Determination of the Natural Frequency Change of the Screw Conveyor Carried the Different Bayburt Stone (Tüfit) Dimensions

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Abstract

The mechanism that carries the powder or tiny granular particles with the rotational movement of the spiral shaft is called the screw conveyor. The working principle of screw conveyors is transporting dust particles due to rotating the screw shaft placed in a cylindrical pipe with engine power. The transport process transfers the powder particles to the conveyor from the feed pipe at the top of the mechanism to the wings (helix) of the helix shaft. In this study, a scaled prototype of the screw conveyor was produced. Different Bayburt stone (Tüfit) sizes were transported utilizing the prototype, and changes in the natural frequency of the screw conveyor were measured during particle transportation. The natural frequency value of the fine particles of Bayburt stone is determined as the lowest (15.67 Hz), and the natural frequency value is determined as high in the coarse particles (20.32 Hz). This is expected for this test, which is an example of forced vibration. The increase in the weight of the particles with increasing volumetric size also causes an increase in the external force values they create. The increase in mass value and the change in dynamic loads increased the natural frequency value for forced vibration. It has been observed that the natural frequency values increase in the range of 10-15 percent with the increase in particle sizes from fine to coarse. As a result, it has been determined that the size of the particles carried on the conveyor is important in determining the natural frequency of the system.

Keywords: Bayburt stone (Tüfit), Screw conveyor, Natural frequency

Farklı Bayburt Taşı (Tüfit) Boyutlarını Taşıyan Helezonun Doğal Frekans Değişiminin Belirlenmesi

Öz

Helezon milin dönme hareketi ile tozu veya çok küçük tanecikli partikülleri taşıyan mekanizmaya helezon konveyör denir. Helezon konveyörlerin çalışma prensibi silindirik bir boru içerisine yerleştirilmiş helezon milin motor gücü ile dönmesi sayesinde toz partiküllerinin taşınmasıdır. Taşıma işlemi toz taneciklerini mekanizmanın tepesindeki besleme borusundan konveyöre helezon milinin kanatlarına (heliks) aktarılması ile olmaktadır. Bu çalışmada vidalı konveyörün ölçekli bir prototipi üretilmiştir. Prototip kullanılarak farklı boyutlardaki Bayburt taşı (Tüfit) taşınmış ve taşıma sırasındaki doğal frekans değişimleri ölçülmüştür. Bayburt taşının ince partiküllerin de doğal frekans değeri en düşük belirlenirken (15.67 Hz), kaba partiküllerde ise doğal frekans değeri yüksek belirlenmektedir (20.32 Hz). Bu durum zorlanmış titreşimin bir örneği olan bu ölçüm için beklenen bir durumdur. Hacimsel boyutu artan partiküllerin ağırlıklarının da artmasıyla beraber meydana getirdikleri dış kuvvet değerleri de artmaktadır.

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Kütle değerindeki artış ve dinamik yüklerdeki değişim doğal frekans değerini artırmıştır. Partikül boyutlarının inceden kalına doğru artmasıyla beraber doğal frekans değerleri de yüzde 10-15 aralığında arttığı gözlemlenmiştir. Sonuç olarak, konveyörde taşınan parçacıkların boyutlarının sistemin doğal frekans değerini belirlemede önemi olduğu belirlenmiştir.

Anahtar Kelimeler: Bayburt taşı (Tüfit), Helezon konveyör, Doğal frekans

1. Introduction

Screw conveyors were used in feed and grain transportation in the 18th century. In particular, screw conveyors are preferred in the industry due to their advantages, such as high-efficiency transport of dust and small particles, material transfer at high temperatures, and compact structure [1]. In the literature, there are studies on the design of screw conveyors, their theoretical approach, power and design calculations, and their usage areas. Minglani et al. [2] conducted a literature review on the production stages, usage areas, and theoretical calculations of screw conveyors. They stated that the basic screw conveyors involve the helix shaft, the tank structure where the product is transferred, the product feeding, and output hoppers. In their work, they shaped the basic screw conveyor mechanism (Figure 1).

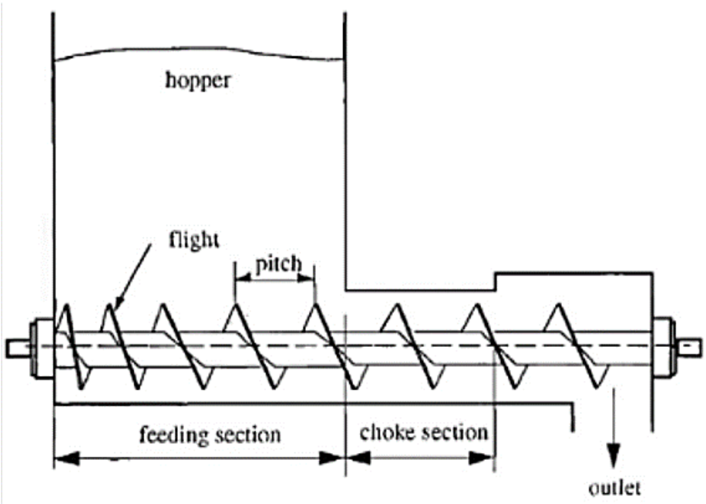

Figure 1. Screw conveyors mechanism [2]

In the theoretical study, the volumetric efficiency of the screw conveyor is given as follows [2];

$$Q = \Gamma \omega D^3 \eta_v$$
$$\Gamma = \frac{1}{8}\left[\left(1+2\frac{C}{D}\right)^2 - \left(\frac{D_i}{D}\right)^2\right]\left[\frac{p}{D} - \frac{t_s}{D}\right] \tag{1}$$

where, D is the diameter of the screw, D_i is the diameter of the shaft, p is the screw pitch, ω is the angular velocity of the screw (rad/s), C is the radial clearance, t_s is the screw blade thickness and η_v is the volumetric efficiency. Production of a prototype that works with high efficiency for the perfect transport of stone particles is the main goal of this study. Therefore, the screw diameter, screw pitch, and shaft diameter values in Equation 1 were tried to be determined in a way that would give the highest efficiency value (See Figure 2). It should be stated that different studies exist in the literature with the theoretical approaches of screw conveyors [3-4]. Unlusoy and Kocaman [5] examined the usage areas, working principles, and project calculations of screw conveyors. In addition, they classified the materials that can be used in the screw conveyor, considering the factors such as density, stance angle, corrosivity, and abrasion. Bolat and Boğaçlu [6] conducted a parametric study that would theoretically increase the volumetric efficiency (capacity) of the screw conveyor given Equation 1 in their study.

Screw conveyors are subject to mechanical vibrations in accordance with their working principles. The vibration occurs on the conveyor mechanism both during product feeding and the transportation of the product with the movement of the screw shaft. It is known that determining the vibration frequencies is extremely important in terms of the safe operation of the conveyor mechanism. Erdlez and Nemeth [7] investigated the determination of the vibration transport rate of granular materials in a screw conveyor. The calculation was made by creating a mathematical model. In conclusion, the systematic analysis of vibration makes it possible to differentiate between the excitatory and excited systems, investigate each separately, and elaborate a synthesized design method based on the results obtained. Saeki et al. [8] investigated the material flow in the vibrating screw conveyor by experimental and analytical methods. The movements of the particles in the conveyor were examined with the discrete element method. They showed that the average movement speed of the particles depends on the frequency and amplitude values of the frequency. Other studies with mechanical vibration affecting screw conveyors [9-12] can also be examined.

In this study, the vibration on the screw conveyor will be determined experimentally. First, a Prototype design will be created by taking the screw conveyors used in the sector as a reference. Then, the prototype production of the screw conveyor will be realized with certain scaling. In addition, the power generation of the prototype will be provided by lithium batteries to create the novelty of this study.

One of the essential novelties brought by the screw conveyor mechanism with lithium battery is to reduce the weight of the mechanism. The system is more portable. The mechanism can be operated anywhere without electricity with rechargeable lithium batteries. It also provides significant advantages in terms of energy consumption. In addition, similar screw conveyors in the literature are generally produced using AC/DC motors or speed-regulating motors [13-15]. In this study, it has been shown that screw conveyors can be produced using different power sources. Subsequently, different sizes of Bayburt stones will be transmitted from the screw conveyor mechanism, and the resulting vibration frequencies will be determined.

2. Material and Methods

2.1 Creation of solid model and prototype

In the scope of this study, firstly, the creation of the three-dimensional design of the screw conveyor is included. The screw conveyor was formed at 1:20 scaled dimensions of those used in the sector. The technical drawing of the mechanism designed for the prototype is shown in Figure 2.

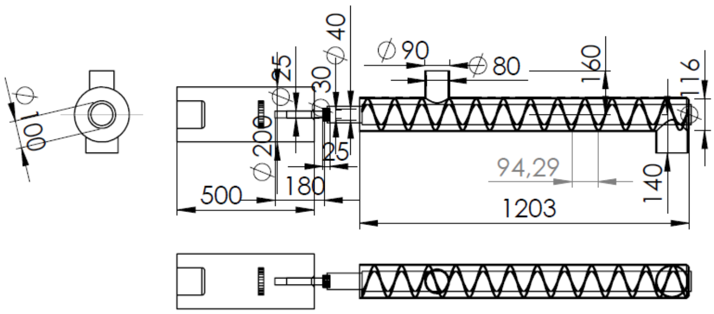

Figure 2. Technical drawing of screw conveyor prototype (Dimensions are in millimeters)

After the design dimensions were determined, the three-dimensional drawing and assembly of the design were carried out in the SolidWorks computer-aided design software before proceeding to the prototype production. The parts that make up the screw conveyor were modeled separately. Then, the assembly process was performed by associating them with each other. The purpose of the three-dimensional design is to observe the contact points during the prototype production stages and determine the assembly sequence. The part and assembly images created in the three-dimensional drawing program of the design are shown in Figure 3.

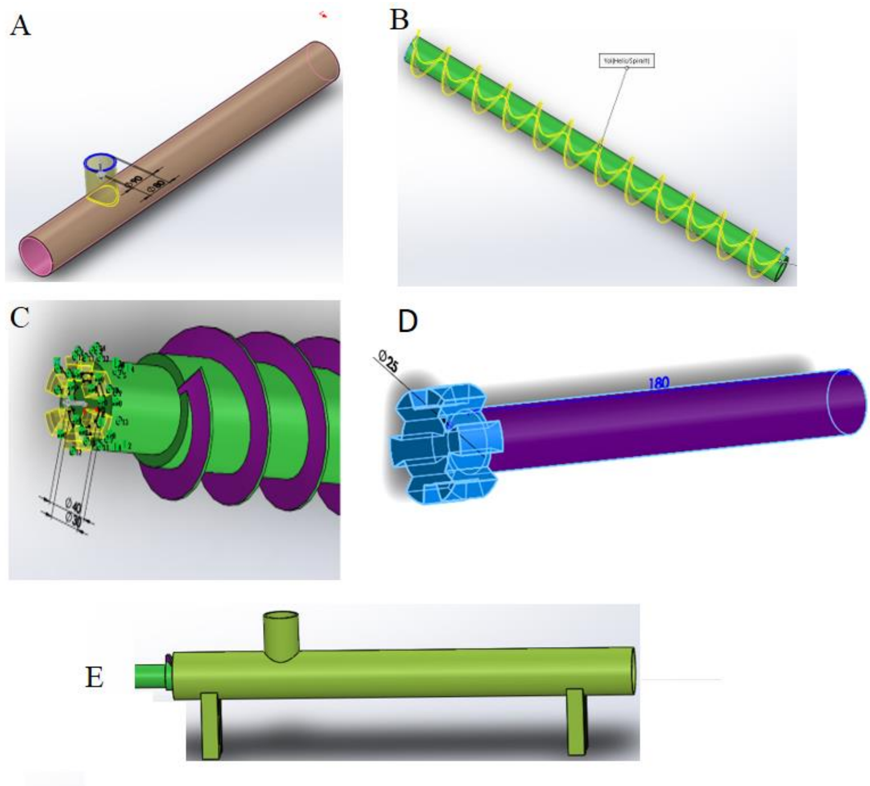

Figure 3. Three-dimensional design of the screw conveyor prototype

The design of the screw conveyor prototype, which was completed and scaled, was produced. Production was carried out using turning, milling, welding and drilling operations in the laboratories of Bayburt University Mechanical Engineering Department. In addition, plastic pipes, elbows, couplings, pipe clamps, bearings and steel materials were used as prototype materials. All materials were obtained from the industrial zone in Bayburt. In this case, it is an important factor that reduces the production cost. In the production phase of the prototype, firstly, the plastic pipe forming the main body of the screw conveyor was welded to the sleeve with a pipe welding machine (Figure A). A DC motor is connected to the prototype, providing the conveyor work and transmitting the product. The motor used is a 12V and 18000 rpm DC motor. It should be declared that a 12 mm diameter drill bit was used as the helix shaft. The spiral shaft is placed in the plastic pipe, and the end of the shaft is connected to the motor (Figure B). The operation of the motor is provided by lithium batteries. The electric ends of the motor are connected to lithium batteries, and the device is worked with a switch. The main reason for using lithium batteries is that the screw conveyor mechanisms equipped with lithium batteries enable the product to be transported with low energy consumption. After the central body scaffolding was finished, metal clamps were placed on the prototype to increase the connection points' strength (Figure D). After the balance of the system was achieved, the product chamber was mounted on the upper part of the conveyor (Figure C). Eventually, the painting was done, and the prototype was produced (Figure E). Production stages are shown in Figure 4.

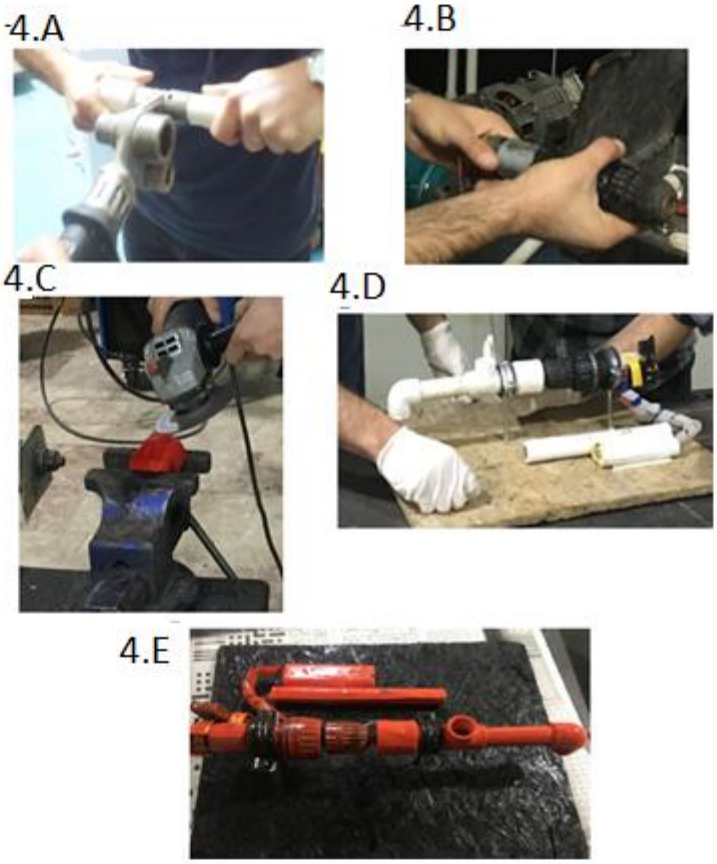

Figure.4 Prototype production stages

2.2 Material and operating prototype

Bayburt stone (Tüfit) was chosen to transport the material on the screw conveyor. Bayburt stone is a yellow-colored stone with low hardness, and fine-grained structure found in our region [16]. The physical and mechanical properties of Bayburt stone are shown in Table 1.

Table 1. Physical and mechanical properties of Bayburt stone [16]

Properties	Bayburt stone
Density (kg/m^3)	23.34
Porosity (%)	23
Weight loss after solidification (%)	3.03
Strength (MPa)	72.6

Bayburt stones were grind to micron levels to maintain the stone from passing through the screw conveyor easily. This process was implemented in the building laboratories in the Department of Civil Engineering at Bayburt University. The dust formed after the breaking process was removed by using a sieve. Fine (60 microns low), medium (closer to 60 microns), and coarse (greater than 60 microns) Bayburt stones were passed through the spiral conveyor system separately, and vibrations of the screw conveyor were measured. The breaking process of the Bayburt stone is shown in Figure 5.

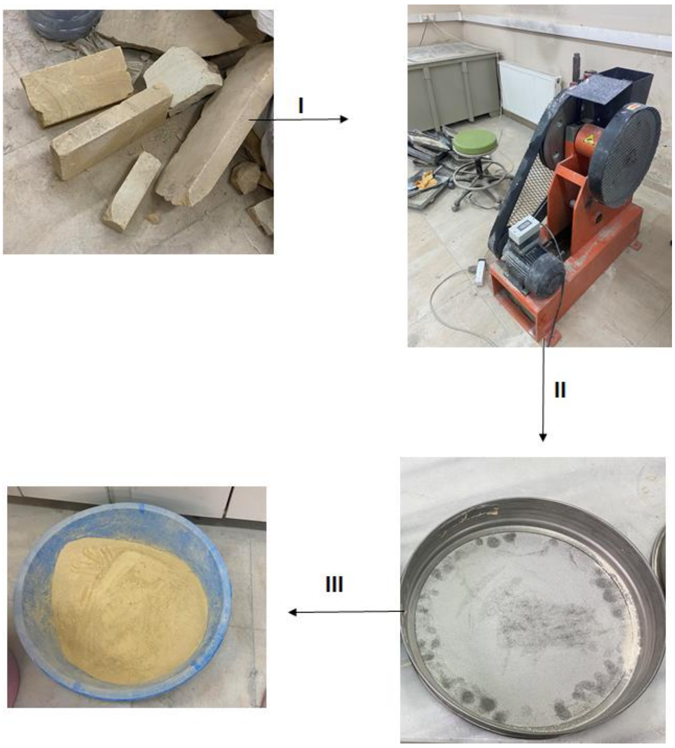

Figure.5 Grinding process steps of Bayburt stone

As shown in Figure 5, Bayburt stones, which are rigid but not in a certain geometry, were broken at the micron level in the grinding device. It should be noted here that the stones were subjected to a preliminary crushing in the chamber located above the grinding device. After the grinding process, the stone particles were passed over a sieve to purify them from dust and other environmental factors. Finally, Bayburt stone at the desired micron level was obtained.

Before measuring the vibration frequencies that occur during the transmission of Bayburt stones, the prototype operation was tested. The system was started by charging lithium batteries. The video image of the operation of the system can be watched by clicking the relevant link. (https://youtube.com/shorts/AMOqy8o3ZVU?feature=share)

3-Results and Disscussion

Natural frequencies were determined utilizing the device that has ±2G value, 500 hz sampling rate, 20-bit sensitivity, single-channel, data storage, and data conversion feature with Arduino software. During the transportation of the particles through the screw conveyor, data was collected in 65 seconds in total. The measurement process was first carried out for the empty state of the prototype without carrying any product. Then, sands of different sizes were passed over the prototype, and natural frequencies were taken.

Natural frequencies were determined with Power Spectral Density-frequency graphs using the vibration data obtained by the accelerometer placed on the prototype. A Power Spectral Density (PSD) measures the power content of the signal versus frequency. A PSD is typically used to characterize random broadband signals. The amplitude of the PSD is normalized with the spectral resolution used to digitize the signal [17]. The graphs obtained at the end of the test are shown in Figure 6-9**.**

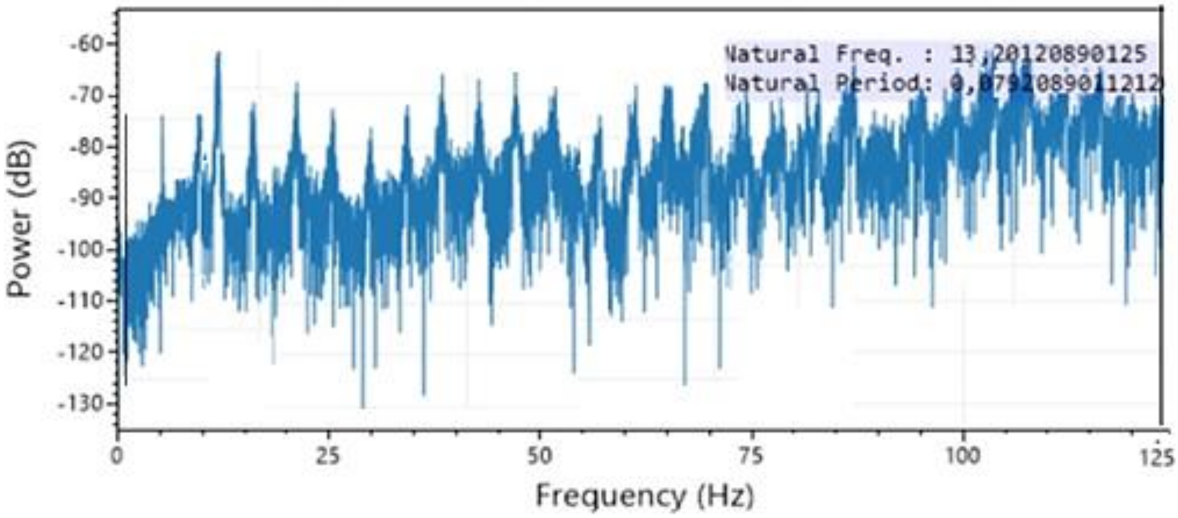

Figure 6. PSD-frequency plot of prototype in empty state

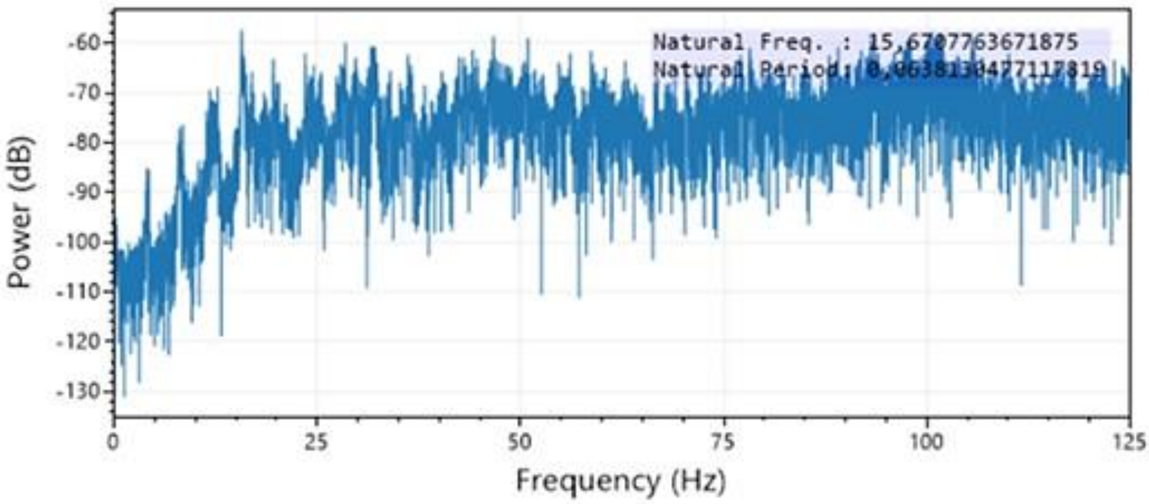

Figure 7. PSD-frequency plot of the prototype in the transmission state of the fine stone

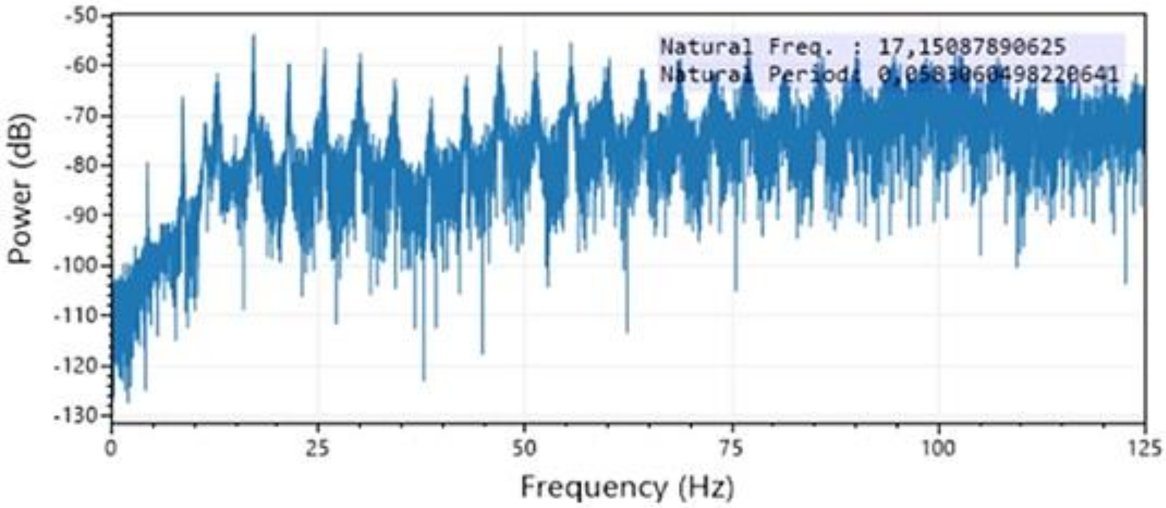

Figure 8. PSD-frequency plot of the prototype in the transmission state of the medium stone

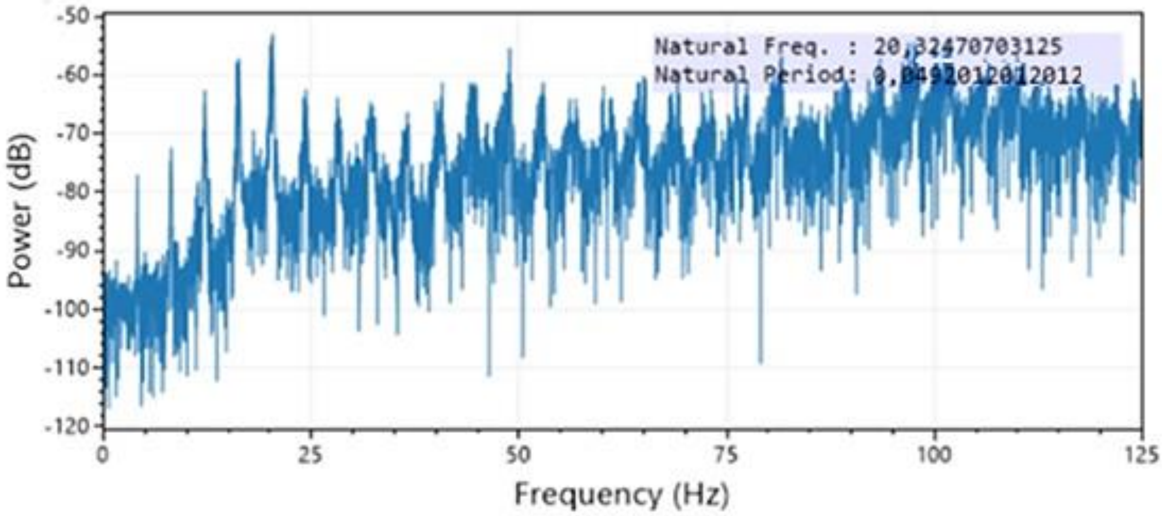

Figure 9. PSD-frequency plot of the prototype in the transmission state of the coarse stone

It should be stated here that the PSD diagrams obtained in Figure 6-9 were compared with the diagram obtained by vibration analysis of the screw conveyor mechanism in the literature, and it was observed that it showed similar vibration behaviors [18]. As shown in Figure 6-9, as the particle size increases, the natural frequency also increases. The increase in the weight of the particles with increasing volumetric size also causes an increase in the external force values they create. The increase in mass value and the change in dynamic loads increased the natural frequency value for forced vibration. As a result, it has been determined that the size of the particles carried on the conveyor is important in determining the natural frequency of the system. The natural frequencies rise from the fine particle to the coarse particle, as seen in Table 2.

Table 2. Effect of particle size change on natural frequencies

Particle size carried in the screw conveyor	Natural frequencies (Hz)
Without particle	13.2
Fine	15.67
Medium	17.15
Coarse	20.32

As seen in Table 2, the natural frequencies increase in the range of 10-15% from the empty state of the prototype to the state where the coarse stone sample is transported. The natural frequency value of the fine particles of Bayburt stone is determined as the lowest (15.67 Hz), and the natural frequency value is determined as high in the coarse particles (20.32 Hz). This is expected for this test, which is an example of forced vibration. It is observed that the dimensions of the particles carried on the screw conveyors affect the natural frequencies. It should be stated here that determining the natural frequency variation is crucial for evaluating the resonance situation where the amplitude goes to infinity and large deformations occur.

4- Conclusion

In this study, the natural frequency varies that occur during the transport of different Bayburt Stone (Tüfit) sizes on the screw conveyor was investigated. A certain scale screw conveyor prototype was created. The results obtained after the study can be explained as follows;

- Product transport was carried out with the screw conveyor, produced in certain scales. It has been shown that very small products can be transported on screw conveyors.
- It has been observed that the different sizes of Bayburt stone (Tuffite) transported on the screw conveyors change the natural frequencies of the device. It can be said that the natural frequency increases with increasing particle size due to the change in dynamic loads.
- It has been shown that different micron sizes of stone particles affect the natural frequency of the screw conveyor. The dimensions, density, and mass of all materials carried on the screw conveyor must be considered when determining the natural frequency value of the conveyor.

Author Contributions

The authors did not declare any contribution

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