Technology Introduction

Methods for Improving Productivity and Quality for Machining EPS Dampers

ITO Susumu, KOUKETSU Hisato

1 Introduction

In response to the new order of electric power steering (hereinafter referred to as "EPS"), we started positioning dampers (Fig. 1) as the core technology/core component in 2007, developed damper machining, and started internalizing production in order to achieve a high quality steering feel. In order to improve the performance, we have been expanding the scope of production internalization with the aims of improving precision and reducing cost in accordance with the internalization policy for core components. We would like to introduce our activities toward productivity improvement and quality improvement through utilization of the existing facilities.

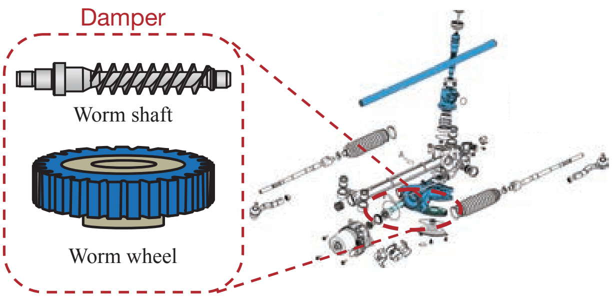

Fig. 1 Internally machined EPS components

2 Overview

2.1 Product Overview

Worm dampers (hereinafter referred to as "dampers"), in which a worm shaft (hereinafter referred to as "worm") and worm wheel (hereinafter referred to as "wheel") are integrated, possess an important function to assist vehicles by transmitting the motor torque to the wheel shaft via the worm to create torque according to the reduction rate (Fig. 2). Since the wheel is on the steering shaft, the engagement precision is easily communicated to the driver's hands. Therefore, this is an important component that largely affects the 3 aspects of quietness, high responsivity, and accuracy, which are required in steering.

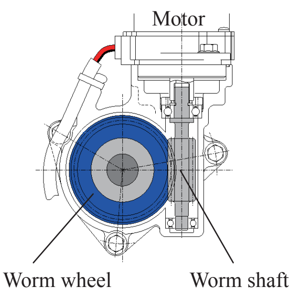

Fig. 2 Worm damper

2.2 Overview of the Damper Machining Lines

Damper machining production lines consist of the worm machining process, which involves turning, gear cutting, grinding, and cleaning, and the wheel machining process, which involves gear cutting, flash removal, cleaning, and matching (Table 1).

Table 1 Process overview

Worm machining

Process name	Process contents
(1) Turning	Outer diameter rough machining
(2) Whirling	Rough gear cutting
(3) Grinding	Outer diameter polishing
(4) Thread grinding	Thread polishing
(5) Brushing	Improvement of the surface roughness of the tooth surface
(6) Cleaning	Contamination removal
(7) Inspection	Visual inspection and engagement test

Wheel machining

Process name	Process contents
(1) Hobbing machine	Gear cutting
(2) Chamfering machine	Flash removal
(3) Cleaning	Contamination removal
(4) Storage	Dimensions are stabilized by storing for a certain period of time
(5) Inspection 1	Visual inspection and engagement test
(6) Inspection 2	Matching

3 Issue and Target

3.1 Productivity-related Issue and Target

We needed to control the investment and enhance the production capabilities in stages in order to reduce the cost in anticipation for production increase in the future (Fig. 3).

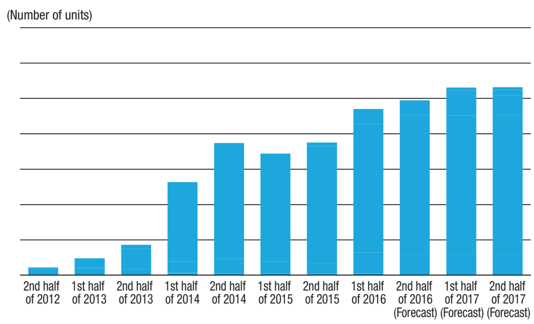

Fig. 3 Production results and forecast for internally manufactured dampers

In order to improve the overall production capabilities by establishing 2 production lines consisting of a "various kinds and small quantity" production line and a "high productivity" production line by using the existing production line from 2012 as the benchmark (hereinafter referred to as "B.M."), we decided to set the target below and promote our efforts (Table 2).

Table 2 Production capabilities of damper production lines

Item	Benchmark (October 2012)	Production line #1 target	Production line #2 target
Concept		"Various kinds and small quantity" production line	"High productivity" production line
CT	B•M	31% reduction	44% reduction
Operation rate	B•M	Same	26% increase
Production capabilities	B•M	45% increase	124% increase

3.2 Quality-related Issue and Target

In order to provide high quality products in terms of noises and feelings, we needed to improve the quality of the engagement error per gear, which represents the changes of the distance between shafts when the worm and wheel are pressed together to turn (Fig. 4).

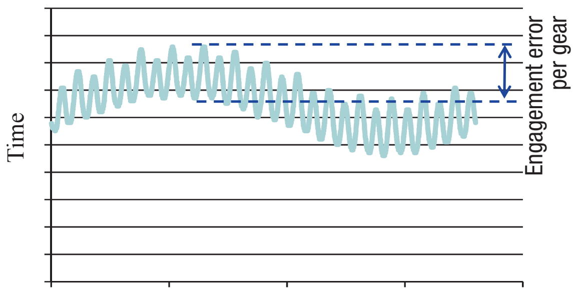

Fig. 4 Changes in the distance between shafts

In operation inspections, dampers with an engagement error with higher severity per gear have greater steering force fluctuations against the steering angle, as shown in the red lines. The smaller the severity of the error is, the smaller the fluctuations are, as shown in the black lines (Fig. 5).

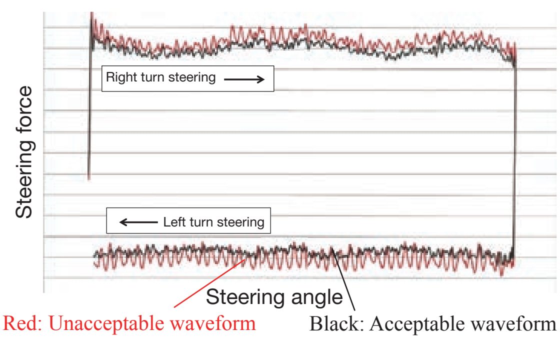

Fig. 5 Operation resistance test data for finished gear products

We decided to promote our improvement efforts by aiming to reduce the defects by 50% compared to the B.M.

4 Implemented Initiatives

4.1 Productivity Improvement

We needed to reduce the machine time (hereinafter referred to as "MT"), which is an obstacle in realizing high productivity production lines (Fig. 6). Below are examples.

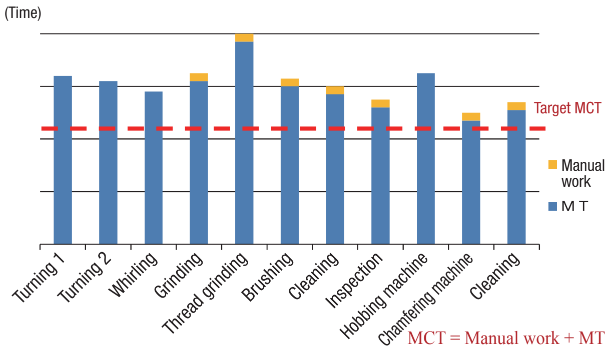

Fig. 6 Manual work + MT for each process

4.1.1 Machine Time Improvement

(1) Thread grinding process improvement

This is the process in which the grinding finish is given to the gear-cut part, which was turned by the whirling machine.

We reviewed the dress cycle in order to complete the machining process within the target MT. The conventional method was as follows: Dressing was done without angling the grindstone or dresser. The dressed grindstone turned in the angle that engages with the worm to grind. It then returned to the no angle position to repeat the process. It took time to turn the grindstone during each cycle, so the manufacturer and KYB focused on this aspect. We

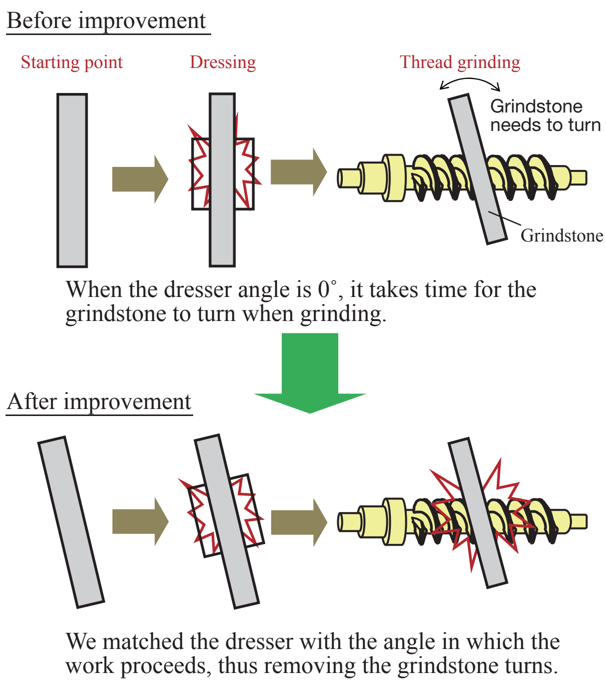

Fig. 7 Turning of the grindstone for thread grinder

aggregated the high productivity production line into one model so that the dressing process could be done with the dresser and the grindstone kept at an angle, and we stopped the turning of the grindstone during each cycle to reduce the MT (Fig. 7).

(2) Brushing process improvement

This is the process to remove the flash on the teeth and improve the surface roughness of the tooth surface after the thread grinding process.

We attempted to reduce the MT by increasing the conditions, but the standard for the surface roughness of the tooth surface was not achieved. With 2 separate processes, the surface roughness is achieved, but the MT is not achieved, thus requiring equipment investment. We had been using a one-shaft brush unit in this process, so we designed and manufactured a two-shaft brush unit. This enabled us to achieve the quality as well as the MT (Table 3, Fig. 8).

Table 3 Brushing matrix

	Number of brush turns	Brush grinding move	MT	Quality (surface roughness)	Cost	Effect
Current condition	B•M	B•M	B•M	○	○	—
Changed condition 1	1.5 times	2.0 times	0.67 times	×	○	×
Process the changed condition 1 twice	1.5 times	2.0 times	1.34 times	○	×	×
Use of 2 brush shafts	1.5 times	2.0 times	0.67 times	○	△	○

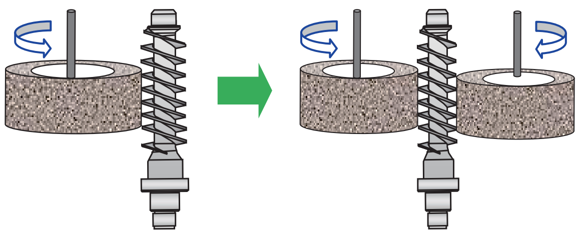

Fig. 8 2-shaft brush unit for brushing

4.1.2 Changeover improvement

In order to establish a "various kinds and small quantity" production line, we needed to improve the changeover (Fig. 9). Below are examples.

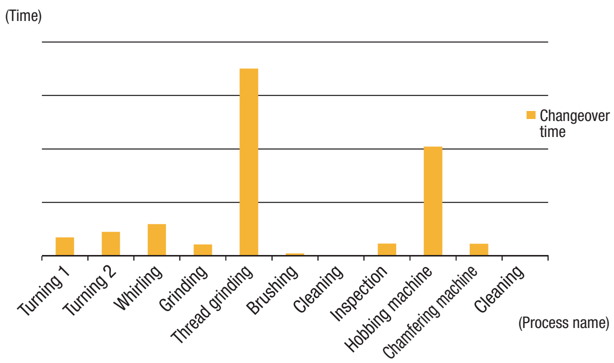

Fig. 9 Changeover time for each process

(1) Thread grinder drive method change

Originally, we used a 3-claw chuck to clamp the work for the thread grinder. It took a long time to control the run out when changing over this 3-claw chuck. When the run out is big, the engagement error per gear becomes more severe, and this was producing defects.

Due to this, we switched from the chuck method to the carry method. Since all models are supported by both centers, we can complete the changeover simply by switching the carry for each model (Photo 2).

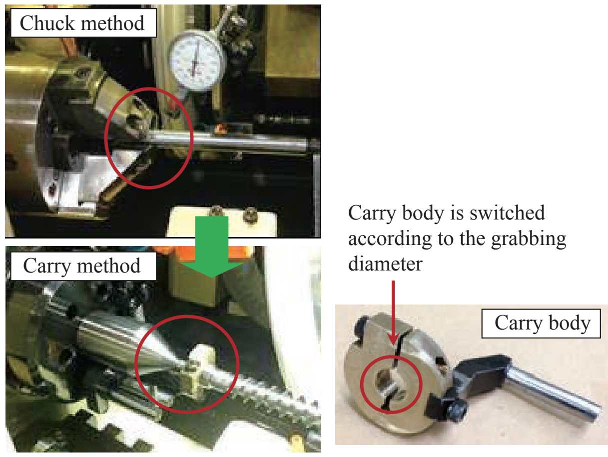

Photo 2 Thread machine driving method

(2) Removing the changeover process for the thread grinder dresser

Since only one dresser can be installed on the thread grinder, we had to switch the dresser to change over to models with different modules. The switching process took 30 minutes, as we had to secure the process precision. We removed this switching process by introducing a mechanism to incorporate 3 dressers (Fig. 10). This also removed the run out of the dressers from switching, leading to quality improvement.

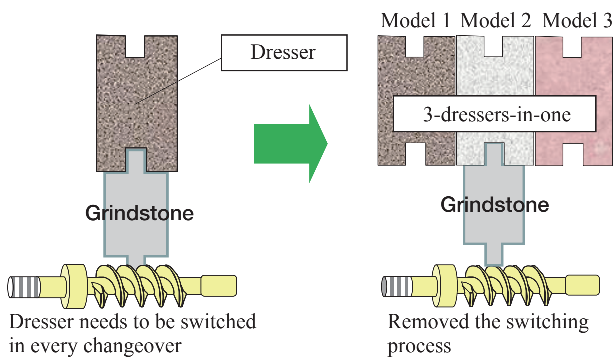

Fig. 10 3-dressers-in-one device for the thread grinder

4.2 Quality Improvement

We changed the material of the tightening nut to change the friction of the contact against the other surface in the quenching process when tightening the hob cutter of the hobbing machine, which is used in the wheel gear cutting process, onto the arbor. This enabled us to easily control cutter run out, enabling us to reduce the engagement error per gear.

Before the improvement, we were using a commercial nut. With this nut, the contact surface would come to a stop during the tightening process due to friction, and the contact surface couldn't bear the external force motion, causing it to momentarily slip over the other surface, which resulted in run out. Due to such issues, we kept having to make adjustments.

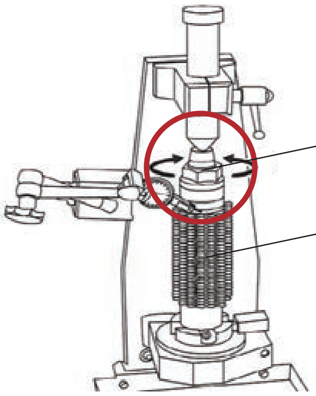

Fig. 11 Detailed diagram for hob cutter installation

5 Result

5.1 Productivity Improvement Result

The CT, operation rate, etc. for the "various kinds and small quantity" production line and "high productivity" production line have changed as follows (Table 4).

Table 4 Result of productivity improvement efforts

Item	Benchmark (October 2012)	Production line #1 target	Production line #1 result
Concept		"Various kinds and small quantity" production line	"Various kinds and small quantity" production line
CT	B•M	31% reduction	31% reduction
Operation rate	B•M	Same	10% increase
Production capabilities	B•M	45% increase	50% increase

Item	Benchmark (October 2012)	Production line #2 target	Production line #2 result
Concept		"High productivity" production line	"High productivity" production line
CT	B•M	44% reduction	42% reduction
Operation rate	B•M	26% increase	16% increase
Production capabilities	B•M	124% increase	97% increase

5.2 Quality Improvement Result

We were able to reduce the engagement error per gear by 98% by changing the tightening nut material, centering the thread grinder, and removing the dresser changeover.

6 In Closing

We focused on the non-machining time in order to secure the productivity capabilities through CT reduction and changeover time reduction. We presented our proposal when the new facility was being established and were able to achieve the effects that exceeded the conventional method.

As the next step, we hope to reduce the required number of human resources through automation.

Finally, I would like to express my sincere gratitude for everyone involved in this project who has provided support.

Author

ITO Susumu

Joined the company in 1993.
Manager of the PS Production Engineering Sect. No.1, Production Engineering Dept., Gifu North Plant, Automotive Components Operations.
Engaged in production preparation and mass production support work for EPS component machining production lines.

KOUKETSU Hisato

Joined the company in 2006.
PS Production Engineering Sect. No.1, Production Engineering Dept., Gifu North Plant, Automotive Components Operations.
Engaged in production preparation and mass production support work for EPS component machining production lines.