rpm roller speed has higher efficiency it results in higher percentage of undersize material in overflow thus requires more sections which in turn leads to longer wobbler feeder configuration.

Particle Velocity

Another parameter affecting efficiency of the wobbler is particle velocity (Figure 8.) It should be examined to improve the screening efficiency and to obtain durable machine. To investigate wobbler efficiency, particle velocity was examined at different roller rotation speeds such as 20, 40 and 60 rpm. Totally, 12 conditions were examined, and data were obtained after reaching steady state to get accurate results. Also, size of particles was chosen to be between 80 and 90 mm for all conditions. The reason is that sizes in that range is larger than from both gap sizes. In Figure 8. absolute velocity of gradations at same gap sizes (40x40 mm and 60x60 mm) shown with respect to the roller rotation speed. As shown in Figure 8. For low bulk density particle, G1, absolute velocity at 20 rpm is 0.25 m/s while it is 0.46 m/s for high bulk density particle G2 at the 60 rpm roller speed for the gap size of 40x40mm. On the other hand, velocity change for G1 and G2 are 528% and 236 % respectively. Moreover, gap size for 60x60 mm is shown in Figure 8. For the particle G1, absolute velocity at 20 rpm is 0,18 m/s whereas for G2, it is 0,63 m/s. Also, velocity percentages are 412% and 44% respectively. It is clear that particle velocities are directly proportional to rollers rotation speed. As rollers speed is increasing, particle absolute velocity also increases.

Particle Resident Time and Trajectory

In addition to the particle velocities on the wobbler, particle resident time is another parameter that helps understand particle behavior over the wobbler. When particle resident time is decreasing, there is a possibility of undersized particles escaping to overflow section. On the contrary, increased particle resident time results in undersized particles passing from spacing. Former leads to decrease of performance. To this extent, optimum resident time should be obtained for high performance wobbler. Figure 9. gives detailed information about particle resident times for all cases. The resident times described as particles traveling time between entry and exit of the boundary domain. All values obtained after system reached steady state regime.

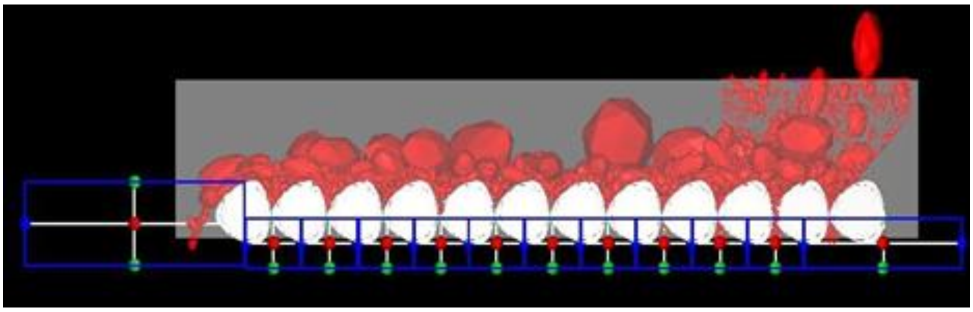


Figure 5. Simulation cube setup for particle passing percentages

***Şekil 5.** Parçacık geçiş yüzdeleri için simülasyon küpü kurulumu*

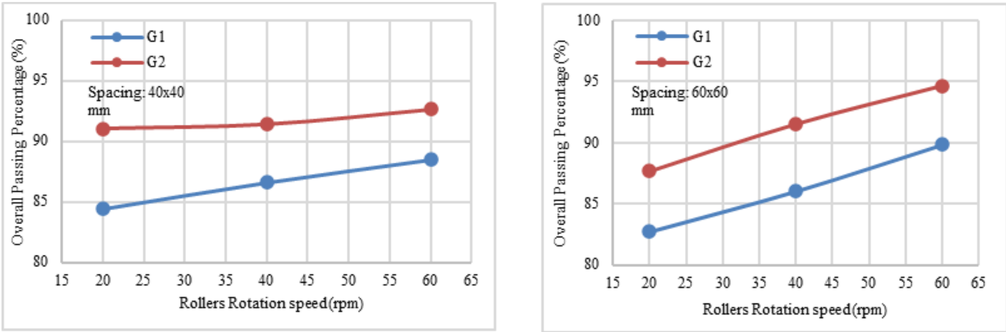


Figure 6. Overall passing percentage

***Şekil 6.** Genel geçme yüzdesi*

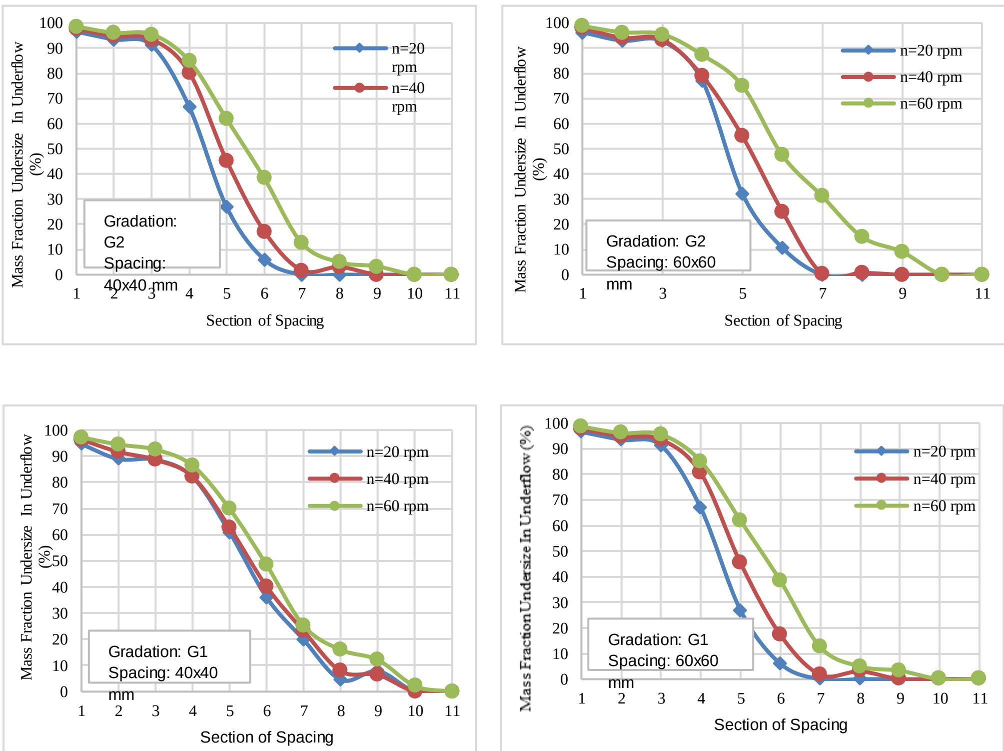


Figure 7. Undersize mass fraction for each spacing

***Şekil 7.** Her boşluk için küçük kütle kesri*

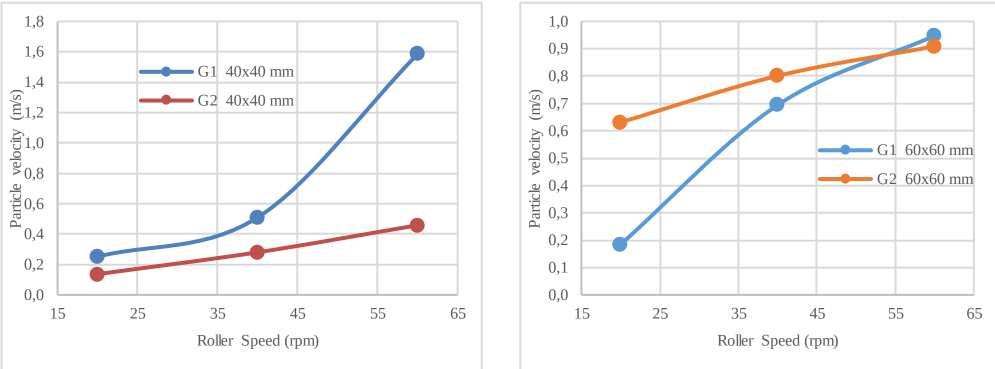


Figure 8. Absolute translational velocity of oversized particles

Şekil 8. *Büyük parçacıkların mutlak öteleme hızı*

Figure 9. shows particle resident time with respect to roller speeds for both low and high bulk density particles. All cases were examined for constant feed rate of 300 t/h. It became obvious that particle bulk density does not have enormous effect on resident time. Nonetheless, resident time is decreasing while roller rotation speed is increasing. For low bulk density particle, resident time is 29.5 sec, 15.45 sec and 11.2 sec in 20 rpm, 40 rpm and 60 rpm respectively for spacing of 40x40 mm. Besides, for high bulk density, resident time is 23.8 sec, 18.9 sec and 11.8 sec in 20 rpm, 40 rpm and 60 rpm respectively for spacing of 40x40 mm (In Figure 9.) Although having higher translational velocity at that time oversized particles moving forward on the Wobbler feeder may experience delayed motion and keep tumbling when stuck in between rollers and result in increased resident time. To understand particle behavior in detail, trajectory of the oversize particle is examined.

Only one particle is selected for all cases and size is chosen between 80-90 mm. In Figure 10, trajectories of the particles are shown for Gradation 1 and spacing 40x40mm. As it can be seen from figures, while rotation speed is smaller, particle is tumbling repeatedly between two rollers. However, in high roller speed, particle moves more quickly as expected. In addition, for undersized and very large particle, trajectories were obtained which

is presented in Figure 11. Undersized particle (21.58 mm) directly passed form gaps whereas oversized particle (575.5 mm) moves forwards without any tumbling at 40 rpm, 40x40 mm gap and G1 gradation conditions.

Effect of Different Configurations on Screening Efficiency

The following formula is used to calculate the screening efficiency for condition of 40 rpm,40x40 mm gap and G1.

$$E_u = \frac{Mass_{U_{Underflow}}}{Mass_{U_{Feed}}} \quad (1) \qquad E_O = \frac{Mass_{O_{Overflow}}}{Mass_{O_{Feed}}} \quad (2) \qquad E = E_U * E_O \quad (3)$$

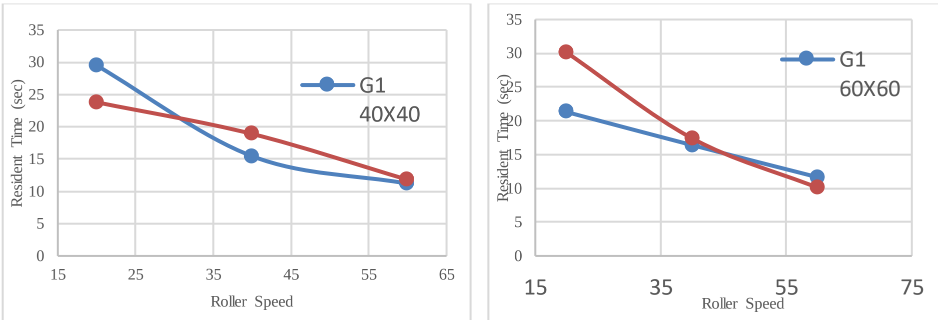


Figure 9. Particle resident time vs. roller speed

Şekil 9. *Parçacık kalma süresi ve silindir hızı*

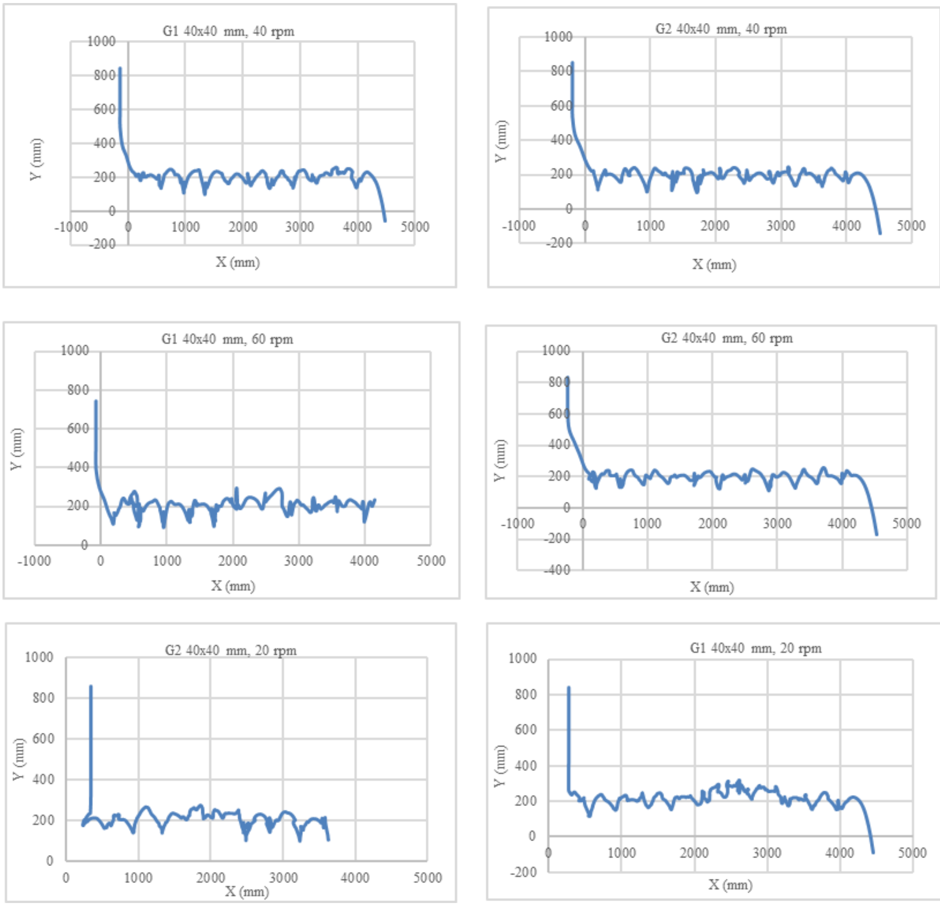


Figure 10. Oversize particle trajectory

Şekil 10. *Büyük boyutlu parçacık yörüngesi*

Efficiency results for corresponding configurations are as follows:

Herringbone configuration:

$$E_u = \frac{1250{,}38\ \text{kg}}{1266{,}85\ \text{kg}} = 0{,}986 \qquad E_O = 1$$

$$E = E_U = 98{,}6\%$$

Straight configuration:

$$E_u = \frac{1238{,}75\ \text{kg}}{1261{,}17\ \text{kg}} = 0{,}982 \qquad E_O = 1$$

$$E = E_U = 98{,}2\%$$

Cross configuration:

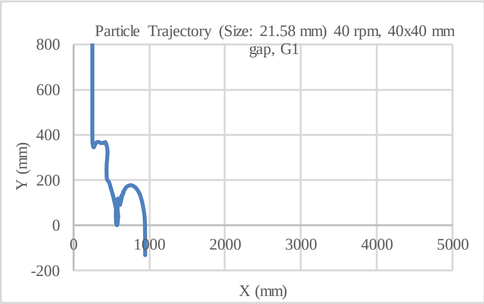
$$E_u = \frac{1196{,}2\ \text{kg}}{1231{,}45\ \text{kg}} = 0{,}971 \qquad E_O = 1$$

$$E = E_U = 97{,}1\%$$

CONCLUSION

In this study, motion of complex raw material for Wobbler Feeder is simulated with Discrete Element Method considering the effects of resident time and particle velocity. Simulations were run for three parameters 20,40 and 60 RPM, which maintains regular feeding of oversize particles and screening of undersize particles from gaps formed by triangular shaped discs.

Based on the results of screening efficiency and particle resident time the optimum roller speed was observed to be 40 RPM for both 40x40 and 60x60 gap. For low bulk density material (G1) resident time is 15.45 seconds whereas for high bulk density material (G2) resident time is 18.9 seconds for 40x40 mm gap. These results indicates that roller rotation speed has an important effect on particle flow characterization and screening efficiency.



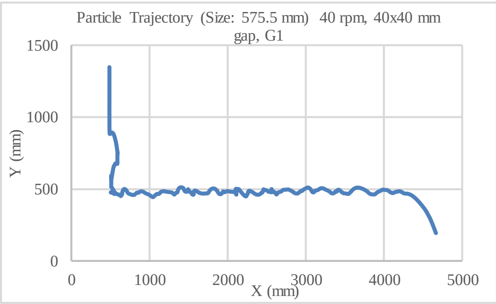


Figure 11. Undersize and oversize particle trajectory

Şekil 11. *Küçük ve büyük boyutlu parçacık yörüngesi*

Although with the increasing rotation speed feeding performance is increasing, it has an adverse effect in terms of particle resident time. For G1 material 40x40 mm and G2 material 40x40mm gap resident times are 13% and 6% higher comparing in 60 RPM compared to 40 RPM. Since decrease in resident time creates a possibility of undersize particle to escape into overflow, and increase of resident time means feeding of oversized particle will slow down, 40 RPM speed is an optimum choice rather than 60 RPM, where resident time is lower and 20 RPM where resident time is higher in described configuration. According to efficiency results herringbone configuration is higher than both straight and cross configurations, while latter two are still have quite adequate efficiency percentages.

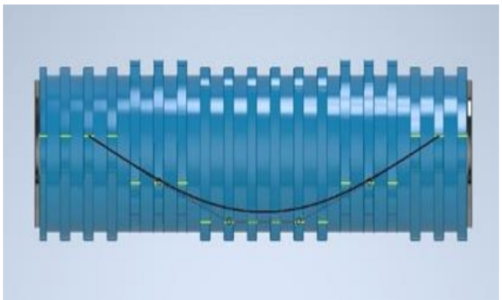


Figure 12. Herringbone configuration

Şekil 12. Balıksırtı form

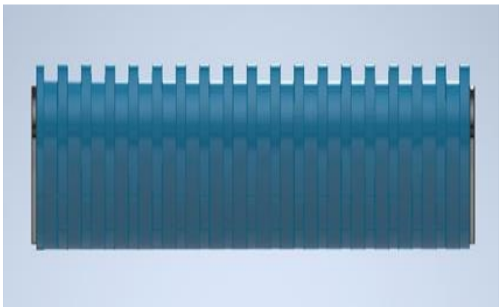


Figure 13. Straight configuration

Şekil 13. *Düz form*

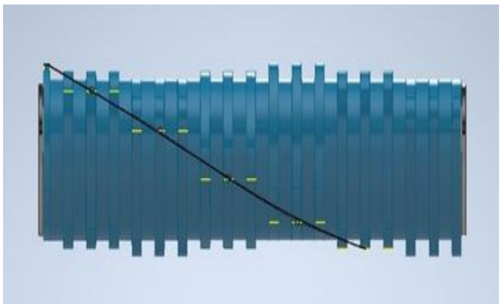


Figure 14. Cross configuration

Şekil 14. *Çapraz form*

For future work study can be done on comparison of simulation results with site tests. Effects of interaction coefficients could also be studied for different types of particles.

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