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H-shaped Steel Manufacturing Technology

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Abstract

The outline of the H-shaped steel manufacturing technologies of Nippon Steel & Sumitomo Metal Corporation is introduced. Compared with the conventional technologies of manufacturing general H-shaped steel, the technologies introduced here are characterized by four features for producing H-shaped steel of various dimensions with high efficiency. The features enable the production of H-shaped steel having (1) different web height dimensions without any significant difficulty using a pair of skewed rolls and free size finishing rolls (barrel-length adjustable finishing rolls), (2) high flange/web thickness ratio using rolling temperature control technology, (3) different flange width without changing edging rolls using free-size edging rolls (caliber-depth adjustable edging rolls), and (4) enable production of a variety of sizes of H-shaped steel from a single rectangular cross-sectional material using sizing rolling technology.

1. Introduction

The conventional rolling method of H-shaped steel comprises the process of, as shown in **Fig. 1**, shaping a material heated in a reheating furnace to a beam blank shape by a roughing mill, shaping to the final product size by reducing the flange and web thicknesses in universal mills, and the sizing flange width by edger mills. Accordingly, the inside web height is determined by the barrel length of the horizontal rolls used, and the flange width (flange depth) is determined by the caliber depth of edging rolls. Therefore, the inside dimensions of H-shaped steel are made inevitably constant. To manufacture products having different inside web height and/or flange width (flange depth), horizontal rolls and/or edging rolls have to be changed (**Fig. 2**).

Furthermore, in the hot rolling of H-shaped steel, there generally exists a limit in the size range of producible H-shaped steel because of internal stress caused by the temperature difference within a section developed by a difference in the transition of temperature during rolling, which causes web buckling when it grows excessively large.

To solve the above, Nippon Steel & Sumitomo Metal Corporation has realized the manufacturing of products having different web height and flange width by employing free web height rolling technology capable of freely adjusting web height and by employing free-size edging rolls capable of manufacturing products having different flange width without changing rolls. Furthermore, with regard to flange and web thicknesses, the production of H-shaped steel having various sizes has been realized by fully utilizing the rolling temperature control technology for higher flange/web thickness ratio products.

In addition, products of various sizes are characteristically pro-

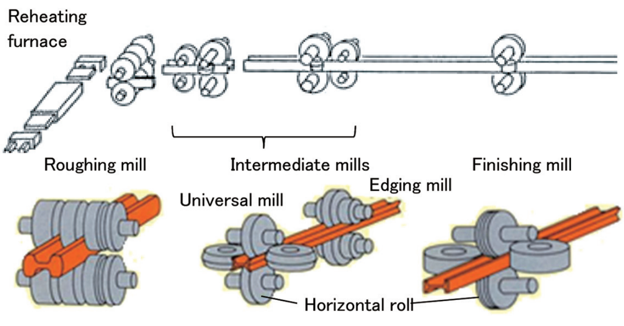

Fig. 1 Conventional manufacturing process of H-shapes

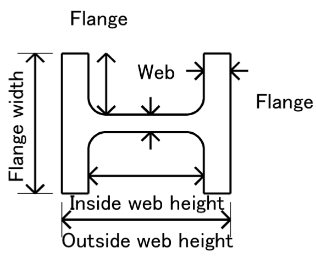

Fig. 2 Name definition of each part

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duced from a single rectangular slab by using slab sizing rolling technology.

2. Highly Efficient Free Size Rolling Technology

2.1 Inside web height adjust-rolling by skewed rolls

As methods for adjusting inside web height without changing rolls, technologies such as partial inside web rolling, inside web stretching, and width direction web rolling have been proposed. Nippon Steel & Sumitomo Metal have adopted the skewed roll type rolling method, which is capable of efficiently adjusting inside web height in a wide range with only one pass. The principle of this rolling method is shown in **Fig. 3**, wherein the centerlines of four rolls installed on in the left, right, top, and bottom positions cross the direction of rolling by an angle of α with a separation distance, L, between the left and right rolls. In this rolling mill, both edges of web which are rolled thicker than the center portion (additional thickness) provided in the foregoing rolling stage are rolled in diagonal direction, thereby expanding the inside web height. In this rolling, products with required web height can be obtained by setting α and L to meet the required expanding condition of the inside web height.

The deforming behavior of a material during the roll bite in the skewed roll type rolling mill is shown in **Fig. 4**. Deforming behavior can be discussed in three separate stages. In the first stage, on the entry side of rolling, although reduction is not applied to web thickness, the roll side face contacts with the inner side of a flange and the whole of the web are elongated in the width direction, and thereby, the inside web is expanded. In the second stage, the web portion with additional thickness is rolled in the width direction and a large increase in inside web height is provided. In the third stage, on the exit side, although rolling reduction of the web is finished, the roll still remains in contact with the inner side of the flange and the whole of the web is stretched, and the expansion of the inside web height is achieved. As mentioned above, an increase in the inside web height in skewed roll type rolling method is brought about by stretching of the web and the flow of an extra thickness portion in the web width direction.

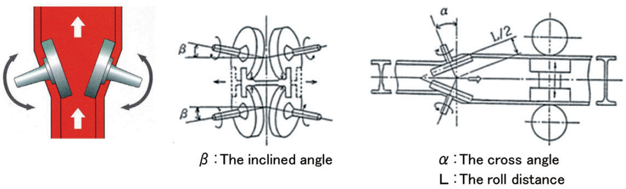

Fig. 3 Principle of the skewed rolling

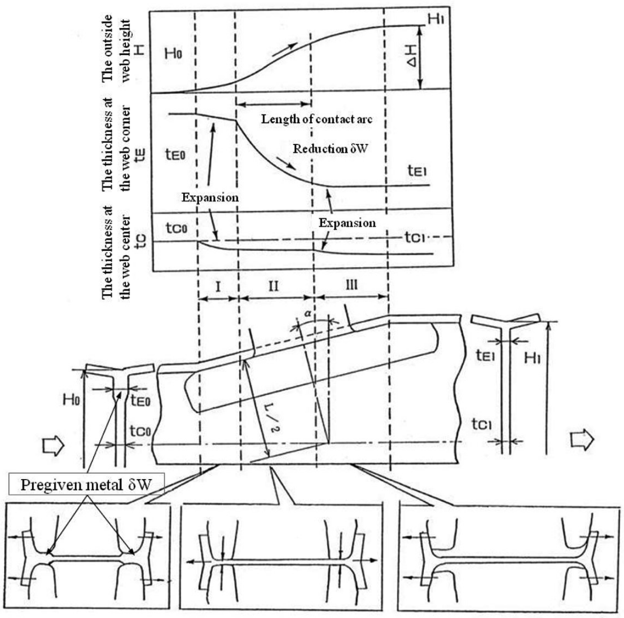

Fig. 4 Deformation activities in the roll bite

The skewed roll type rolling method is superior to other methods in that the inside web height in a wide range is achievable with only one pass, and furthermore, it enables the production of products having a stable shape and high dimensional accuracies, and the rolling load is smaller compared with other rolling methods, enabling compactification of the rolling mill.

2.2 Barrel-length adjustable horizontal roll

In order to finish-roll by the finishing universal rolling mill after adjusting the inside web height to a prescribed dimension by the skewed roll rolling mill, horizontal rolls of which barrel length have to be adjusted within a short time on line are needed, and for the purpose, the barrel length adjustable horizontal roll as shown in **Fig. 5** is used. In the construction of the barrel length adjustable horizontal roll, a highly reliable roll barrel length adjusting mechanism is completed with a highly rigid arbor mounted by roll chocks and with a barrel length adjusting mechanism installed outside the work side roll chock, thus maintaining the bending rigidity of the roll shaft.

Rolls separated for barrel length adjustment are fitted to the arbor and an intermediate sleeve respectively via interface-shrink. The intermediate sleeve with an interface-shrink-fitted work side roll is fixed in the axial direction by a thrust bearing built in the work side roll chock. On the other hand, the arbor with shrink-fitted drive side roll runs through the inside of the intermediate sleeve and is connected to the driving section of barrel-length adjusting mechanism at its end. The work side roll is installed on a double-structured roll shaft, and its rotational force is transmitted via a spline. The barrel length is adjusted by changing the roll separation distance between the left and right side rolls (inner and outer side rolls) with a screw mechanism.

2.3 Free-size edging roll

As shown in Fig. 2, the width of H-shaped steel is the sum of the flange depths of the upper and lower flanges and the web thickness. The rolling function of edging rolls is edge-rolling of the flange edge and web-position-restricting to guide web to proper position. In the case of rolling using edging rolls having a caliber depth markedly smaller than that of the flange depth, web-center-off-ness in either the upward or downward direction with respect to the flange center is caused. Therefore, when rolling a product having larger flange width (larger flange depth), the edging rolls have to be

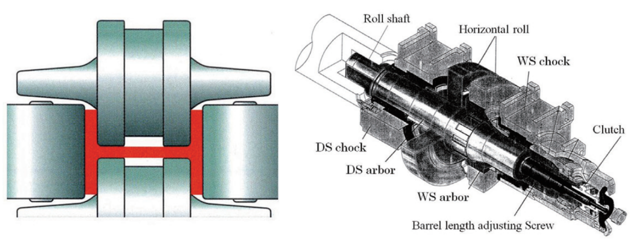

Fig. 5 Structure of free size finishing roll

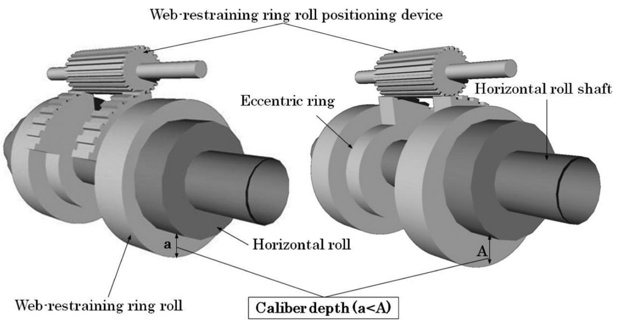

Fig. 6 Structure of free size edging roll

changed to one which has a caliber depth close to the flange depth of the product. The free-size edging roll (caliber-depth adjustable edging roll) has been specifically developed to roll products of different flange width without changing edging rolls.

Figure 6 shows the construction of a free-size edging roll having a variable edging caliber depth. In the free-size edging roll, the flange-edge-rolling section is separated from the web-restricting roll section, and the two sections are linked by an eccentric ring. By turning the eccentric sleeve using the eccentric ring for positioning use installed outside the horizontal roll, the distance between the flange-edging-rolling position and the web-restricting ring roll top position can be changed, thereby making the caliber depth variable.

The advantage of using the free-size edging roll is that the caliber depth of an edging roll is maintained close to the depth of the flange of a product in any pass in rolling, and therefore products having improved web-center-off-ness can be manufactured as compared to the case of using conventional edging rolls.

2.4 Rolling temperature control technology

Generally, in rolled H-shaped steel, the web thickness is smaller than the flange thickness; therefore thermal stress is caused by the difference between the flange and web temperatures developed by the difference in heat capacity and heat radiation in the rolling and cooling stages. Such stress is accumulated within the flange as tensile stress and as compressive stress within the web, and when the web compressive stress exceeds a certain limit (buckling stress), web buckling (web waviness developed during cooling) occurs.

Figure 7 shows schematically the transitions of temperature and thermal stress of the flange and web of an H-shaped steel when it is air-cooled from a high temperature. Cooling progresses faster in a web of thickness smaller than that of the flange, and its temperature always changes at a lower temperature than that of flange. When closely observed, it is found that the temperature difference reaches a peak when the $\gamma \rightarrow \alpha$ transformation (heat-generating transformation) in a flange is completed, the temperature difference tends to decrease gradually afterwards, and the cooling speed of the web after completion of the transformation in a flange is smaller. In light of such an unparalleled cooling speed, thermal contraction in the flange and web varies moment by moment of which difference is mutually constrained by flange and web. Therefore, thermal stress in longitudinal direction is caused.

The thermal stress value of the flange has an opposite sign to that of the web, and vice versa. When attention is paid to web thermal stress, it is found that as the temperature difference grows smaller after completion of the transformation in the flange, compressive stress is accumulated in the web by the flange having a higher cooling and contracting rate. In this regard, as the transformation accompanies expansion, compressive stress is caused in the

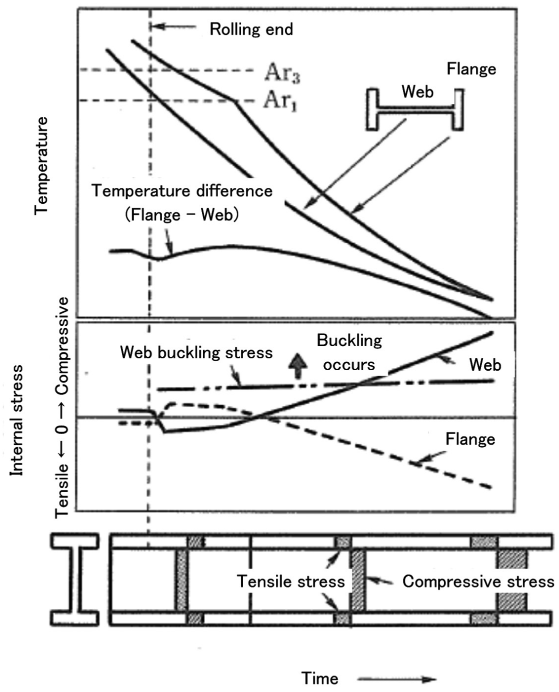

Fig. 7 Transition of cooling curve and heat stress of H-shapes

web and tensile stress is caused in the flange when the transformation in the web takes place, and an opposite state of balance of stress is caused when transformation in the flange takes place. However, thermal stress does not grow large as plastic deformation is developed more easily until the transformation is completed. Web buckling is more prone to take place in the products with larger flange to web thickness ratio, where the temperature difference between the flange and web grows larger. To suppress web buckling, it is necessary to minimize the temperature difference, and, to achieve this, water cooling of the outer flange right after rolling is employed.

If water cooling is excessively applied, a quenched and hardened structure is formed on the water-cooled surface which may result in heightened hardness or, if the rolling temperature of the flange is lowered excessively, a fine ferrite phase may be formed by rolling in the medium temperature zone, resulting in heightened yielding strength and a remarkable rise in the yielding ratio. For this reason, in rolling temperature control technology of H-shaped steel, steps are taken to control the material quality as well as to suppress web buckling.

3. Slab Sizing Rolling Technology

Rolling methods of H-shape steel are basically classified into two processes depending on the kind of the material used; one uses roughly H-shaped beam blanks, and another uses rectangular slabs. In the case of using beam blanks as the material, since the material is nearly shaped to a section appropriately corresponding to the dimensions of the products, the process has the advantageous ability of forming the product size in a stable manner. On the other hand, in the case of using rectangular slabs, the process is superior in productivity as materials of higher unit weight can be used. Therefore, the highly productive method of using slabs is employed currently, although the process is disadvantageous in forming the shape compared to the process using beam blanks, since a higher extent of shaping is required.

In the case of manufacturing H-shaped products from rectangular slabs, the flange section of H-shaped steel is formed by wedging the edge side surface of a slab in the roughing rolling process. Through edge rolling with the subsequent plural edging grooves, the width is gradually increased; thus a required flange width is obtained. After edge-rolling, a beam blank material, appropriately shaped to correspond to the desired product, is rolled by using a groove having the profile of the shape. As the number of grooves that can be accommodated in a roll of the roughing mill is restricted by the barrel length of the roll, and the amount of reduction in edging rolling is restricted, the selection of the optimum slab width according to the product dimension (web height) is necessary. Therefore, there is a need for methods of preparing material slabs of various widths to enable the manufacture of products of various web heights. In order to solve this problem, a sizing mill for specifically edging-rolling is installed ahead of the roughing mill which enables the manufacturing of products having different web heights from slabs having a common width.

It has been already stated that, as compared to the method using beam blanks, the method of rolling H-shaped steel from slabs is disadvantageous in that it lacks the stability in shaping the beam blanks. In edging-rolling, unless the steel material is guided properly to the center position of a groove of the roll, an imbalanced flange thickness is developed. Therefore, in order to cope with this problem, in the sizing mill the steel material rolling position is always unchanged, and the groove to be used is chosen by shifting the stand. By employing this method, proper steel material guiding is secured. **Figure 8** shows the method.

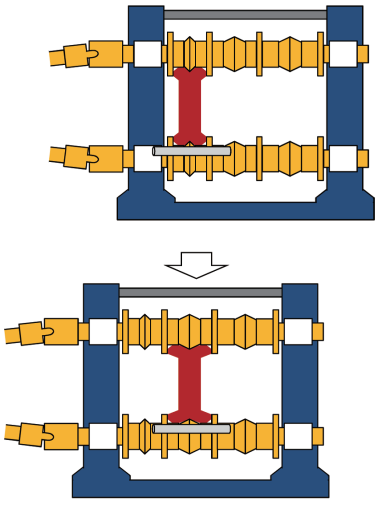

Fig. 8 Structure of sizing mill

4. Conclusion

Figure 9 shows the manufacturing process that has realized the highly efficient production of H-shaped steel as described herein. Slabs heated in the reheating furnace are rolled to form prescribed shaped beam blanks by two roughing mills. In this stage, the sizing mill is exclusively used for edging-rolling, and common use of material is achieved. In the intermediate rolling mill group, the material is rolled and finished to the desired thickness, and further, by the use of free size edging rolls installed in the edging mill, the flange width of various sizes can be freely rolled.

At the final stage of the process, the adjustment of the web height is achieved by the skewed roll mill, and by using the barrel-length adjustable roll which is installed in the finishing rolling mill. Furthermore, by applying water flange cooling before and after the intermediate rolling mill and after the finishing rolling mill, the production of H-shaped steel with high flange-web thickness ratio can be manufactured without web buckling.

By using these technologies, the highly efficient production of H-shaped steel with constant outside web height and unrestricted flange and web thickness ratio, as desired by customers, has become possible. Currently, constant outside-web-height H-shaped steel of max 47 series, 611 sizes in the size range from 400 × 200 to 1 000 × 400 is achievable. Furthermore, H-shaped steel of various international standards can also be produced without changing rolls.

In the future, it is necessary to promote the development of technologies that can comply with customers' needs, such as heavier sections and higher strength.

References

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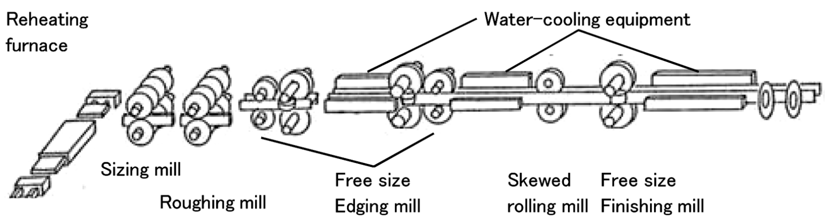

Fig. 9 Flexible universal rolling process of H-shapes

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