Realizing Reduced Energy Consumption and Improved Safety With the Induction Heated Jacket Roll

Yoshihide Kitano
Managing Director, TOKUDEN CO., LTD.
www.tokuden.com/english/

1. Obsolescence of Oil Heated Rolls

For many reasons beyond their dissatisfaction with the performance of heated rolls, many satisfied users of our induction heated rolls probably never want to go back to oil heated rolls again. For many enterprises, reducing energy consumption has become an important management issue, so the high-energy consumption of fluid circulation rolls—typical examples of which include oil, hot water, and steam heated rolls—is a problem. Our core product, the Induction Heated Jacket Roll, which heats itself through electromagnetic induction, has been adopted in many cases for its high-precision temperature control and uniform temperature profile. More recently, however, our customers have come to better understand the contribution the Induction Heated jacket Roll makes to reducing energy consumption, which is accelerating the obsolescence of oil heated rolls.

2. Development Background of Induction Heated Jacket Rolls

It has been more than 50 years since Tokuden developed and commercialized the world's first induction heated roll. In the 1960s and 70s, nearly all of our rolls were employed in synthetic fiber thermal stretching applications at home and abroad. In fact, we have shipped a total of more than 200,000 rolls for this application over the years (Photo 1). The Induction Heated Jacket Roll (Jacket Roll) was later developed and commercialized for applications other than fiber processing, and was thus designed to maintain a constant roll surface temperature profile regardless of the roll face length or the substrate load.

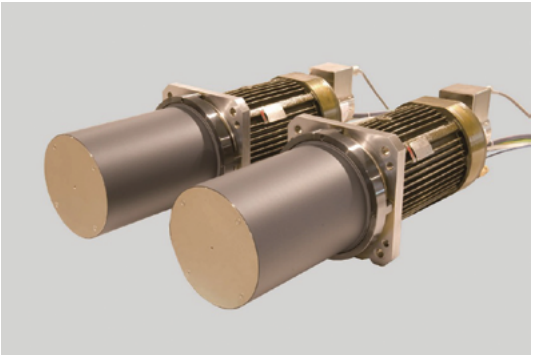

Photo 1 Spin-Draw Godets for Fiber Applications (Dimensions: 220 mm OD x 310 mm L; rotational speed: 6,000 m/min)

Following the Jacket Roll's commercialization in 1969, many adopters praised it highly as its performance far exceeded that of other types of conventional heated rolls in almost all applications where a heated roll is necessary—film preheating/stretching, coating, laminating, nonwovens/paper calendering. In this way, the Jacket Roll has become our core product.

In one example, the Jacket Roll has a temperature control precision of +/- 1°C and a mechanical precision of several micrometers, even at 400°C. With a 1,250 mm outer diameter (OD), a 7,600 mm face length (L), and a maximum temperature of 300°C, the largest roll Tokuden has ever delivered was designed for a paper calendering application (Sweden, 2004).

3. Jacket Rolls Consume 20% Less Energy Than Oil Heated Rolls

Although the induction heated roll has become the mainstay

heating roll for synthetic fiber stretching applications, for other applications, induction heated rolls and Jacket Rolls are only adopted when high-precision is required. Meanwhile, older fluid circulation rolls—hot water rolls for low-temperature and oil heated rolls for high-temperature—have conventionally been used for all other applications. More recently, however, the Jacket Roll is increasingly being adopted even when the application or process does not demand high precision. One reason for this is the energy savings.

Although many people have the impression that induction heating consumes more energy rather than reduces energy consumption—in reality it is the opposite. In order to minimize energy consumption, the only option is to increase efficiency. Although the only thermal energy required is the heat applied to the substrate (the heat stolen by the substrate), in fact, the area of the roll that does not contact the substrate and the journals radiate heat (this is inevitable). As such, the total of the two is the minimum required energy for the heated roll.

If thermal efficiency is the minimum required energy divided by the total energy consumption, then the induction heated roll and Jacket Roll have a thermal efficiency of approximately 99%. In other words, a loss of 1% or less. This 1% loss is attributable to the thermal loss from the wiring and electrical components of the heating system. In contrast, the efficiency of an oil heated roll, at most, is about 80%. In this way, the 20% difference in thermal efficiency between the Jacket Roll (99%) and the oil heated roll (80%) is equivalent to a 20% difference in energy consumption (Fig. 1). The reasons for this 20% difference in energy consumption are as follows:

1. The power consumed by the oil circulation pump does not contribute to heating the roll, so is a complete waste.

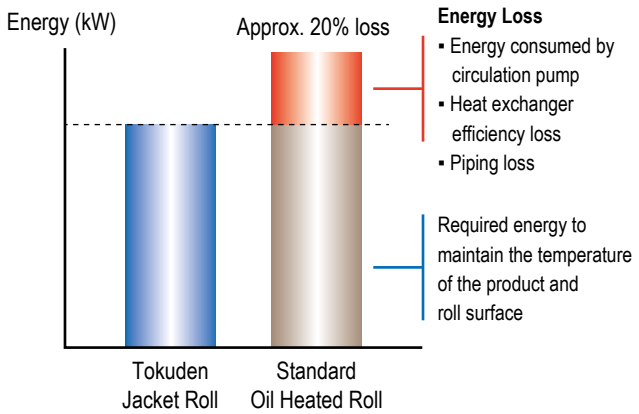

Figure 1 Difference in Energy Consumption Between Jacket Rolls and Standard Oil Heated Rolls

2. Efficiency loss from the oil heating unit.
3. Radiated heat loss from the surfaces of the oil piping between the oil heating unit and the roll.

The energy consumed by the oil pump during stable operations changes depending on the roll specifications, so it is generally impossible to quantify power consumption. As such, it is necessary to increase the oil flow volume and speed to improve the roll surface temperature profile. In this way, the portion of total energy consumption accounted for by this increase is significant.

The efficiency loss within the oil heating unit is also large. Even though a new oil heating unit's thermal efficiency may be 90%, long-term deterioration of the unit and oxidation of the oil itself will reduce the efficiency to close to 50%. (In this case, the comparative energy reduction rate of a Jacket Roll would be 50% better.)

This situation is not limited to oil heated rolls, but is also seen in water and steam heated rolls as well. Although a circulation pump is unnecessary for a steam heated roll, when we consider the low-efficiency of the steam boiler and steam discharged from the drain in the steam piping, it is evident that a significant amount of energy is wasted.

3.1 Difference Between Energy Savings and Operating Cost Reductions

Considering the global environment, including CO_2 reduction, it has become important for companies to reduce energy consumption. At the same time, although reducing energy consumption is also aimed at reducing operating costs, the rate of energy consumption reduction is not always equal to the rate of operating cost reduction. For example, when looking at the 20% difference in energy savings between the Jacket Roll and oil heated roll, as mentioned earlier, the prerequisite is that the oil heating source for the oil roll be electric. As long as the heating source for both rolls is electricity, the energy consumption reduction rate and the operating cost reduction rate are the same.

Let us next consider the case when the heating source of the oil heated roll is not electricity. For example, if we assume the heating source is a steam boiler, compared with electricity, the efficiency advantage of the Jacket Roll is practically eliminated due to the lower cost of generating steam using heavy oil on a per kilowatt basis. Therefore, energy consumption reduction rate=operating cost reduction rate is only true when the oil heating unit also uses an electric heater as the heating source, whereas in other cases the cost of heavy oil, for example, and boiler efficiency come into play.

3.2 Reduced Maintenance Costs and Down-Time, Improved Safety and Ecology

One of the features of the Jacket Roll is its low maintenance. Specifically, the induction coil inside the roll is a stator, so support bearings are used to hold the induction coil shaft. The grease inside the bearings has a fixed lifetime of several years before regular maintenance is required. For this reason, we have already developed and commercialized a bearing-less Jacket Roll construction to eliminate the need for even this regular preventative maintenance.

In contrast, fluid circulation rolls require unscheduled and frequent maintenance. One particular problem is fluid leakage from the rotary joints. The rotary joint used to supply the fluid from the fluid piping to the rotating roll contains a seal, which can degrade rapidly depending on the fluid temperature and rotational speed. Sudden leakage can also require production lines that must operate 24 hours a day to be stopped to replace the seal material. In the case of oil heated rolls, the oil must also be regularly changed because oxidation deteriorates the oil's thermal efficiency over time. Fire and safety regulations must also be followed. Although visible oil leakage can be easily handled by replacing the seal material, the negative effect of oil fumes on the product and the factory environment cannot easily be resolved. With hot water rolls, the accumulation of scale on the roll's internal flow channels reduces the thermal efficiency, which can require regular flow channel cleaning and roll replacement depending on the water quality.

We have experienced many cases where oil heated rolls have been replaced with Jacket Rolls as a direct result of oil leakages that resulted in fires or led to injuries after personnel slipped on puddles of oil. When considering the total operating cost, safety, and improvement of the factory environment, the Jacket Roll is overwhelmingly superior.

3.3 Temperature Control and Surface Temperature Uniformity of +/- 1°C

When producing high-quality products and products with uncompromising temperature specifications, roll precision is indispensable. For example, the temperature precision and mechanical precision of a heated roll has an important influence on the quality of films and nonwovens.

Our electromagnetic self-heating Jacket Roll realizes a stable roll temperature even when the load conditions vary, while the roll surface temperature profile over the area that contacts the substrate remains constant and uniform due to the latent heat of vaporization of the hydraulic fluid that is vacuum sealed inside the "jacket chamber." The Jacket Roll can be used in low and high temperature regions, and has a rapid heat-up time. The uniform roll temperature realized by the jacket chamber also contributes to the stability of mechanical precision at operating temperatures. In recent years, given the high evaluations their performance has received, Jacket Rolls have increasingly been adopted for carbon fiber precursor drying applications, as well as for lithium-ion battery electrode press applications.

3.4 Replacing Outmoded Rolls with Jacket Rolls

Much of the manufacturing equipment used to produce general-purpose films, nonwovens, and textiles is outmoded. For this reason, Japanese film manufacturers aiming to compete with overseas manufacturers have attempted to improve product quality and reduce costs by upgrading existing equipment—biaxial stretching lines installed 30–40 years ago—and production processes. There are countless examples where Jacket Rolls have been used to replace oil rolls on this type of stretching equipment to improve product quality.

More recently, however, the reasons for replacement have been slightly different. Users are increasingly aware of the aforementioned performance advantages of the Jacket Roll, including reduced energy consumption, improved safety, reduced maintenance costs, and reduced down-time, which have been judged valuable enough to replace existing conventional rolls with Jacket Rolls (Photo 2).

4. Jacket Roll Issues and Their Solutions

The Jacket Roll does have drawbacks, namely the cooling function and cost.

For example, film forming lines, in which oil heated fluid circulation rolls are often used, require approximately 20 heating rolls in the preheating and stretching processes. Heat intro-

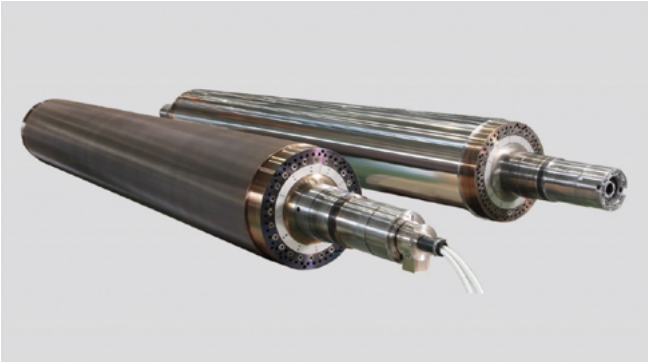

Photo 2 Nonwoven Embossing Calendar Applications (700 mm OD x 5,000 mm L)

duced from the outside during the stretching process, however, makes it impossible to control temperature if the rolls themselves lack a cooling function.

Over the 40 years since the Jacket Roll was developed, there were many cases where it was not adopted because it lacked such a cooling function. In 2009, we developed the "Mist Cooled Hybrid Roll" to overcome this drawback. Specifically, the roll is cooled by supplying a small amount of water in the form of mist to the interior of the roll. The water and air are supplied from the stator induction coil shaft end, which eliminates the need for a rotary joint (Photo 3).

Another shortcoming is the initial investment. Although we have continuously worked to improve the Jacket Roll Design, more recently we have placed particular emphasis on rationalizing our manufacturing processes and on in-housing production. As a result, we have realized cost reductions of 10-15% compared to rolls of 10 years ago for rolls designed for converting applications that are resistant to material cost fluctuations. This has substantially narrowed the cost difference when considering the cost of the Jacket Roll and the heating unit as a whole compared with that of the oil heated roll, oil heating unit, and piping together. Going forward, we aim to continue reducing costs through further design improvements and rationalization.

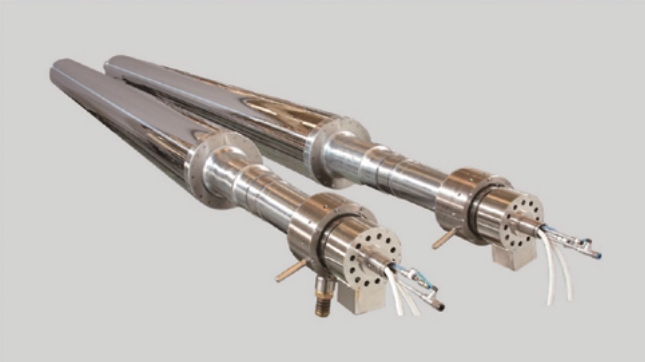

Photo 3 Mist Cooled Hybrid Roll for Film Stretching Applications (250 mm OD x 1,500mm L)

***Jacket Roll and Hybrid Roll are registered trademarks of TOKUDEN**