Oil/Air Lubrication Systems for Steel Production Facilities

T. MIYACHI*

**Product Engineering Center, Industrial Machinery Application Engineering Department*

The main lubricating method for rolling bearings used in steel production facilities is grease or oil mist lubrication. Recently, however, concern regarding the environment has increased in relation to ISO14000 requirements. As a result, much attention has been given to oil/air lubrication systems, which do not have the leaking and emission problems as other lubrication methods. Oil/air lubrication has several other advantages over alternative lubrication methods as well.

This report details the general features and benefits of oil/air lubrication systems and outlines the Koyo oil/air lubrication system developed for application in the steel production industry.

1. Introduction

Oil/air lubrication continuously can supply small amounts of oil directly to the position requiring lubrication, and because minimizes agitation resistance of the lubricating oil, it is widely accepted as a suitable lubrication method for high-speed conditions. An example of this would be high-speed precision spindle bearings for machine tool applications, in which oil/air lubrication has been commonly used.

In recent years oil/air lubrication has been studied in various steel mill applications. The roll necks of rolling mills are one application in which oil/air lubrication systems have been utilized with favorable results. Compared to conventional lubrication used in steel mill applications, oil/air lubrication reduces environmental pollution, increases lubricating and sealing performance, improves the high-speed capability of the bearings, and reduces running and maintenance costs.

At Koyo, basic development of an oil/air lubrication system for steel mills has been completed and many good results have been achieved in the field. However, we have been working to develop further improved technology, and a summary of these results is reported herein.

2. Principle of Oil/Air Lubrication[1)]

With oil/air lubrication systems, a specified small amount of oil (approx. 0.1~0.5 ml) is intermittently supplied to continuously flowing compressed air as shown in **Fig. 1**. Oil, in the form of droplets, adheres to the walls of the transport piping, and is made uniform by a turbulent flow of compressed air. Also, because a continuous oil film is formed inside the piping, even if there is little oil, the oil is continuously supplied to the final outlet (lubrication position).

A distinctive feature of the transport process is that oil and air are separated during transportation in the piping, and because the oil exists in the form of droplets, it is not sprayed as in oil mist lubrication. As a result, the working environment does not become polluted.

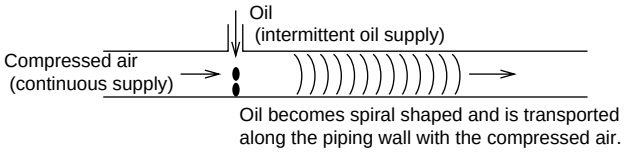


Fig. 1 Principle of oil/air lubrication

3. Oil/Air Lubrication System for Steel Mills

3. 1 Features of Oil/Air Lubrication System for Steel Mills

A comparison of features of oil/air lubrication systems and oil mist and grease lubrication systems is given in **Table 1**.

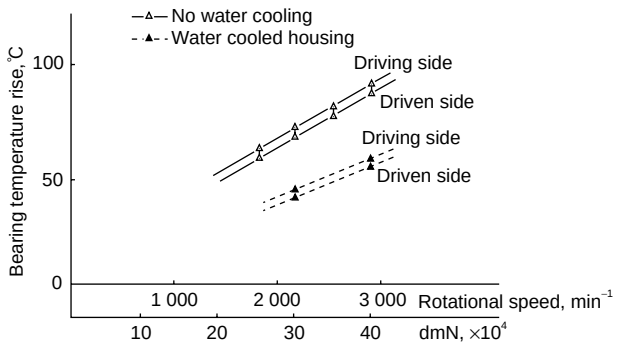
Bench testing regarding the oil/air lubrication system was done to evaluate temperature rise during high-speed rotation and starting torque when internal pressure is applied. Results are given in **Fig. 2** and **Table 2**. With oil/air lubrication, a dmN value of 400 000 is possible even without water-cooled housings. Also, by applying internal pressure to the oil/air lubrication system, seal contact pressure is reduced. As a result, the starting torque is reduced by approximately 1/6. This is effective in preventing damage from roll slippage.

3. 2 Structure of Koyo Oil/Air Lubrication System[2)]

The Koyo oil/air lubrication system is a general purpose unit designed to enable construction of a flexible system. Multiple applications can be simultaneously handled by a single Koyo oil/air unit including application according to different oil supply conditions within the same equipment (roll neck, guide roll, auxiliary equipment, etc., handled by the same unit) according to scale of equipment (from several to more than 1 000 oil supply positions).

Table 1 Features of oil/air lubrication

Evaluation item \ Lubrication system	Oil/air lubrication	Oil mist lubrication	Grease lubrication (grease supply type)
Environmental pollution	None · Oil not released into the atmosphere · Clean working environment due to oil drainage	Exists · Releases oil mist into the atmosphere	Exists · Discarded grease must be treated.
Sealing performance (internal pressure)	High · Internal pressure 0.01～0.05 MPa	Somewhat high · Internal pressure 0.005 MPa or less	Low (depends on seal design) · Zero internal pressure · Negative pressure may develop due to temperature variation.
High-speed capability (low torque)	High · High reliability due to oil lubrication · Seal contact pressure drop due to internal pressure (low torque) · Cooling effect due to air flow	High · High reliability due to oil lubrication	Somewhat high · Large fluctuation in agitation resistance of grease
Lubricant consumption	Low	Somewhat low · Approx. 5 times that of oil/air lubrication systems	High · Higher than for oil/air lubrication or oil mist lubrication
Piping	Easy · Oil-supply piping direction not restricted · Piping that enables multiple node branching of oil and air by oil/air distributor (patent pending) has been simplified to facilitate maintenance. · Automatic coupler and multi-coupler also applicable	Requires attention · Oil supply piping direction restricted	Somewhat easy · Grease supply piping direction not restricted



Bench test conditions (bearing temperature rise)
- · Test bearing : 22318RHW33 (bore diameter ϕ90 mm, outer diameter ϕ190 mm, width 64 mm)
- · Rotating ring : inner ring
- · Radial load : Fr=9.8 kN
- · Lubrication : Oil/air lubrication Oil supply 3 cm^3/h
- · Oil type : ISO VG220
- · Cooling : 1) None 2) Water cooled housing

Fig. 2 Bearing temperature rise

An example is given in **Fig. 3**. The complete lubrication system (from oil/air supply to oil drain) for a roll neck bearing from a rolling mill is described in 1)～4).

1) Two lines of oil supplied from the main oil unit, and one line of air are supplied separately in parallel to the mixing block (intermittent oil supply and continuous air supply). The mixing blocks are mounted on each stand.
2) Oil and air are mixed in the mixing block and distributed to four positions. Oil and air are supplied to the various housings via flexible hoses and couplings.
   The mixing block is contained together with the equipment for monitoring all supply settings in the panel (mixing panel in **Fig. 3**).
3) The oil and air supplied to each housing are further distributed by the oil/air distributor in the housing. There are two supply positions for bearings and one position for the seal, for a total of three positions. The distribution

Table 2 Results of bearing torque (mean values of 10 measurements)

Ratation	Grease lubrication	Oil/air lubrication
Forward	210.2 N·cm	32.9 N·cm
Reverse	204.3 N·cm	32.9 N·cm

Bench test conditions (starting torque)
- · Test bearing : RM783C (bearing integrated roll, roll outer diameter ϕ190 mm, width280 mm)
- · Rotating ring : Roll (outer ring rotation)
- · Load : No load
- · Lubrication : 1) Grease lubrication 2) Oil/air lubrication (internal pressure 0.055～0.06 MPa)
- · Lubricants : 1) ISO VG460 for oil/air lubrication 2) Grease for centralized lubrication

rate differs for each.

4) The oil and air supplied to the housing are discharged all at once from drain piping in the housing units, and only oil is collected in the drain tank (air is discharged into the atmosphere from the drain line).

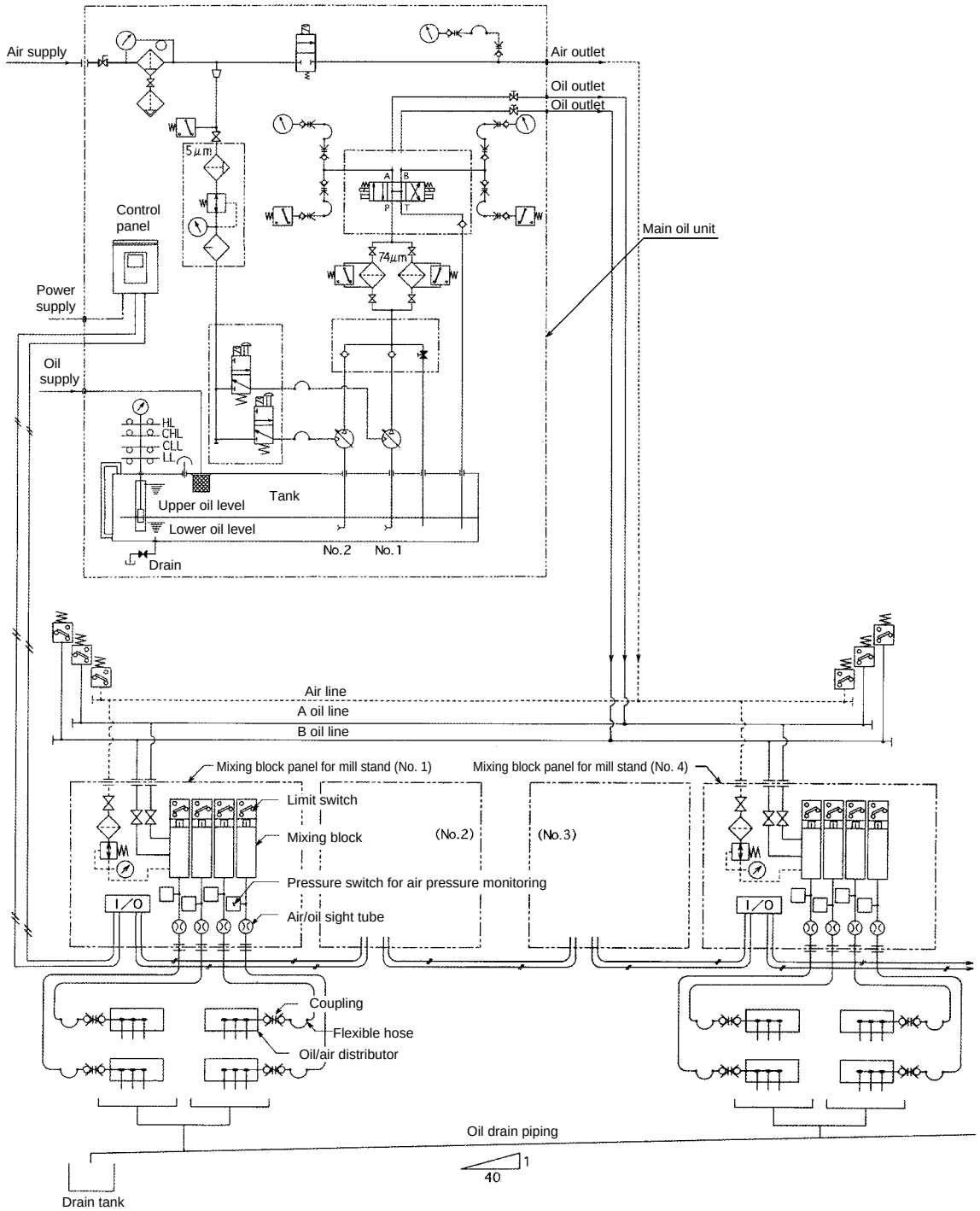


Fig. 3 Flow diagram of oil/air lubrication system

Basic components that make up the Koyo oil/air lubrication system and their functions are detailed in **Table 3**.

Table 3 Components and functions of oil/air lubrication systems

Components	Function
①Main oil unit **(Fig. 4)**	1) Supply of compressed air to mixing block ・Removal of foreign materials from air ・Pressure adjustment of secondary air supply 2) Intermittent supply of oil to mixing block ・Removal of foreign materials from oil ・Lubrication route changeover (timer control)
②Mixing panel **(Fig. 5)**	1) Oil quantity distribution and flow rate adjustment 2) Air quantity distribution and flow rate adjustment 3) Oil and air mixing (oil/air generation)
③Oil/air distributor **(Fig. 7)**	1) Oil/air distribution (distribution ratio 1∶1~1∶8) *patent pending
④Drain tank	1) Drain for lubrication oil 2) Release of supply air into the atmosphere (mist removal)
⑤Control panel (operation panel) **(Fig. 6)**	1) Operation control of main oil unit ・Normal operation ・Filling of initial oil ・Manual operation 2) Monitoring of operating conditions (including abnormal position display) 3) Interface (interlock with related equipment)

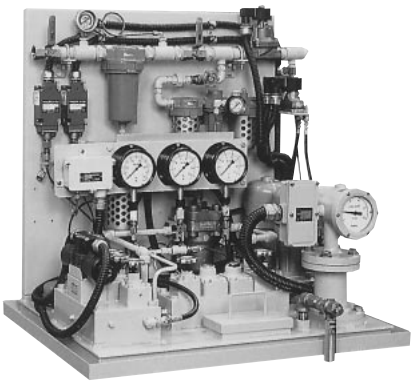


Fig. 4 Main oil unit

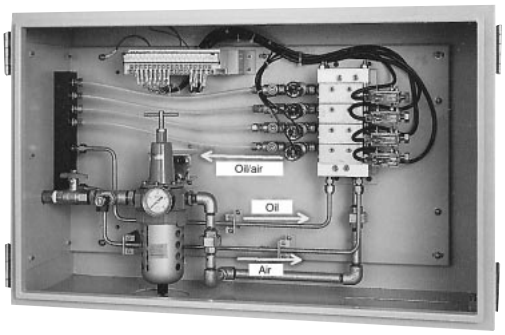


Fig. 5 Mixing panel

Fig. 6 Control panel

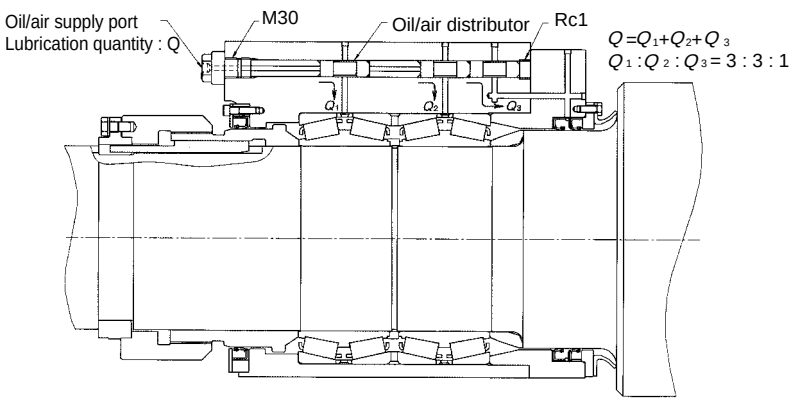


Fig. 7 Oil/air distributor

With the Koyo oil/air lubrication system, reliability of proper lubrication is achieved through an automated monitoring system, which continually monitors the items indicated in **Table 4**.

Table 4 Monitoring system (for detection of abnormalities)

Monitoring position	Monitoring item	Monitoring method
Main oil unit	· Oil level in tank	· Level switch (two upper limit positions, two lower limit positions)
	· Pressure inside oil piping	· Pressure switch
	· Clogging of oil filter	· Differential pressure switch
	· Pressure inside air piping	· Pressure switch
Main lubrication piping	· Pressure inside oil piping	· Pressure switch
	· Pressure inside air piping	· Pressure switch
Mixing panel	· Actuation of oil distributor inside mixing block	· Cycle switch Monitors whether or not oil is being supplied to oil/air piping by cycle switch of mixing block.
Oil/air piping	· Decrease of air flow rate and oil/air piping status (leakage and clogging)	· Pressure switch (upper limit, lower limit) Detects air flow rate decrease of 25% or more due to leakage or clogging.
Drain line	· Internal pressure of housing (air pressure of drain line)	· Pressure switch
Drain tank	· Oil level inside tank	· Level switch (two upper limit positions, two lower limit positions)

4. Application to Steel Mills

In addition to the characteristic requirements previously mentioned, steel mills must have sufficient lubrication effect and reliable operation and be easy to inspect and maintain maintenance/inspection[3]. Application conditions and the advantages of oil/air lubrication system for various types of equipment are given in **Table 5**.

Table 5 Application conditions for Koyo oil/air lubrication systems

1. Lubrication position	Bearing : one position per set (however, with multiple bearing rows, there is one position for every two rows of bearings.)
2. Oil/air consumption	①Oil consumption · Case of horizontal shaft : $Q = 0.085\ dR/A$ · Case of vertical shaft : $Q = 0.17\ dR/A$ Here Q : Lubrication quantity, cm^3/h d : Bore diameter, mm R : Number of bearing rows A : Speed coefficient 5 (high speed)~10 (low speed) ②Air consumption · Per one lubrication position, $Q = 40\ N\ell$/min or less (regardless of lubricant quantity and shaft direction)

Table 5 Continued

3. Housing specifications	①Oil/air supply port ・If the number of bearing rows is two or less, an oil supply port through one of the bearing positions is provided on the housing (Can also be used as a grease hole for grease lubrication). There are no axial or radial restrictions for the positioning of oil supply port. ・If the number of bearings rows is more than two, an oil supply port is provided for each lubrication position, or the oil is distributed inside the housing using an oil/air distributor. (See **Fig. 4**.) ②Waste oil discharge port ・A waste oil discharge port is provided in the housing at the oil level (the oil level is normally at the lowest level of the bearing rolling element PCD position). The discharge ports are positioned in the axial direction and can be on one or both sides of the bearing, but never between bearing rows. ③Housing internal pressure ・Maximum internal pressure is 0.05 MPa
4. Piping specifications	①Oil piping (from main unit to mixing block) ・Size：Selected from **Fig. 5** according to oil supply quantity and piping length ・Material：Stainless steel is recommended (carbon steel pipes for high-pressure piping). Used pressure 7 MPa ・Piping length：No restriction ・Direction：No restriction ②Air piping (from main unit to mixing block) ・Size：Selected from **Fig. 6** according to air supply quantity and piping length. ・Material：Stainless steel is recommended (carbon steel pipes for high-pressure piping). Used pressure 0.4 MPa ・Piping length：No restriction ・Direction：No restriction ③Oil/air piping (from mixing block to housing) ・Size：Bore diameter ϕ4～ϕ6 (distributor not used) Bore diameter ϕ6～ϕ8 (distributor used) ・Material：Stainless steel is recommended (copper pipe is acceptable). ・Piping length：Maximum of 20 meters (10 meter allowable difference between piping length.) ・Direction：No restriction ・Joint：Flexible hoses, self seals, and automatic couplers are available. ④Drain piping (from housing to drain tank) ・Size：selected from **Fig. 7** according to air supply quantity and piping length ・Material：Galvanized steel or carbon steel pipes ・Piping length：No restriction ・Direction：1/40 slope
5. Others	①Influence of temperature change ・Koyo oil/air lubrication systems are not affected by temperature (heater not required). ②Oil viscosity ・There are no viscosity restrictions for the oil/air device (the best viscosity can be determined from bearing performance). ③Piping when oil and air stopped ・Residual oil in the piping system accumulated during oil/air stop is re-transported by repeat air supply. ④Seal orientation ・Faces outward if internal pressure is applied (if facing inward, high surface pressure on lip may cause wear)

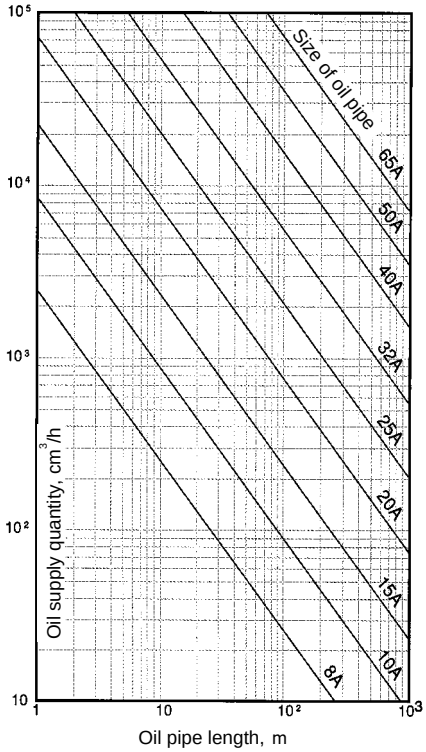


Fig. 8 Size of oil pipe

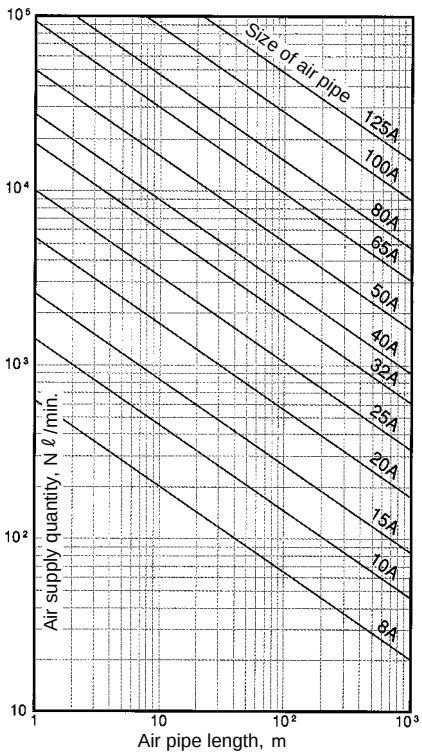


Fig. 9 Size of air pipe

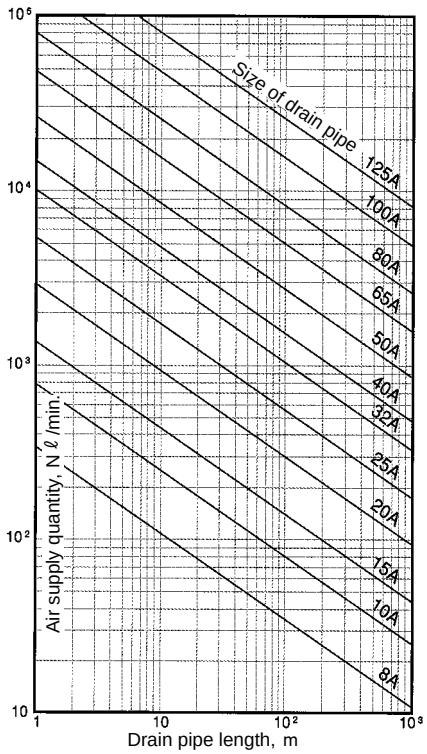


Fig. 10 Size of drain pipe

The advantages that can be expected when Koyo oil/air lubrication systems are utilized in various types of steel mill applications are given in **Table 6**.

Table 6 Advantages for steel mills

Facility	Machine name	Environment	Sealing performance	High speed Low torque	Maintenance cost	Running cost	General purpose Applicability	Developed technology
Hot strip mill	Rolling mill (work roll, back up roll)	○	◎			○		・Oil/air distribution ・Filling of initial oil ・Internal pressure monitoring ・Internal pressure control
	Auxiliary equipment (table, etc.)	◎	○	◎	◎	◎		
Cold strip mill	Rolling mill (work roll, back up roll)	○	○	◎		○		・Oil/air distribution ・Filling of initial oil
	Auxiliary roll (reel, coiler, etc.)	○	○	◎		○	○	
Wire mill	Rolling mill	○	○	○	○	○		
	Auxiliary equipment (guide roll, etc.)	○	○	◎	○	○	○	
Bar and rod mill	Rolling mill	○	○	○	○	○		
	Auxiliary equipment (guide roll, etc.)	○	○	○	○	○	○	
Structure mill	Rolling mill	○	○	○	○	○		
	Auxiliary equipment (guide roll, etc.)	○	○	○	○	○	○	
Continuous casting facility	Roll stand (guide roll, pinch roll)	◎	◎		◎	◎		・Internal pressure monitoring ・Internal pressure control ・Multi-coupler
Rolling facility for nonferrous metals	Rolling mill (work roll, back up roll)	○	○	○		○		・Oil/air distribution
	Auxiliary roll	○	◎	○		○	○	・Oil leakage countermeasure by housing suction
	Sendzimir mill	○	◎	◎		○	◎	・Oil/air distribution

◎ : Large advantage
○ : Advantage

5. Conclusion

As was previously stated, there are many advantages to using of oil/air lubrication systems for steel mill applications. Changing to an oil/air lubrication system reduces environmental pollution, improves lubrication conditions, and reduced running and maintenance costs. As the use of air/oil lubrication systems expands and their superiority is verified through favorable results, such systems will likely become the main means of lubricating not only steel mill equipment but equipment of all types of industries.

References

1) T. Miyachi : Jyunkatsu Keizai, 368 (1996).
2) Koyo Seiko Co., Ltd. : CAT. 167.
1) T. Inoue : Atsuenki no Riron to Jissai (1969).