 Results of construction of integrated production line.

	Before improvement (%)	After improvement (%)
Production capacity	100	180
Manual work	100	40
Productivity improvement	100	250
Lead time	100	50
Rejection ratio	100	15

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