Summary of the tests presented in the article: "Self-tuning regulatory controller of cyclical disturbances using data-driven frequency estimator based on fuzzy logic".

The tests were conducted in two phases. The first phase was at a specified speed and lasted 900 s. In the second phase, the casting speed was modified, consequently changing the bulging frequency. To implement the simulation using the same bulging frequency found in a real mold plant (Pereira et al., 2021; You et al., 2011), casting speeds of approximately 10 mm/s (in Scenarios 1, 2, and 3) and 20 mm/s (in Scenario 4) were considered; the roller spacing of continuous casting was fixed at $D = 200$ mm. The four scenarios are described as follows.

Scenario 1. The casting speed and bulging frequency are 10 mm/s and 0.05 Hz, respectively. Using Eq. (1), the number of samples during the disturbance cycle is 200 for a sampling period of 0.1 s. At 900 s, the casting speed is increased to 10.52 mm/s, thereby increasing the bulging frequency to 0.0526 Hz. In this case, according to Eq. (1), the number of samples during a cycle is $N_d = 190$.

$$N_d = \frac{T_p}{T_s}, \tag{1}$$

Scenario 2. The casting speed and bulging frequency are 10 mm/s and 0.05 Hz, respectively. Using Eq. (1), the number of samples during the disturbance cycle is determined to be 200, from 0 to 900 s. Afterwards, the casting speed and bulging frequency increase to 10.80 mm/s and 0.054 Hz, respectively. The corresponding number of samples during the cycle is $N_d = 185$.

Scenario 3. Similar to Scenarios 1 and 2, the initial casting speed, bulging frequency, and number of samples during the disturbance cycle are 10 mm/s, 0.05 Hz, and $N_d = 200$, respectively. Then, after 900 s, the casting speed, bulging frequency, and number of samples change to 11.20 mm/s, 0.0565 Hz, and $N_d = 177$, respectively.

Tests with the AF-ILC controller

Tests in Scenario 1

The test of AF-ILC with the fuzzy estimator turned on for Scenario 1 is shown in Fig.1. In this test the controller can automatically adjust the tuning parameter, N, and thus reduce the bulging disturbance.

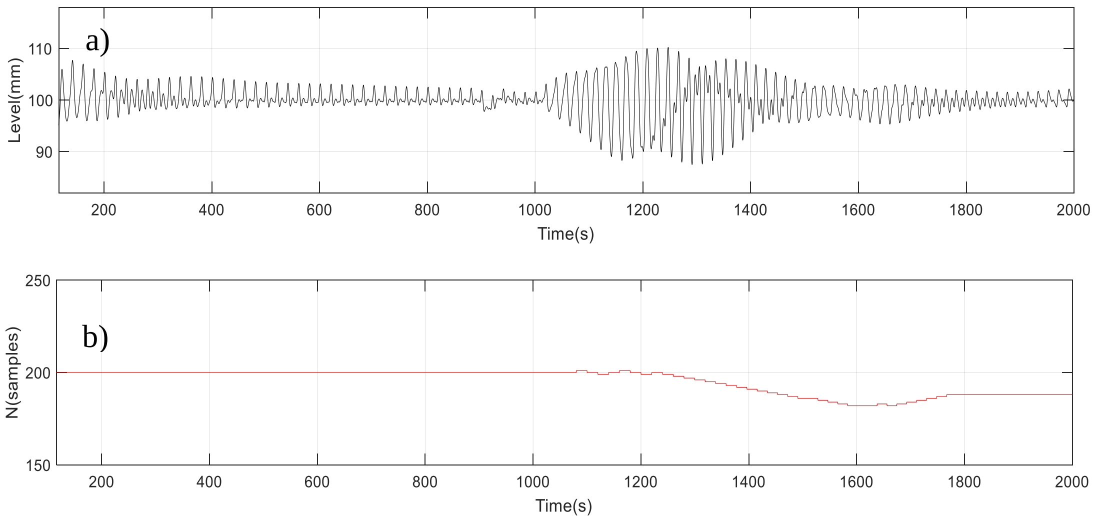

Fig. 1. AF-ILC with fuzzy estimator turned on in Scenario 1: (a) mold level and (b) values of N.

Tests in Scenario 2

The test of the AF-ILC with the fuzzy estimator turned on for Scenario 2 is presented in Fig. 2. In this test the AF-ILC does not perform well, because the fuzzy estimator cannot converge to 185 samples.

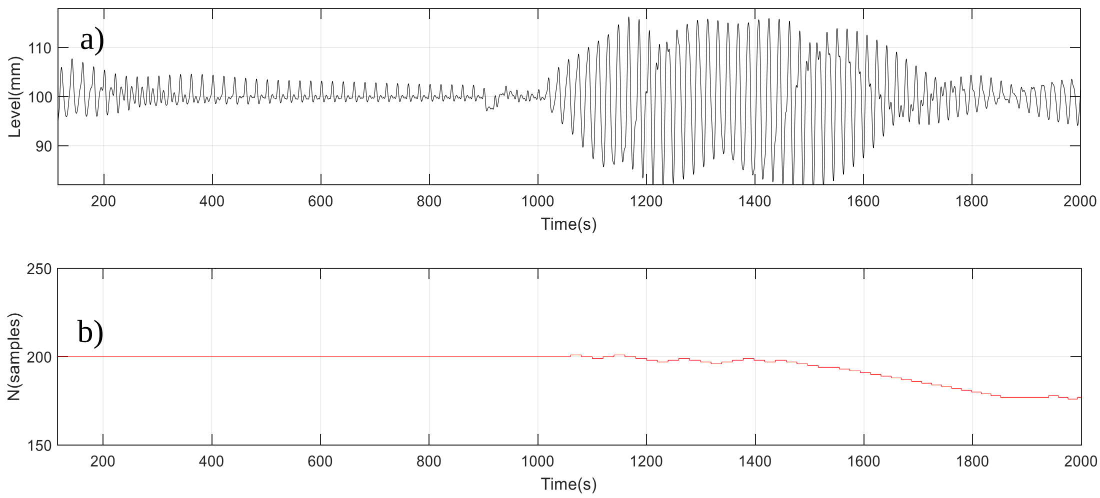

Fig. 2. AF-ILC with fuzzy estimator turned on in Scenario 2: (a) mold level and (b) values of N.

Tests in Scenario 3

In this scenario, the N_d variation from 200 to 177 samples does not allow the AF-ILC to reduce the periodic signal (Fig. 3) because the tuning parameter, N, does not converge to N_d; this is similar to the situation in Scenario 2.

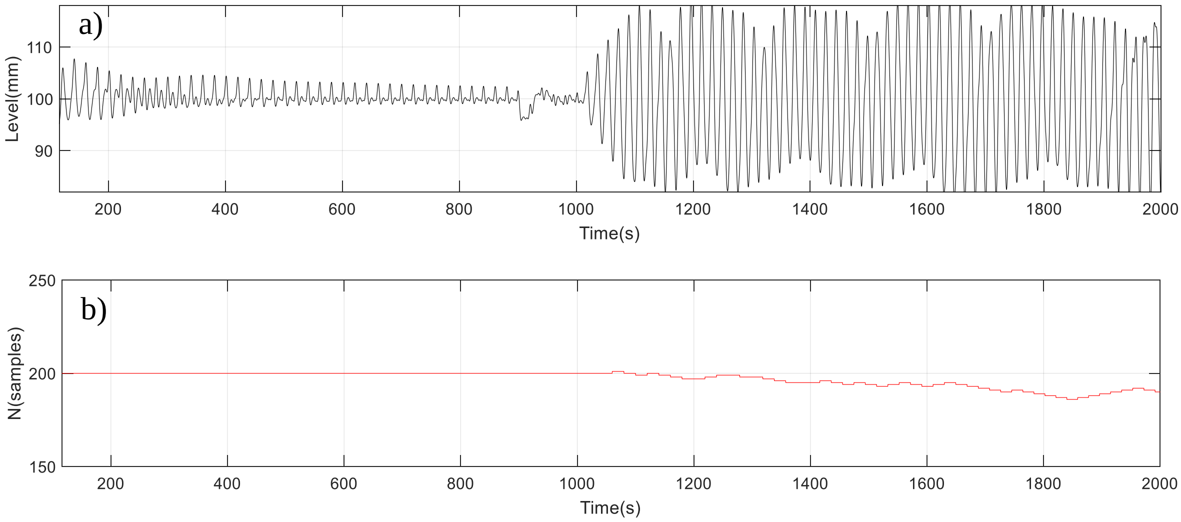

Fig. 3. AF-ILC with fuzzy estimator turned on in Scenario 3: (a) mold level and (b) values of N.Tests in Scenario 4.