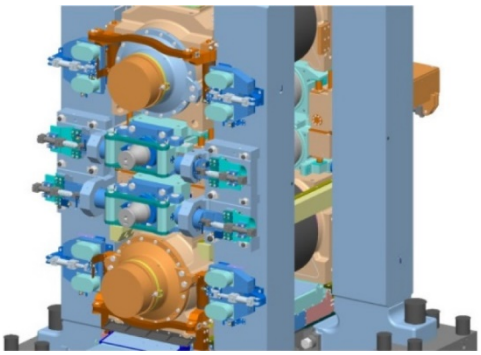
4th Generation PC Mill Promoting DX (Digital Transformation) for Saving Maintenance Works



Primetals Technologies Japan, Ltd.

In the hot and cold strip rolling process in steel manufacturing, there has been greater-than-ever demand for thin strip and high strength steel rolling (demand for high-load rolling) along with high productivity (demand for high-speed rolling), to meet the recent need for light-weight vehicle bodies for better fuel efficiency and tightened emissions control regulations in the automobile industry. Meanwhile, due to improved efficiency in motors for hybrid vehicles and electric vehicles, a small strip crown is desirable for the electrical steel sheets used in the iron cores of motors (demand for greater control over the cross-section shape of the strip). Furthermore, in order to address the imminent decrease in the size of the working population, demand for labor saving and automation in facility maintenance has also been increasing. Among the many technologies developed to realize these needs, the key for hot rolling equipment is a hot rolling mill with high ability to control the cross-section shape of the strip. Primetals Technologies has been developing a hot rolling mill called the Pair Cross Mill (PC Mill) that has the capability to address current needs. The PC Mill offers greater competitive advantages over high-load rolling or high-speed rolling, since it can utilize a flat roll for the work roll and back up roll. On the other hand, it also has a disadvantage in that the large number of parts makes maintenance difficult. The 4th generation PC Mill developed as the next flagship hot rolling mill has fewer parts requiring maintenance due to its full hydraulic cylinder control and is capable of automatic roll position adjustment in the rolling direction, which used to be handled manually. This has been achieved through the utilization of a sensor embedded in the cylinder. This report will introduce the features and other relevant information of the 4th generation PC Mill, as well as actual orders from Nippon Steel Corporation in Setouchi Works (Hirohata Area) and a U.S. company for installation in hot rolling mills.

1. Thinner, harder and faster

The 4Hi mill shown in **Figure 1** has many applications in hot rolling mills and the PC Mill has the same 4Hi mill structure. As you can see in Figure 1, when the strip is rolled, the work roll is deformed by the rolling load, which creates a strip crown. Rolling out a hard material causes a high rolling load, which generates a large strip crown. **Figure 2** illustrates the principles of the PC Mill. The PC Mill can adjust the roll gap at the end of the strip by crossing the upper and lower rolls across the strip without changing the roll gap in the center of the strip, which allows control of the strip crown. On the other hand, the high pressure on the contact surface between the work roll and back-up roll and high-speed rotation can damage the rolls. One of the features of the PC Mill is to let the work roll and back-up roll work in tandem without crossing them where flat rolls can be used, which is a greater competitive advantage over high-load rolling and high-speed rolling. Since launch, these features have been highly evaluated, with more than 150 stands of the PC Mill in actual use around the world.

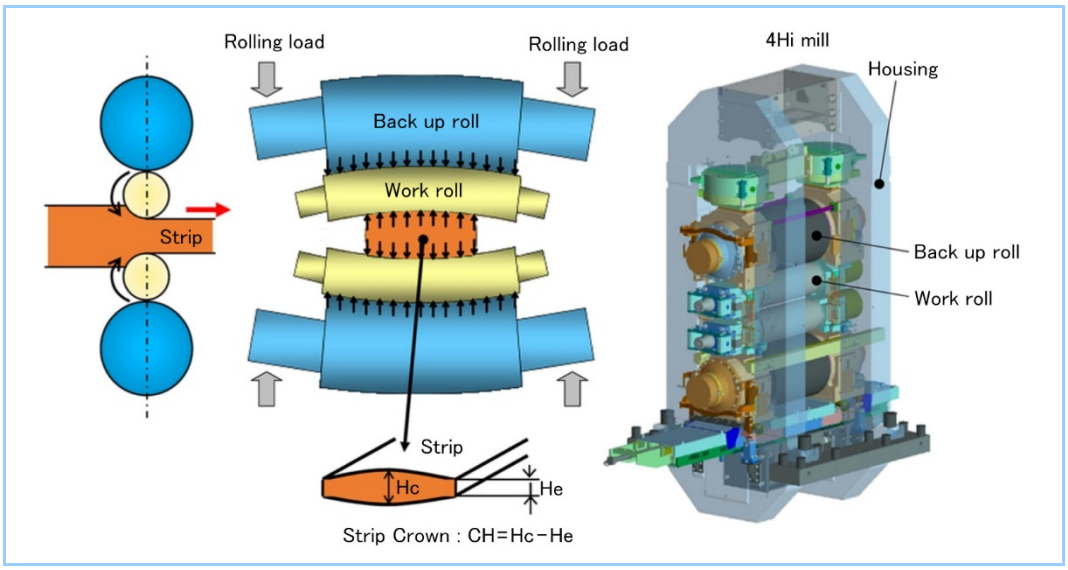


Figure 1 4Hi mill

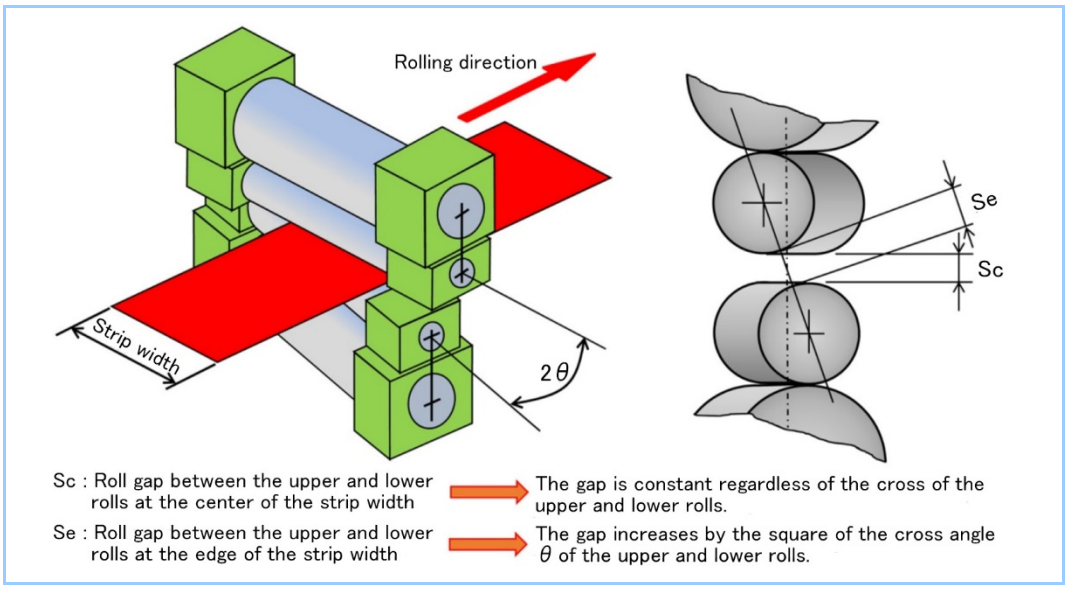


Figure 2 Principles of PC Mill

2. Further challenges of high-load rolling and high-speed rolling

Under the conditions of high-load rolling and high-speed rolling, the mill vibration becomes significant and depending on the extent thereof, the rolling load is restricted. In order to solve this issue, the Mill Stabilizing Device (MSD) was developed as a vibration damping device for the hydraulic cylinder models, and has been in use since the 3rd generation PC Mill. It has been confirmed on actual equipment that the use of the MSD reduces the mill vibration as shown in **Figure 3** and improves the restriction of the rolling load as shown in **Figure 4**.

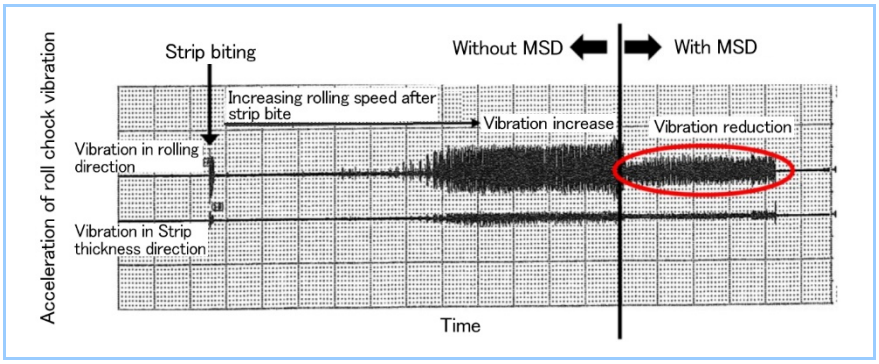


Figure 3 Reduction of mill vibration by MSD

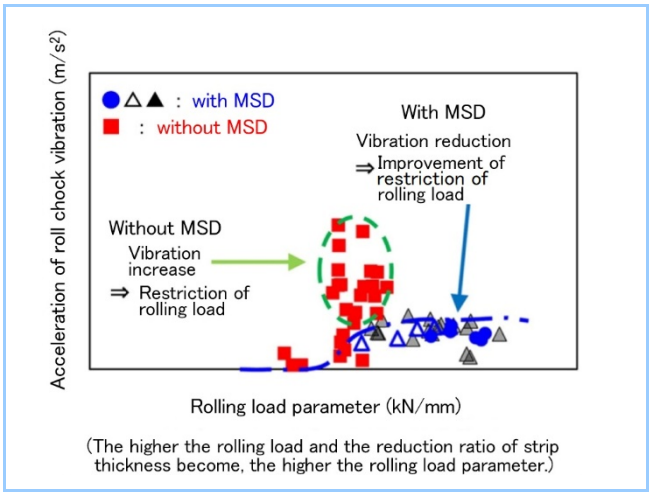


Figure 4 High load rolling by MSD

3. History to the development of the 4th generation PC Mill

As described above, while the PC Mill offers advantages, it also had a disadvantage in that maintenance work is difficult due to the large number of parts. Therefore, the history of the PC Mill upgrade is both a path to simplification as well as performance enhancement. **Figure 5** shows the history of the PC Mill simplification. If we say the number of parts required for the mechanical electromotive drive unit of the 1st generation PC Mill (i.e., motors, reducers, screws, nuts, etc.) was 100, the 2nd generation PC Mill was reduced to 40 and the 3rd generation PC Mill was further reduced to 25. In the 4th generation, by completely removing the mechanical electromotive drive unit and driving the mill directly by the hydraulic cylinder, we have achieved a significant reduction in the number of parts.

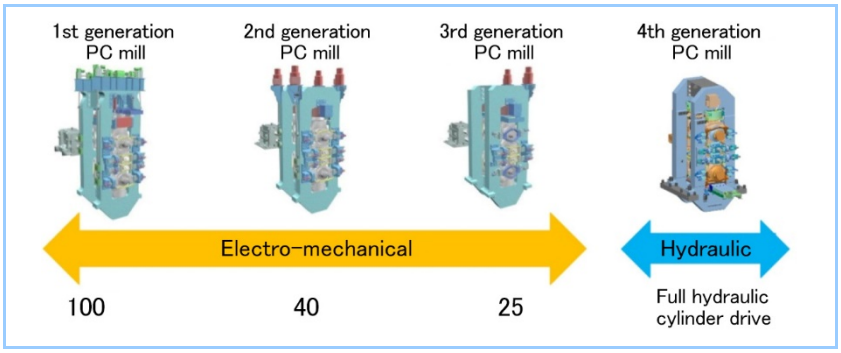


Figure 5 History of PC Mill simplification

4. Contribution to labor saving and DX promotion

To roll a strip straight and even is very important in order to avoid problems occurring inside the rolling mill, which is of particular importance in thin strip rolling. Conventional mills as shown on the left-hand side of **Figure 6** inevitably require a gap between the housing and roll chock so that the roll can be pulled out of the housing. It is considered that it is very effective to keep the gap as small as possible and to maintain the roll axis perpendicular to the rolling direction in order to the strip in straight, which, however, is quite difficult to manage. In terms of conventional mills, the only option for managing the housing liner is to measure and replace it manually at the time of maintenance shutdowns. On the other hand, while the 4th generation PC Mill as shown on the right-hand side of Figure 6 has achieved a “zero gap” between the housing and roll chock during rolling thanks to the MSD, the sensor incorporated in the cross cylinder enables the automatic correction of the roll position in the rolling direction and liner wear compensation, which used to be handled manually. Furthermore, since the roll position control is driven directly by the hydraulic cylinder without interposing any mechanical parts such as gears or screws, the structure not only allows a low parts count, but also prevents machine backlash. Consequently, strip threading troubles attributable to machine backlash are also reduced.

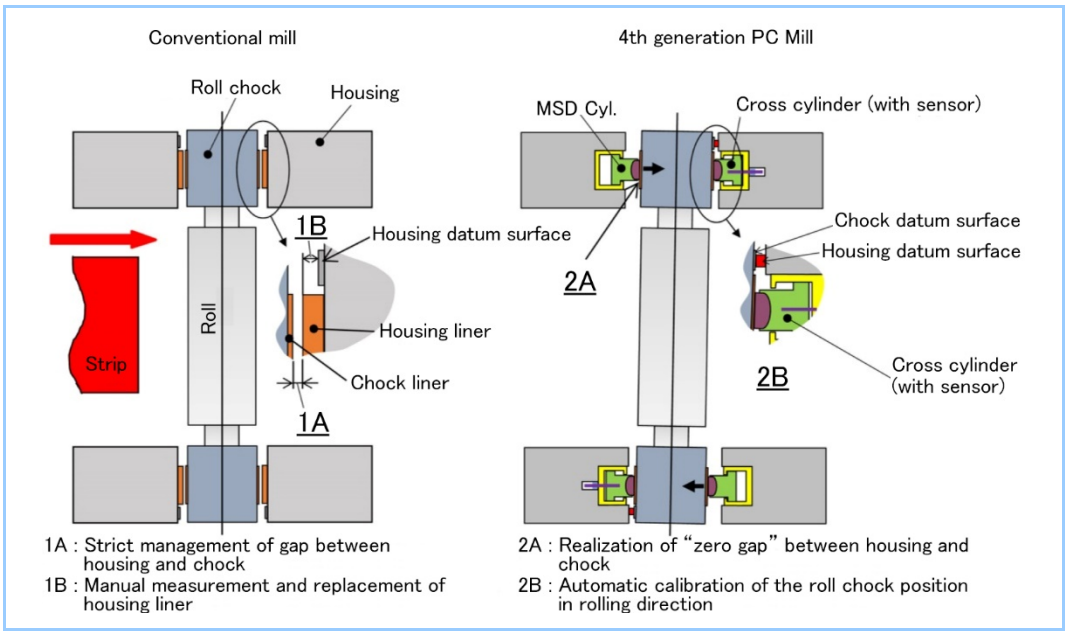


Figure 6 Labor saving and automation in liner management

5. Further development

We have scheduled installation of the 4th generation PC Mill into hot rolling mills at Nippon Steel Corporation in Setouchi Works (Hirohata Area), as well as at a U.S. company. This installation aims to achieve better productivity by simplifying maintenance procedures, removing the gap between the housing and roll chock and reducing troubles in strip threading caused by backlashes of machine parts, while enhancing the control over the cross-section shape of strips with the extended range of application of the PC Mill functions through the proper administration of the roll position and the vibration control effect.

In the future, we will continue to extend the range of application of the 4th generation PC Mill to cover newly-constructed hot rolling mills and provide solutions to meet the demand for high-load rolling, high-speed rolling, straight rolling, higher productivity, less maintenance and labor saving.