CUMCM-2021 Problem D

Online Optimization of Continuous Casting of Cutting Steel

Continuous casting is the productive process of turning molten steel into billet. The specific process is as follows (Fig. 1): Molten steel is continuously poured into the mold from the tundish, pulled down from the mold at a certain speed and entered the secondary cooling section. When molten steel passes through the mold, a solid billet shell is formed at the place in contact with the surface of the mold. During the secondary cooling section, the billet shell gradually thickens and finally solidifies to form billet. Then, the billet is cut according to certain size requirements.

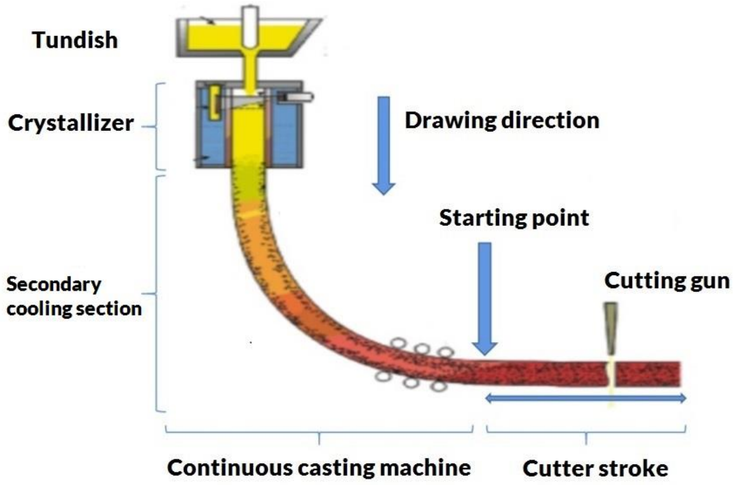

Fig. 1 Schematic diagram of continuous casting process

When continuous casting is stopped, the tailstock will be produced. The length of the tailstock is related to the amount of molten steel remaining in the tundish and other factors. Therefore, the cutting of the tailstock is also a part of continuous casting cutting.

When cutting billet, the cutting machine must start from a fixed starting point. During the cutting process, the cutting machine rides on the billet and moves simultaneously with the billet to ensure that the cutting line is perpendicular to the drawing direction. After cutting, it returns to the starting point and waits for the next cutting.

In the cutting scheme, the priority is cutting loss, which is required to be as small as possible. Here, the cutting loss is defined as the length of the scrapped billet. Then considering the user's requirements, under the same cutting loss, the cutting billet should meet the user's target value as well as possible.

In the process of steel pouring, the mold may be abnormal. At this time, a section of billet inside the mold should be scrapped, which is called scrapped section (Fig. 2). When the mold is abnormal, it will be known instantly so that the cutting scheme will be adjusted immediately.

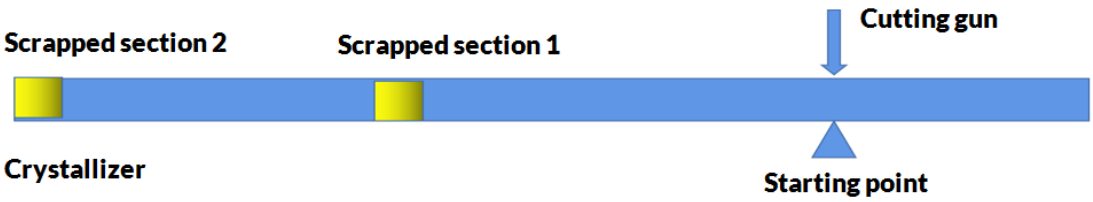

Fig. 2 Schematic diagram of scrapped section of billet

The cutting billet attached with the scrapped section cannot enter the next process. In case of scrapped section occurs, the billet attached with the scrapped section will be cut off firstly, and then make the remaining billet meet the length requirements of the next process by off-line secondary cutting. In addition, the billet entering the next process must also meet the length requirements of the next process.

Please establish mathematical models or design algorithms to solve the following problems:

Problem 1 Under the basic and standard requirements, please give the optimal cutting scheme according to the length of the tailstock. Assuming that the user's target value is 9.5 m and the target range is 9.0~10.0 m, please give specific optimal cutting schemes respectively for the following tailstock lengths: 109.0, 93.4, 80.9, 72.0, 62.7, 52.5, 44.9, 42.7, 31.6, 22.7, 14.5, and 13.7 (unit: m). The numerical results of the optimal cutting schemes should be listed in a table with fields tailstock length, cutting scheme, cutting loss, etc.

Problem 2 When the mold is abnormal, please give the real-time optimal cutting scheme: (1) when the scrapped section of billet occurs first time, give optimal cutting scheme for this section of billet; (2) after a new scrapped section occurs (Fig. 2), give optimal cutting scheme for the new section of billet and the adjustment scheme of the current section of billet cutting, or state that no adjustment is needed.

Assume that the abnormal times of crystallizer are 0.0, 45.6, 98.6, 131.5, 190.8, 233.3, 266.0, 270.7, and 327.9 (unit: min), the user target value is 9.5 m and the target range is 9.0~10.0 m. Under the basic and standard requirements, please give specific optimal cutting schemes at these times, and list the numerical results in a table with fields initial cutting scheme, adjusted cutting scheme, cutting loss, etc.

Problem 3 Assume that the real-time optimal cutting scheme and the abnormal time of the mold are all the same as Problem 2. Under the basic and standard requirements, please give specific optimal cutting schemes respectively for the following two cases: (1) the user target value is 8.5 m, the target range is 8.0~9.0 m, and (2) the user target value is 11.1 m and the target range is 10.6~11.6 m. The numerical results should be listed in a table with fields initial cutting scheme, adjusted cutting scheme, cutting loss, etc.

Appendix: Parameters and Requirements

Process parameters: The time for cutting a billet by the cutter is 3 min, and the time for returning to the starting point after cutting is 1 min. The length of the billet from the center of the mold to the starting point is 60.0 m, and the speed of continuous casting is 1.0 m/min. When the mold is abnormal, the length of the scrapped section is 0.8 m.

Basic requirements: The length of the cutting billet is 4.8~12.6 m, otherwise it cannot be transported and will hinder production. The acceptable billet length in the next process is 8.0~11.6 m. If it is not within this range, the billet can be transported for secondary off-line cutting. In this case, the cut part is scrapped, which results in loss. For example, a 12.6 m billet can be cut 1.0 m to 11.6 m, and the cut part with length 1.0 m will be scrapped. The billets less than 8.0 m must be scrapped.

Standard requirements: Normal cutting is to cut according to the length required by the user. User requirements include target value and target range. The cutting length of billet should meet the target value as close as possible, and the length within the target range is also acceptable. For example, if the target value is 9.5 m and the target range is 9.0~10.0 m, the cutting length should be 9.5 m as close as possible, and the length between 9.0~10.0 m is acceptable. Loss occurs when the billet length is not within the target range. For example, the billet length is 11.6 m, and the extra length 1.6 m is scrapped.