Laminação
Rolling
49º Seminário de Laminação - Processos e Produtos Laminados e Revestidos
49th Rolling Seminar - Processes, Rolled and Coated Products
ISSN 1983-4764

NEWLY DEVELOPED UNIVERSAL CROWN CONTROLL MILL "HYPER UCM" FOR ROLLING OF HIGH-STRENGTH STEEL[1]

Toyotsugu Masuda [2]
Ichiro Maeno [2]
Shin-ichi Yasunari [2]
Hajime Higuchi [3]

Abstract

The demand of high-strength steel, for example "High-tensile strength steel" in the automotive industry and "Electrical (silicon) steel", has been increasingly accelerated in recent years. Particularly in the cold rolling field, harder- and thinner-strip rolling techniques have become urgent requirements which must be dealt with. The HYPER UCM, which was newly developed for rolling harder- and thinner-strips with a higher accuracy, provides a high degree of strip quality by the use of smaller work rolls driven by work roll drive system using new M-H spindle developed by Mitsubishi-Hitachi. HYPER UCM is the advanced 6 High UCM mill (Universal Crown Control Mill) which has best combination of work roll diameter, intermediate roll diameter and back up roll diameter in consideration of strip shape control ability and hertz stress between rolls. As a result, HYPER UCM has achieved 20-40% smaller work rolls compared with existing standard UCM mills' under the work roll drive system. And, the one of key-technologies that realize HYPER UCM is high-performance work roll drive system consisting of optimally designed gear reducer and new M-H spindles. To drive smaller work roll, these components have been developed to keep sufficient rigidity and stability under the condition of high revolution. In this paper, Mitsubishi-Hitachi will highlight the specification, configuration and performance, which will be achieved by HYPER UCM in the tandem mill and reversing mill.

Key words: High-tensile strength steel; Small work roll; Work roll drive system; Spindle.

[1] *Technical contribution to the 49th Rolling Seminar – Processes, Rolled and Coated Products, October, 22nd-25th, 2012, Vila Velha, ES, Brazil.*
[2] *Mitsubishi-Hitachi Metals Machinery Inc, Tokyo, Japan*
[3] *Mitsubishi-Hitachi Metals Machinery Inc, Hiroshima, Japan*

ISSN 1983-4764

1 INTRODUCTION

In recent years, there has been growing demand for high strength automotive steel sheets for improved crashworthiness and body weight reduction, with the aim of improving fuel efficiency in response to increased global environmental awareness. To satisfy these competing objectives, auto makers have a strong need for an expanded range of applications and increased strength of HSS (high-tensile strength steel). Demand for high quality electrical steel sheets for low-loss/high-efficiency motors is also rapidly growing due to increasing regulations on the efficiency of industrial motors, etc. from the viewpoint of energy saving. However, due to the high restricted-yield stress of HSS and high quality electrical steel sheets, difficult load requirements are placed on the rolling mills used to manufacture these products.

The conventional manufacturing process for HSS is the tandem cold mill (TCM) using 4-high or 6-high rolling stands with a work roll diameter of approximately 420-630 mm. In recent years, harder materials with strength exceeding 980 MPa have been manufactured by modifying TCMs, for example, by adding one to six stands. However, the recent need for increased material strength of 1,470 MPa or higher makes it almost impossible to manufacture HSS by simple addition of rolling stands. Smaller-diameter work rolls with reduced the rolling loads are required to solve this problem. Conventionally, high quality electrical steel sheets have been manufactured using the ZR mill, but attempts are now being made to apply a trial rolling process using the TCM in order to obtain higher productivity.

In order to apply smaller-diameter work rolls to a TCM, Mitsubishi-Hitachi Metals Machinery, Inc. (M-H) carried out a comprehensive study of the influence of work roll diameter on the shape control capability and hertz stress between rolls and the reduction ratio, focusing on the reduction capacity of the tandem mill. This study showed that the highest reduction ratio is achieved with work rolls having a diameter approximately 20-40% smaller than those of the standard UCM-Mill. A new type of spindle capable of transmitting higher torque with small-diameter work rolls was also developed. As a result, the HYPER UCM was developed as a new rolling mill which uses these smaller work rolls and high strength spindles to enable rolling of higher strength materials than standard UCM-Mill (Figure 1).

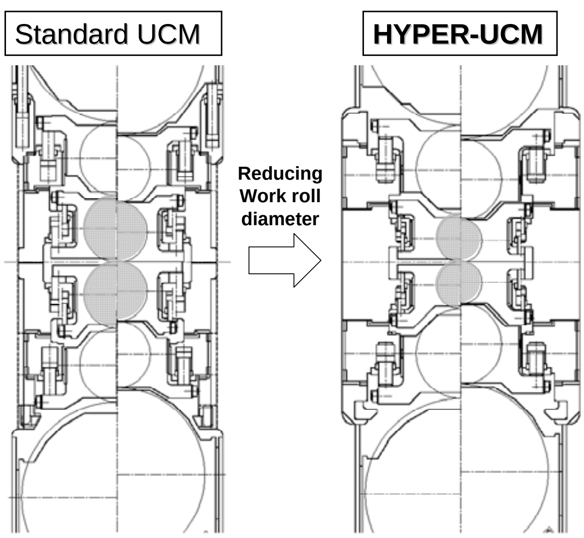

Figure 1. Comparison of roll arrangement between standard UCM and HYPER UCM.

ISSN 1983-4764

2 CONVENTIONAL TECHNOLOGIES FOR USE OF SMALLER-DIAMETER WORK ROLLS AND RELATED ISSUES

Rolling loads can be reduced and a higher reduction ratio can be obtained by using work rolls (WR) with smaller diameters. However, in the contact area between the WR and back-up roll (BUR), the portion extending outside the strip width, which is called the undesirable contact area, causes work roll deflection and makes it difficult to roll strip with satisfactory flatness. Therefore, the ratio of the work roll diameter to the maximum strip width (work roll diameter/max. strip width ratio) had remained at around 0.33 in the case of 6-ft 4H mills. M-H later developed the UCM-MILL by successfully reducing the undesirable contact area causing work roll deflection. The work roll diameter/max. strip width ratio of this MILL has now been reduced to around 0.25 (Figure 2).

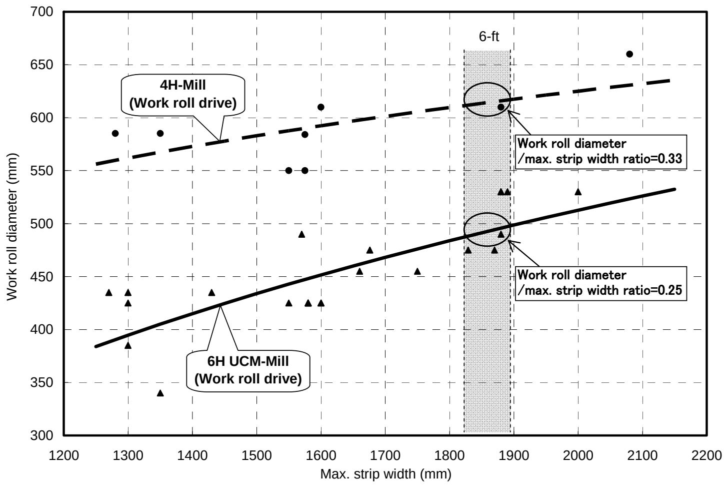

Figure 2. Curves showing Variation of Work roll diameter with Max.strip width for 4H-Mill and 6H UCM-Mill.

In the UCM, the undesirable contact area can be eliminated by shifting intermediate rolls (IMR) in the roll axis direction according to the strip width. This suppresses work roll deflection, and also makes it possible to maximize the effect of WR and IMR benders. The key features of the UCM-MILL are: i) one kind of crown (straight) work roll can be used, so the roll inventory can be reduced, ii) a higher reduction ratio can be achieved by using smaller-diameter work rolls, iii) a stable shape can be maintained under varying rolling loads, and a higher shape control capability can be obtained, and iv) material yield can be improved as a result of reduction of edge drop (Figure 3).

ISSN 1983-4764

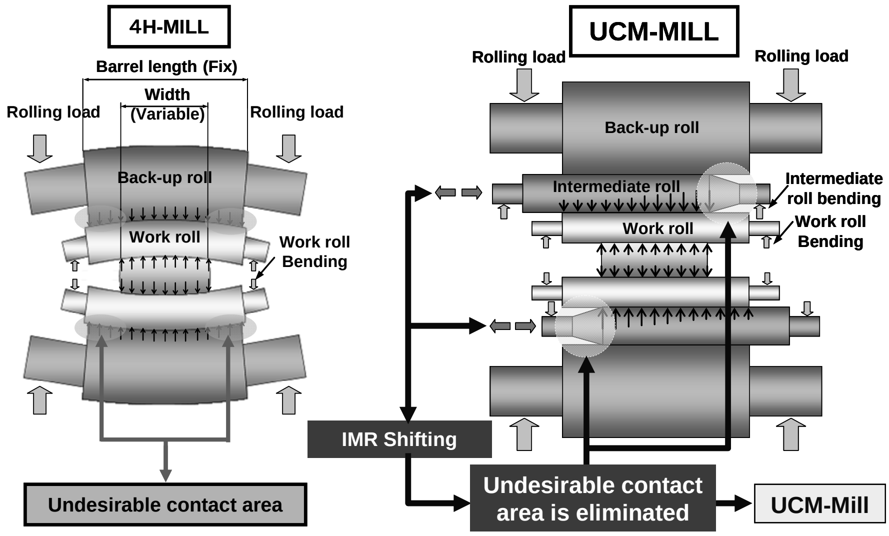

Figure 3. 4H-MILL vs. UCM-MILL.

However, as mentioned previously, material strengths exceeded 980 MPa are now required, and a much smaller work roll diameter is necessary to manufacture higher strength materials of 1,470 MPa or more. In addition, if the work roll diameter/max. strip width ratio is reduced to less than 0.25 by introduction of smaller-diameter work rolls, an IMR drive system had been required due to the insufficient strength of the spindle used in the work roll drive system. However, an IMR drive system has two large inherent disadvantages which do not exist in work roll drive systems: i) slip occurs between the rolls, and ii) the shape control capability of the mill is not fully utilized due to the horizontal deflection of the work rolls caused by the tangential driving force acting on the work rolls. In other words, the drive system is a critical point for mills due to its influence on stable mill operation and the manufacture of high quality products.

As illustrated above, to meet the recent need for high strength material rolling, it is important to develop i) smaller-diameter work rolls and ii) a work roll drive system for those smaller-diameter work rolls.

3 TECHNOLOGY DEVELOPED AS SOLUTION FOR TECHNICAL ISSUES

As a solution to the issues outlined above, M-H investigated the best combination of roll diameters for achieving the maximum reduction ratio. Specifically, a simulation technique was used to calculate i) maximum limit rolling load to maintain good strip shape and ii) maximum allowable loads based on roll strength (i.e., hertz pressure between rolls). The maximum reduction ratio was then calculated for each work roll diameter considering rolling at the maximum limit load. This simulation revealed that the highest reduction can be achieved with work roll diameters between 300 to 400 mm for a UCM-Mill with a maximum width of 5-ft to 6-ft (Figure 4).

ISSN 1983-4764

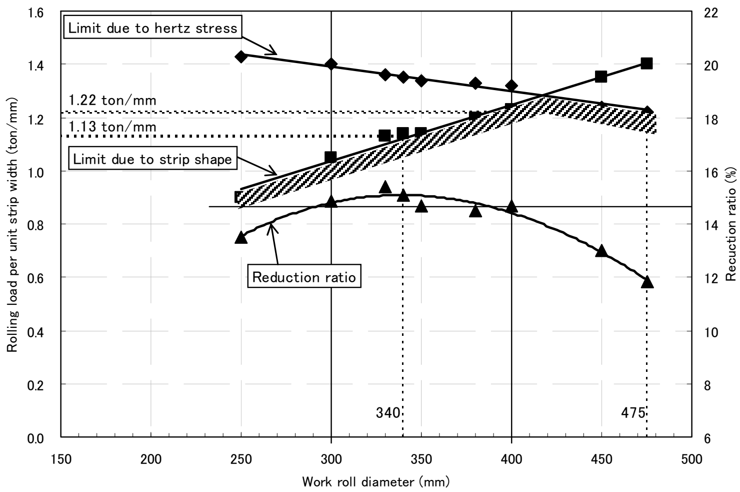

Figure 4. Variation of Rolling load per unit strip width (ton/mm) and reduction ratio (%) with Work roll diameter.

The following presents a detailed explanation of Figure. 4. From the viewpoint of the shape control capability, the rolling load at which good strip shape can be maintained tends to decrease with the work roll diameter because smaller-diameter work rolls inherently have lower rigidity. Although larger-diameter IMRs are used with small-diameter work rolls in order to compensate for this drawback, the limit load imposed by the strip shape is still smaller. The limit of the rolling load is determined by the hertz stress between the BUR and IMR, since the roll hardness and strength of the BUR is generally the lowest among the 3 types of rolls. Therefore, as a larger IMR diameter is used in combination with smaller-diameter work rolls, as mentioned above, the limit rolling load increases. Based on a calculation of the reduction ratios assuming these limit rolling loads as the upper limits, it was found that the maximum value exists in the range of work roll diameters of 300 to 400 mm. This means that the reduction capacity reaches its maximum in this range of work roll diameters. In this case, the work roll diameter/max. strip width ratio for a 6-ft UCM-Mill configuration is in the range of 0.16-0.21, which means the work roll diameter is reduced by 20-40% compared with that in a standard UCM-Mill.

Although the required rolling torque decreases as the work roll diameter becomes smaller, a higher strength spindle is required in order to maintain the larger transmission torque due to the reduction of spindle diameter. Therefore, M-H improved the structure and material of the spindle and succeeded in dramatically increasing the strength of the spindle compared to that of the conventional mill. This technology, which is called “New M-H Spindle,” can transmit approximately 2.7 times the torque of the conventional UJ-type spindle (Figure 5).

ISSN 1983-4764

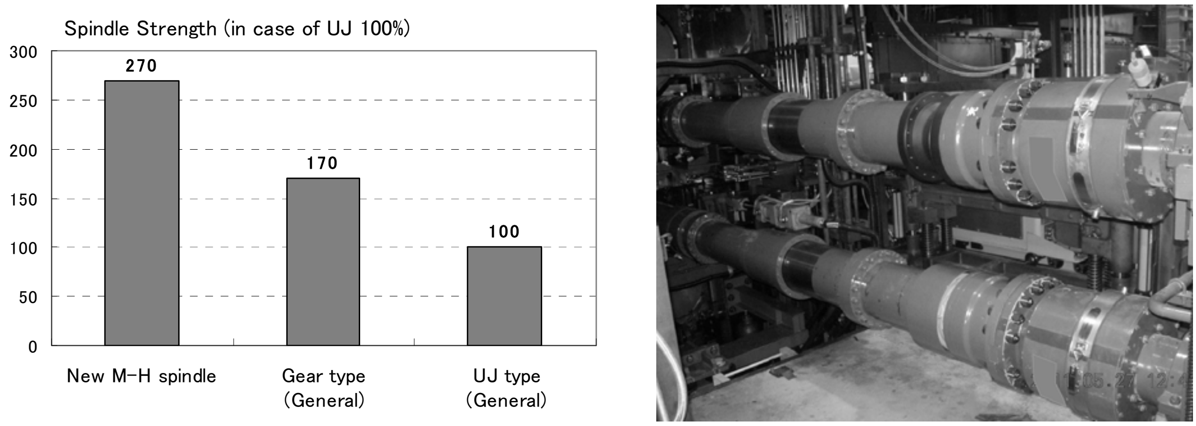

Figure 5. (Left) A bar graph showing comparison of spindle strength at each spindle type. (Right) A photo showing New M-H spindle at laboratory.

This new UCM, which has the optimum work roll diameter for achieving the maximum rolling capability, is called HYPER UCM. Rolling of higher quality products and more stable operation are possible using HYPER UCM, since work roll drive is possible when the New M-H Spindle is applied.

4 FUNCTIONS AND EFFECTS OF DEVELOPED TECHNOLOGY

The following explains the effects of HYPER UCM with a work roll diameter of 340 mm as a typical example of application to TCM. The comparable standard UCM-Mill is a TCM with a work roll diameter of 475 mm. Figure 6 shows a comparison of the necessary number of rolling stands with HYPER UCM and the standard UCM-Mill, assuming rolling of 1,180 MPa class HSS. The limit rolling load is 1.13 ton/mm for HYPER UCM and 1.22 ton/mm for the standard UCM-Mill, as shown in Figure 4. When the standard UCM-Mill with 5 stands is used, if the rolling load is limited to the allowable values from the No. 1 stand onwards, the rolling load at No. 5 stand will eventually exceed the maximum limit value, resulting in unsuccessful rolling to the desired thickness. This means that 6 stands are required in order to keep the rolling load within the limit values. In contrast, in comparison with the standard UCM-Mill with 6 stands, the HYPER UCM enables rolling to the desired thickness with 5 stands while remaining within the limit rolling load.

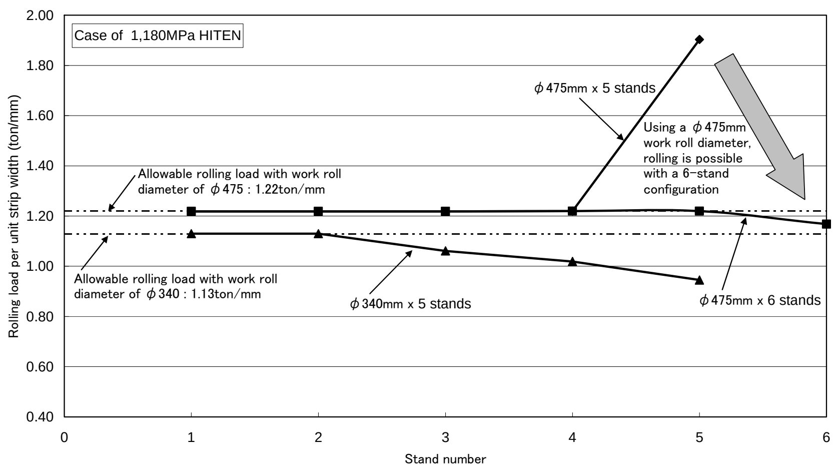

Figure 6. Comparison of necessary number of rolling stands with HYPER UCM (work roll diameter 340mm) and the standard UCM-Mill (work roll diameter 475mm).

ISSN 1983-4764

Figure 7 shows the reduction ratio and cumulative reduction ratio at each stand in Figure 6. In this figure, the HYPER HCM comprises a total of 5 stands and the standard UCM-Mill comprises 6 stands. From the bar graph, it can be understood that 2 to 3% higher reductions can be achieved at each stand with HYPER UCM in comparison with the standard UCM-Mill. The line graphs show the cumulative reduction ratios after passing each stand. Comparing the result of these two mills, HYPER UCM achieved a cumulative reduction ratio approximately 8% higher than that of the standard UCM-Mill after No. 4 stand, demonstrating the possibility of reducing the number of stands.

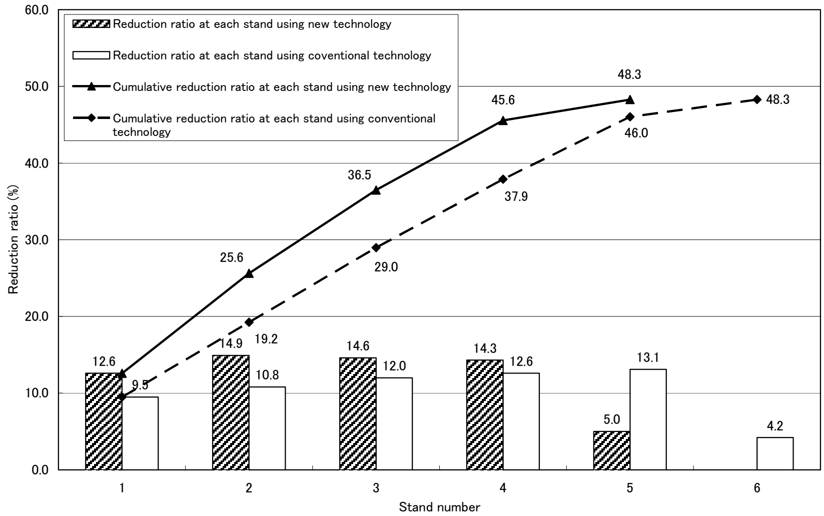

Figure 7. Comparison of reduction ratio and cumulative reduction ratio at each stand in Figure 6.

5 CONCLUSIONS

As described above, HYPER UCM enables rolling of higher strength materials than is possible with conventional mills, and material of the same strength can be rolled to thinner thicknesses by using HYPER UCM. In addition to other benefits to steel makers, the investment of TCM mills can be reduced by reducing the number of rolling stands. With reversing mills, productivity can be improved by reducing the number of rolling passes.

As a final comment on the new HYPER UCM, Mitsubishi-Hitachi Metals Machinery, Inc. is pleased to announce that the design and manufacture of the first HYPER UCM (RCM) are currently progressing smoothly for a customer in China, with the first hot run scheduled for June 2013.