

**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) were considered; the roller spacing of continuous casting was fixed at  $D = 200$  mm.

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  $N_d = 190$ .

$$N_d = \frac{T_p}{T_s}, \quad (1)$$

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 AFR-GPC controller

### Tests in Scenario 1

For the proposed adaptive controllers AFR-GPC, the tests with the fuzzy estimator turned on for Scenario 1 is shown in Fig.1. The AFR-GPC can automatically adjust the tuning parameter,  $N$ , and thus reduce the bulging disturbance.

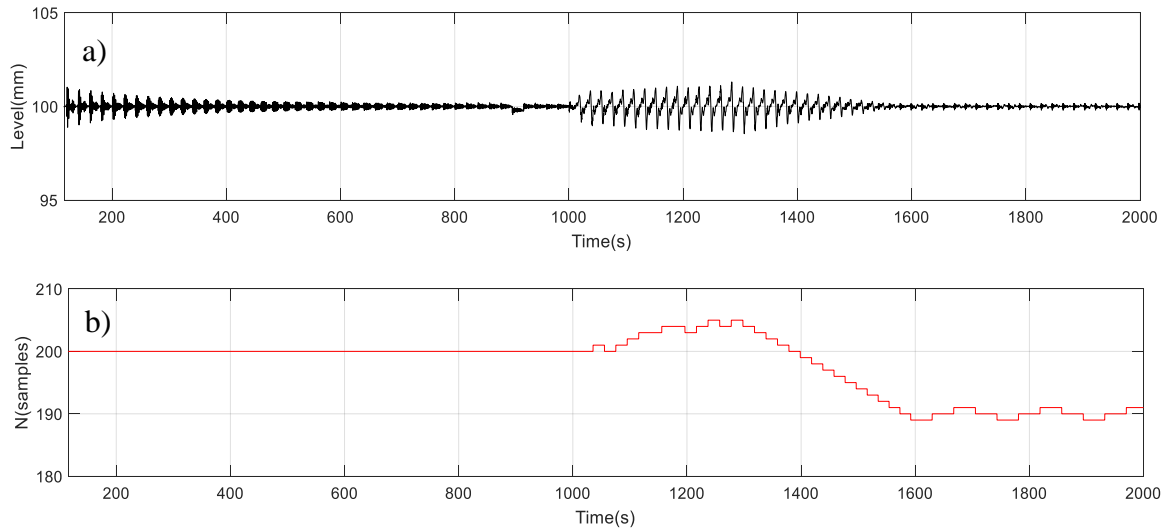


Fig. 1. R-GPC without fuzzy estimator turned on in Scenario 1: (a) mold level and (b) values of  $N$ .

### Tests in Scenario 2

The tests of the AFR-GPC with the fuzzy estimator turned on for Scenario 2 are presented in Fig. 2. The AFR-GPC demonstrates a great cyclical disturbance reduction.

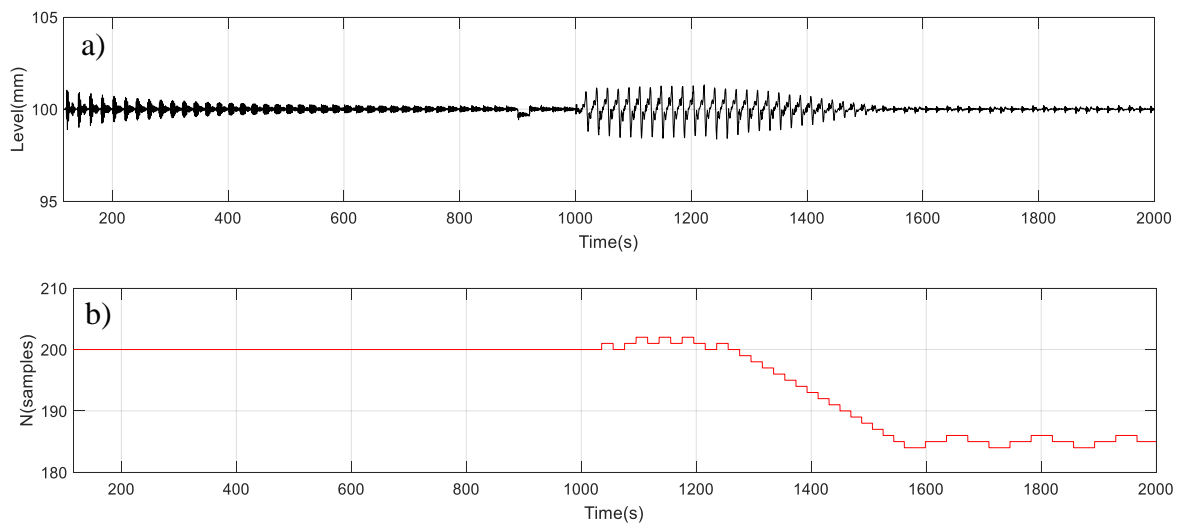


Fig. 2. AFR-GPC with fuzzy estimator turned on in Scenario 2: (a) mold level and (b) values of  $N$ .

### Tests in Scenario 3

In this scenario, the  $N_d$  variation from 200 to 177 samples. The AFR-GPC, is able to reduce the bulging disturbance, as shown in Fig. 3.

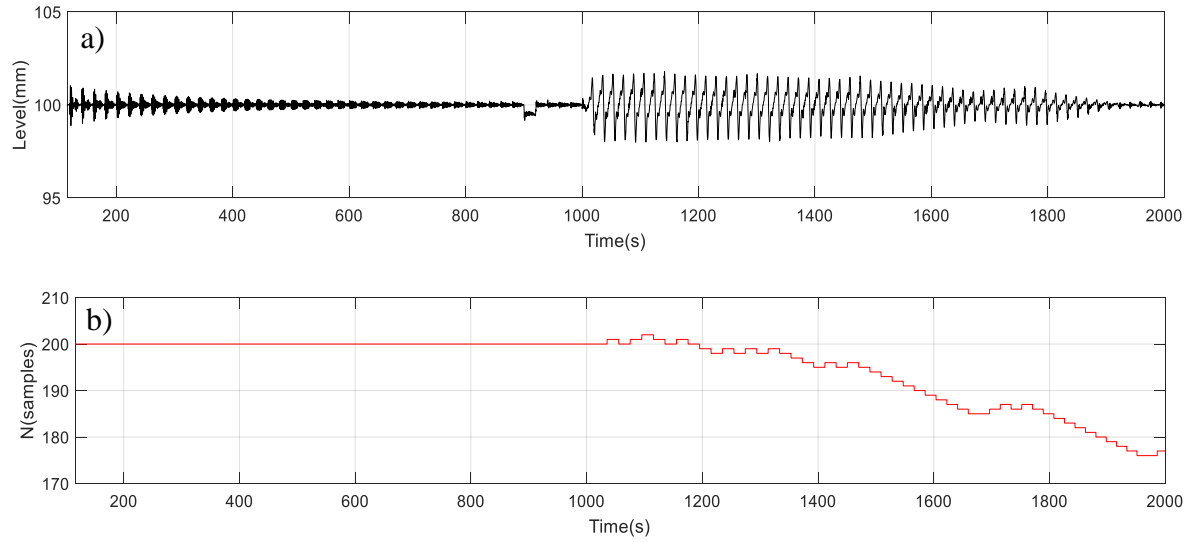


Fig. 3. AFR-GPC with fuzzy estimator turned on in Scenario 3: (a) mold level and (b) values of  $N$ .