Higher Performance of Traction Drive Units for Printing Machines

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The traction drive unit is a power transmission device utilizing the rolling contact of rollers which has been adopted in printing machines and the like for many years now due to serving as a smooth and backlash-free reducer.

In commercial printing, high-performance color laser printers for on-demand printing have been used due to the market needs of high-mix, small-volume production lots and short delivery time. In recent years, other demands have emerged for high performance including adoption of high-quality images, special colors, paper versatility and high speed, and the traction drive unit used to meet such demands is also required to improve rotational accuracy and to extend life.

In this report, we will introduce the planetary roller style traction drive unit technology developed by JTEKT to satisfy these needs.

***Key Words**: traction drive unit, planetary roller, reducer, rotational accuracy, printing machines*

1. Introduction

The traction drive unit is a power transmission device utilizing the rolling contact of rollers which has been adopted by industry for many years due to serving as a smooth and backlash-free transmission. JTEKT began development of traction drive units in the 1980s. In 1990, it commercialized a speed-increase spindle for machining centers as a high-speed increaser[1)], and this was also adopted in the printing field as a high-precision film feeder for plate-making machines[2)]. In 1993, the product began being mass produced as a quiet reducer for motor-assisted bicycles[3)]. JTEKT's traction drive unit has also been adopted in electric power steering systems, etc.

However, due to market needs for transmissions to be lightweight, compact and low cost, there have been efforts to increase the performance of resin gears, etc. even further, and in recent years, traction drive units are practically no longer used as general-purpose transmissions.

Meanwhile, there are no reducers capable of surpassing traction drive units in terms of transmitting power smoothly, therefore there are still areas in which demand for this product is ongoing.

In commercial printing, there is an increasing need for on-demand printing due to the needs of high-mix, small-volume production lots and a short delivery time. Here, high-performance color laser printers are used and recent demands for higher performance, such as high-definition, special colors, paper versatility and high speed have led to demands for the traction drive units used in such printers to have better rotational accuracy and longer life.

This report will introduce the planetary roller style traction drive unit technology developed by JTEKT to satisfy these needs as a high-accuracy feeder.

2. What is a Traction Drive Unit?

2. 1 Principle and Structure

A traction drive unit is a power transmission devise that utilizes the rolling contact between rollers, whereby high-precision and high-strength rollers are assembled through elastic deformation to create a high contact force between rollers. Furthermore, by adopting traction grease which achieves high viscosity in high pressure conditions, power transmission is achieved whilst simultaneously securing lubricating performance (**Fig. 1**).

JTEKT has used this principle to construct a planetary structure, thus achieving the commercialization of a planetary roller transmission with extremely small rotational speed variation to replace the planetary gear (**Fig. 2**).

Gear ratio is determined from the sun shaft diameter (di) and stationary ring internal diameter (do), i.e. (di+do)/di, and normally ranges from 3 to 12 per stage. Moreover, by making transmissions multi-stage, a large reduction ratio is possible. With a planetary roller style traction drive unit, the input shaft and output shaft are the same axis, therefore a multi-stage structure is easily achieved, and we have successfully developed a product with a gear ratio of 1 000.

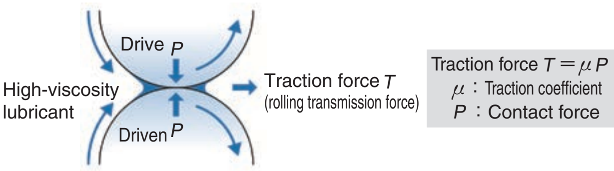


Fig. 1 Principle of traction force

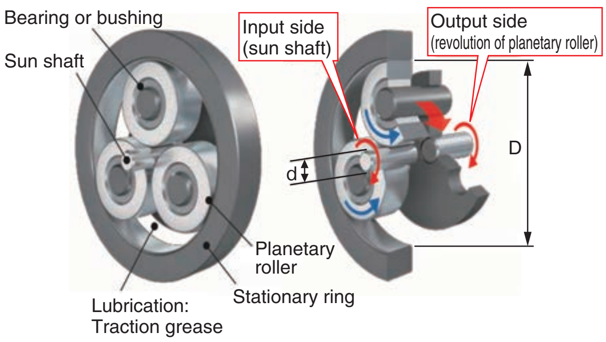


Fig. 2 Structure of a planetary-type traction drive unit

2. 2 Technologies Demanded for Traction Drive Units

The planetary roller style traction drive unit adopts a simple structure yet requires a variety of technologies in order to maintain high performance. **Figure 3** shows the core technologies that are required. Below are the equations used for transmission torque.

$$Ti = \mu \cdot P \cdot Z \cdot d/2$$

or

$$To = \mu \cdot P \cdot Z\ (d+D)/2$$

Here,

Ti: Transmission torque on the high-speed shaft side
To: Transmission torque on the low-speed shaft side
μ: Traction coefficient
P: Contact force for planetary rollers
Z: No. of planetary rollers
d: Sun shaft outside diameter
D: Stationary ring inside diameter

In order to maintain high transmission torque, there is a need to increase contact force between rollers and use lubricant with a high traction coefficient, however increasing contact pressure tends to reduce rolling fatigue life. Moreover, the traction coefficient of lubricant differs depending on its ingredients, as does temperature properties, durability, etc., therefore there is a need to select the optimal oil by considering operating conditions.

Furthermore, in order to maintain rotational accuracy, there is a need to control various geometrical tolerances such as dimensional accuracy, roundness, cylindricity and perpendicularity for each roller, as well as roughness at and below the sub-micron level.

JTEKT has developed a traction drive unit capable of higher performance by applying core bearing technologies accumulated over the years such as high-strength material, heat treatment, high-precision machining and optimal surface pressure calculation.

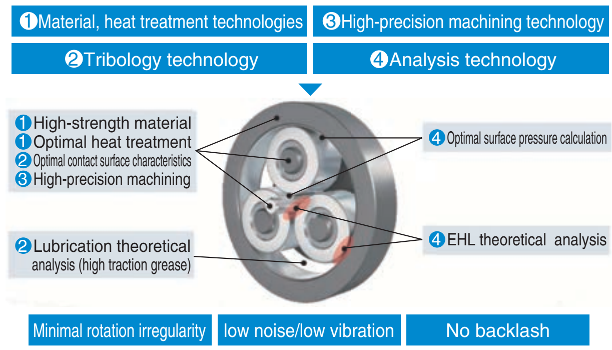


Fig. 3 Core technologies required of traction drive units

2. 3 Features

In general, traction drive units have the following features.

①Minimal rotation irregularity
②Low noise/low vibration
③Minimal backlash
④High-speed rotation

Table 1 shows a comparison with the planetary gear and it can be seen that the torque capacity is around one-fifth of a planetary gear of the same build.

Typical characteristics, including actual measurement results, are given below.

Table 1 Comparison with planetary gear

Mechanism	Rotation irregularity	Noise/ vibration	Backlash	High-speed performance	Torque capacity
Traction drive unit	◎	◎	◎	○	△
Planetary gear	△	△	△	△	◎

◎: Extremely advantageous ○: Advantageous
△: Disadvantageous

2. 3. 1 Rotation Irregularity (Rotational Speed Fluctuation Coefficient)

The greatest advantage of a traction drive unit is its extremely small rotational speed fluctuation. **Figure 4** shows comparison results with a planetary gear of the same reduction ratio.

We used a stepping motor as the drive motor and measured the rotational speed of the output shaft with a rotary encoder then displayed a waveform of the rotational speed via an FV convertor. As a result, we observed that the rotational speed fluctuation coefficient was reduced by around 80%.

2. 3. 2 Noise

Unlike gears, traction drive units have no vibration or noise caused by meshing, therefore offer excellent quietness. **Figure 5** shows the results of a noise comparison with a planetary gear.

As the measurement method, we used the same stepping motor to measure sound pressure while continuously increasing the rotational speed, then performed a frequency analysis. The measurement results showed that, whilst the traction drive unit retained the noise of the drive motor rotating, there was no noise created on several degrees, such as that observed in a planetary gear.

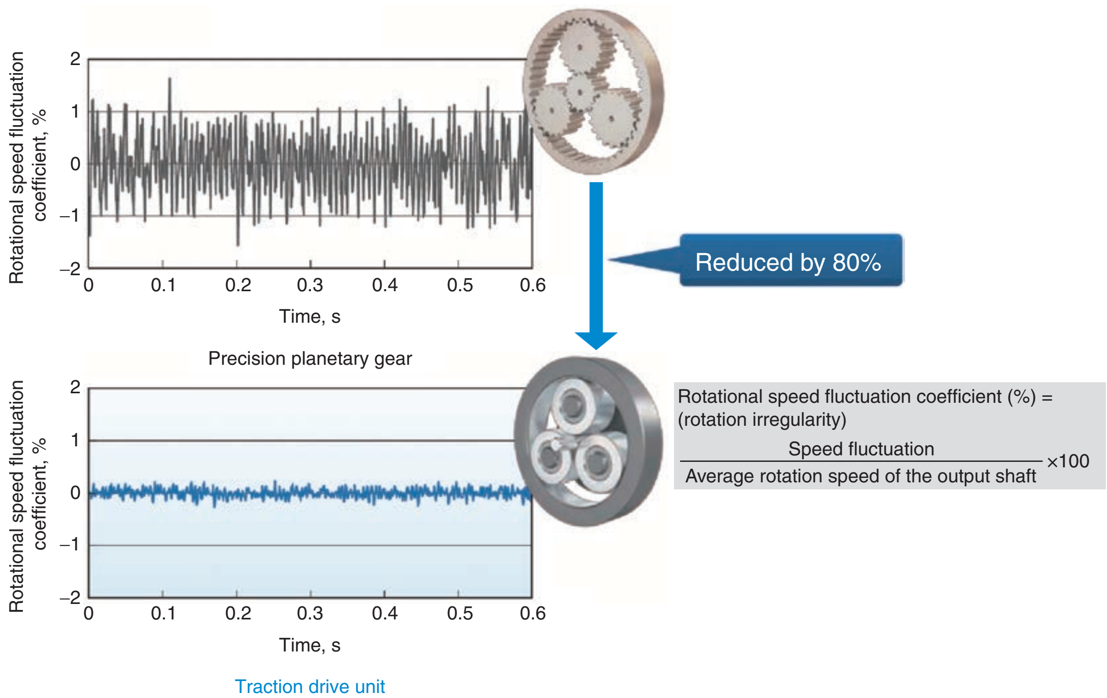


Fig. 4 Rotation irregularity

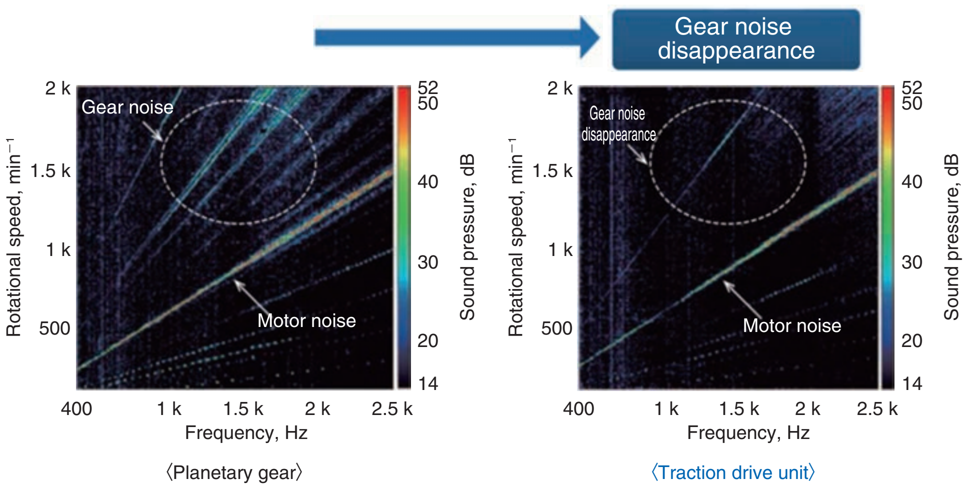


Fig. 5 Noise comparison results of a planetary gear versus a traction drive unit

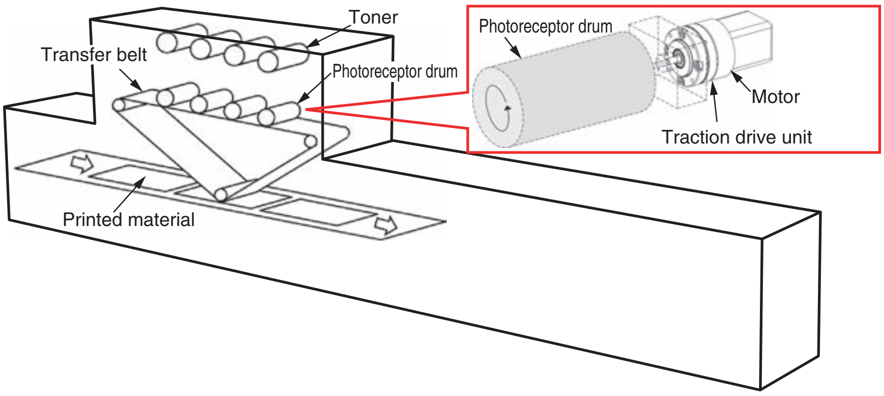


Fig. 6 Structure for attachment to printing machine

3. Higher-Performance Traction Drive Units for Printing Machines

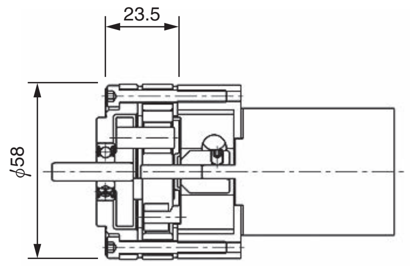
3. 1 Reason for Applying to Printing Machines

A laser printer works by applying toner to a virtual image drawn onto a photoreceptor drum which uses a laser beam to form an image. The color printer adopting a traction drive unit that will be introduced here works by transferring the images from photoreceptor drums for each color onto a transfer belt and forming a color image. Normally, four colors are used, and in order to print a high-resolution image, the respective photoreceptor drums must rotate synchronously, therefore a traction drive unit, which offers minimal rotation irregularity, is adopted (**Fig. 6**).

Recently, in line with advancements in digital printing technology, demands have emerged for even higher accuracy and longer life to achieve maintenance-free printers.

3. 2 Compact Design

Figure 7 shows the specifications of the developed product, while **Fig. 8** shows its structure. The traction drive unit for high-precision feeding developed by JTEKT adopts a structure whereby multiple rows of ball bearings are inserted between the planetary roller and drive pin to fill the gap in order to reduce backlash[2)]. However, for this particular application, rotation during operation is unidirectional so backlash has no particular effect. As such, we adopted a bushing instead of ball bearings. This allowed us to develop a compact product with a reduced number of components, thus making assembly easier.



[Specifications]
・Reduction ratio: 1/10
・Output shaft rotational speed: 100 min^{-1}
・Output shaft load torque: 2.0 Nm maximum

Fig. 7 Specifications of developed product

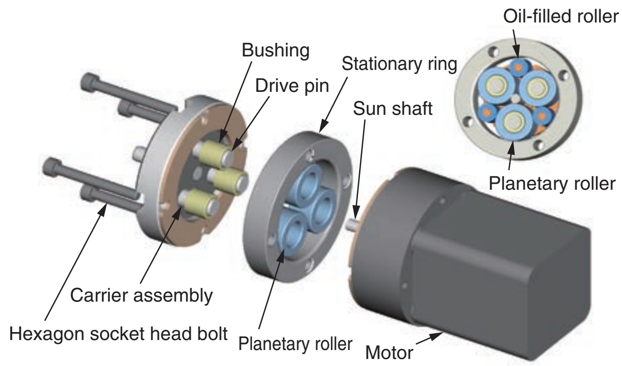


Fig. 8 Structure of developed product

3. 3 Improved Rotational Accuracy (Feed Error)

Rotational accuracy is the quality characteristic with the greatest impact on the quality of images printed by a printing machine, therefore as minimal error as possible is preferable.

Compared to gears, traction drive units, which are power transmission devices utilizing rolling contact, have extremely minimal speed fluctuation, however in printing machines which use multiple, synchronized traction drive units, the rotational angle of the output shaft must also have small relative error during operation. In other words, there is a need to reduce the lead-lag (feed error) of the output shaft in relation to the motor's commands.

In traction drive units with a bushing-based structure, there is clearance with the planetary roller internal diameter and feed error can deteriorate due to misalignment of the relative positions of the revolving drive pin and planetary roller. As the mechanism for this depicted in **Fig. 9** shows, this is affected by the misalignment of the respective revolving centers of the drive pin and planetary roller.

Figure 10 is a schematic of a feed error measurement device. **Figure 11** shows measurement results for feed error due to center misalignment.

It can be observed that feed error increases with center misalignment of several tens of microns. JTEKT has developed its own original center alignment unit to secure high rotational accuracy.

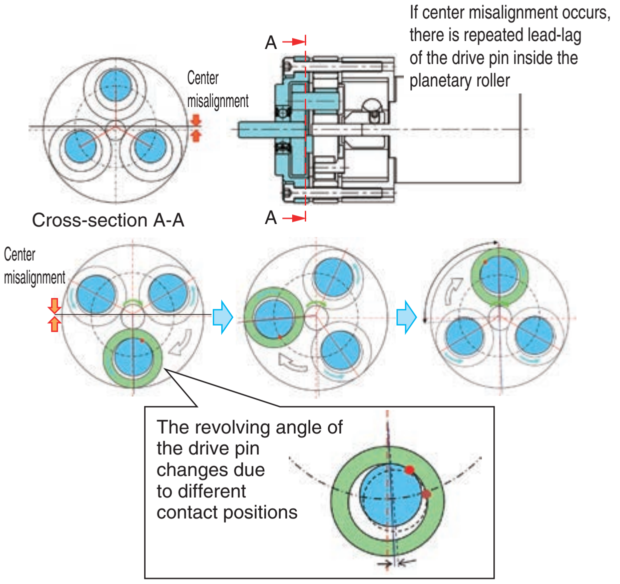


Fig. 9 Mechanism of deteriorating feed error due to center misalignment

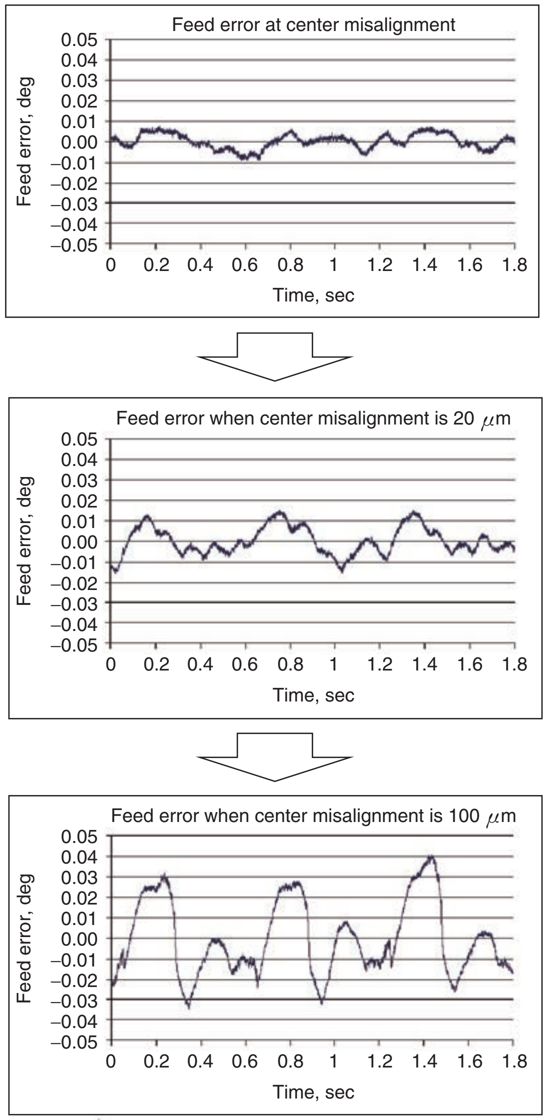


Fig. 11 Comparison of feed error due to center misalignment

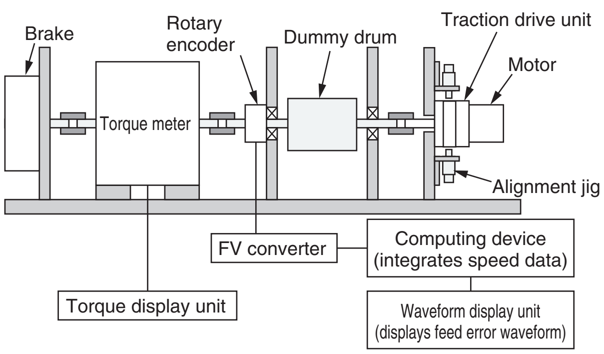


Fig. 10 Feed error measurement device

3. 4 Longer Life

In planetary roller style traction drive units, which have a similar structure to cylindrical roller bearings, factors that affect life are considered to be the flaking and wear of the raceway.

Another factor is believed to be seizure on the sliding portion between the planetary roller internal diameter and drive pin.

JTEKT applied the below technologies to achieve longer product life.

- Prevention of seizure due to the bushing
- Prevention of flaking due to the appropriate surface pressure of each roller raceway
- Prevention of wear due to a raceway oil-replenishment mechanism

In theory, wear should not occur on traction drive units due to the existence of an oil film between rollers. In reality, grease is used as lubricant due to its maintenance-related advantages, however if the raceway becomes void of grease, the oil film will break and wear will occur. If wear occurs even once, the raceway's contact force decreases, and there is increased slip between rollers, causing the wear to progress and leading to insufficient transmission torque. Currently, most cases of malfunction in planetary roller style traction drive units are due to raceway wear caused by lubricant shortage.

As a method of preventing lubricant depletion, JTEKT adopted oil-filled rollers[4] made from resin and filled with a large amount of oil to contact the planetary roller raceway, thus successfully extending product life. We had used oil-filled rollers on motor-assisted bicycles in the past, however this time, in parallel to development of a new grease, we also developed oil-filled rollers using the same type of base oil. Moreover, the grease replenishment structure was improved in order to extend life.

Figure 12 shows the results of a durability test, while **Fig. 13** shows the durability test equipment used. Results show that the traction drive unit adopting the new grease and oil-filled rollers in combination have three times longer life than traction drive units using the conventional grease.

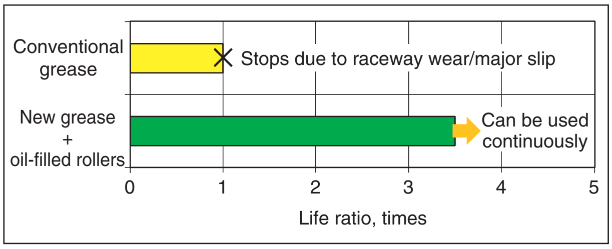


Fig. 12 Durability test result

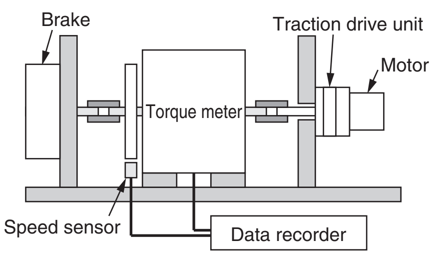


Fig. 13 Durability test equipment

4. Conclusion

In the field of high-precision feed, there are applications in addition to printing machines which require prevention of rotation irregularity and reduced vibration, therefore traction drive units are an effective measure. This paper has introduced JTEKT's initiatives to achieve high-accuracy and longer life, but it is predicted that demands for higher performance in other areas will also intensify. We shall continue development of this product as a solution to issues faced by customers in fields requiring minimal rotation irregularity, low noise and low vibration.

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