Vibratory bowl feeder with elliptical oscillation is quiet and fast

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Abstract:

Vibratory bowl feeders driven by unbalance motors are used in many forges for the automatic feeding of billets in forging lines. The Czech company ROBOTERM has developed a vibratory bowl feeder that fundamentally improves the characteristics of previous vibration technology. The patented elliptical oscillation technology increases the feeding speed compared to straight oscillation, reduces noise, reduces wear on the feeding track and extends the service up to several times over.

1 Introduction

In order to automate a forging line the automatic feeding of billets which are normally stored loose in transport containers must first be solved. Vibratory bowl feeders (Fig. 1), step conveyors or robots with machine vision (bin picking) are used for this purpose. Vibratory bowl feeders offer many advantages over their alternatives, in particular simplicity, mechanical robustness and the ability to feed a wide range of billet shapes and sizes [1].

In many forging lines the vibratory bowl feeders replace manual work and ensure reliable and quiet feeding. However, besides completely problem-free applications there are also known cases in practice where the feeder does not reach the required feeding speed under certain conditions or has an extremely high noise level. The disadvantages of vibratory bowl feeders also include the limited service life of the spiral track which is subject to wear. Repairing a worn track is usually time-consuming and requires longer downtimes of the production line.

ROBOTERM, a Czech manufacturer of induction heaters, produced the first vibratory bowl feeder in 1984 and over the past 40 years of its development has introduced many innovations that have eliminated its weaknesses. The latest innovation is the introduction of elliptical oscillation which fundamentally improves the properties of vibratory bowl feeders. The advantages of the elliptical oscillation have been proven by independent research [2, 3], tests in ROBOTERM [4] and operation in practice. The patented technology has already been used in several Czech and one German forge.

Fig. 1 - Vibratory bowl feeder for automatic feeding of billets into forging lines

2 The principle of the vibratory bowl feeder

The design of vibratory conveyors and feeders varies greatly depending on the application, which can be horizontal or vertical conveying, sorting, screening, orienting and feeding, and the machine can handle parts of various shapes and sizes or bulk material of various grain sizes. A shared feature is a resiliently mounted body with a conveyor track that can be linear (vibratory conveyors and sorters) or helical (bowl feeders, spiral elevators). Different types of drive are used to excite the oscillation. Vibration machines can operate at resonance (excitation frequency is the same as the natural frequency), above resonance (excitation frequency is higher) or exceptionally below resonance (excitation frequency is lower). Depending on the magnitude of the vertical acceleration of the oscillations two basic principles of vibratory conveying are distinguished: the micro-jump principle, in which the gravitational acceleration is exceeded and the material bounces, and the sliding principle, in which the gravitational acceleration is not exceeded and the material only slides along the track.

The ROBOTERM vibratory bowl feeders for feeding billets into induction heaters operate above resonance and are designed for the sliding principle. The billets are filled into a spring supported bowl with a spiral track running along its inner wall. Two unbalance motors (electric motors with an unbalanced rotor that excites vibrations) are attached to the bowl. The unbalance motors synchronize spontaneously when switched on so that the components of the exciting force acting radially to the vertical axis of the bowl cancel each other out. The vertical and torsional components of the forces excite vertical and torsional oscillation of the bowl.

The oscillation of the vibratory bowl feeder is characterized by its shape, amplitude and frequency. The frequency of the vibration is determined by the speed of the unbalance motor. For example a six-pole asynchronous unbalance motor has an excitation frequency of 16.67 Hz at a supply frequency of 50 Hz and synchronous speed of 1000 rpm. The amplitude of the oscillation is mainly determined by the unbalance of the unbalance motor which is usually adjustable. The shape of the oscillation is mainly determined by the position of the unbalance motors [5]. The amplitude and shape of the oscillation are also influenced by factors that bring the bowl closer to resonance of the vertical and torsional oscillations. These factors include the speed of the unbalance motors, the weight of the filling and the stiffness of the springs which in the case of rubber springs can be influenced by their temperature and age.

The amplitude and frequency determine the acceleration of the oscillation. The horizontal and vertical components of the acceleration can be used to calculate the inertial and frictional forces that determine the nature of the material movement. At low accelerations the material lies on the track and does not move. When the inertial forces exceed the frictional force the material begins to move along the track. If the vertical component of the acceleration exceeds the gravitational acceleration the material starts to jump. Jumping of the billets is undesirable as it is accompanied by a strong noise development. To prevent jumping the speed and unbalance of the unbalance motors must not be too high. This limits the feeding speed.

3 Excitation of elliptical oscillation

If the unbalance motors are positioned as shown in Fig. 2 the vertical excitation force and the torsional excitation torque are in the same phase. As a result the spiral track oscillates along the helix and a straight oblique oscillation can be observed on the bowl. The inclination of the unbalance motor determines the inclination of the oscillation and is commonly optimized in practice in order to achieve better transport properties.

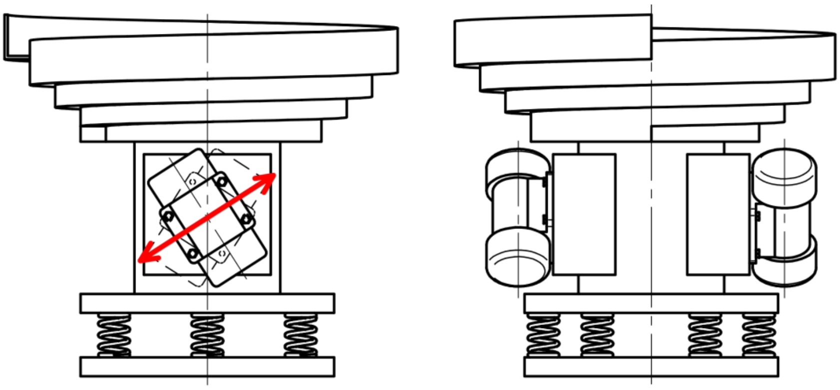

Fig. 2 – Vibratory bowl feeder with linear oscillation

The linear oscillation is only a special case of the general harmonic oscillation. If the vertical and torsional oscillations are phase shifted the result is an elliptical oscillation. An elliptical oscillation can be defined by three variables: amplitude, inclination and ellipticity. The ellipticity of the oscillation is another parameter that can be optimized. The excitation of the elliptical oscillation occurs when the axes of the unbalance motors have a non-zero angle with the plane perpendicular to the line connecting the centers of the unbalance motors [5]. This position of the unbalance motors can be achieved by tilting them as shown in Fig. 3 or by moving them as shown in Fig. 4. The relative positions of the unbalance motors in Fig. 3 and Fig. 4 are equivalent. The excitation of the elliptical oscillation by tilting the motors can also be applied to linear vibratory conveyors which are used in many areas of industry. The excitation of the elliptical oscillation by moving the motors is advantageous for already manufactured vibratory bowl feeders as it can be carried out without complex structural changes.

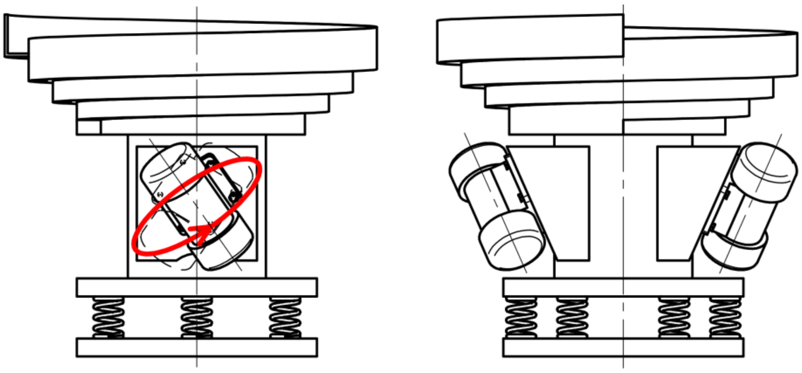

Fig. 3 – Vibratory bowl feeder with tilted unbalance motors

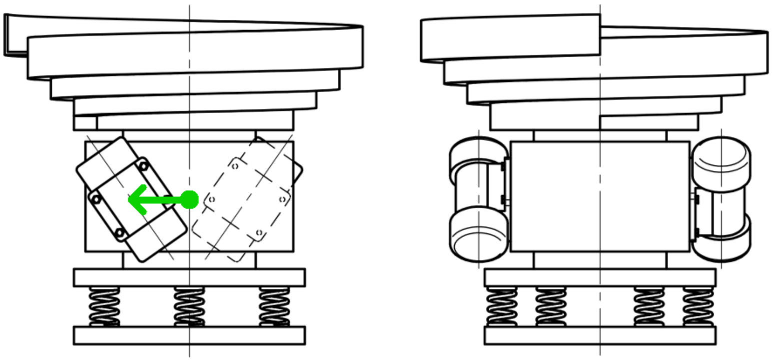

Fig. 4 – Vibratory bowl feeder with displaced unbalance motors

4 Increasing the feeding speed

The feeding speed may be strongly influenced by friction and by the shape of the conveyed billets. Based on a mathematical model, experiments and observations of linearly oscillating vibratory bowl feeders it was determined that in the sliding principle of vibratory conveying on a rising track the friction between the material and the track has a major influence on the feeding speed and in critical cases determines the direction of the material movement. Conveyed material with low friction moves more slowly. Especially if the surface of the billets is greasy or wet an undesirable backward movement can be observed. It is also observed that higher speeds are achieved with long billets that lie well on the track. Lower speeds are achieved with billets with a small length/diameter ratio or barrel-shaped billets that can wobble and swing. This means that longer rusty billets are favorable for feeding while short smooth billets can be problematic to feed.

However this does not apply to elliptical oscillation where high feeding speeds can be achieved even with reduced friction. At ROBOTERM, measurements were carried out on the VZ 1800 bowl feeder in order to evaluate the influence of the oscillation ellipticity on the feeding speed. Two positions of the unbalance motor with different displacements as shown in Fig. 4 were tested. For each position both directions of rotation of the unbalance motors and thus both directions of the elliptical oscillation were measured. Changing the direction of rotation has the same effect as moving the unbalance motors to the other side or tilting the unbalance motors to the opposite angle. A total of four variants of the elliptical oscillation were therefore tested. The vertical amplitude and thus the vertical acceleration were always the same. The feeding speed of different billets was measured for each variant. The results of the measurements are shown in Fig. 5. The displacement of the unbalance motors indicated on the horizontal axis corresponds to the oscillation shape shown below the axis.

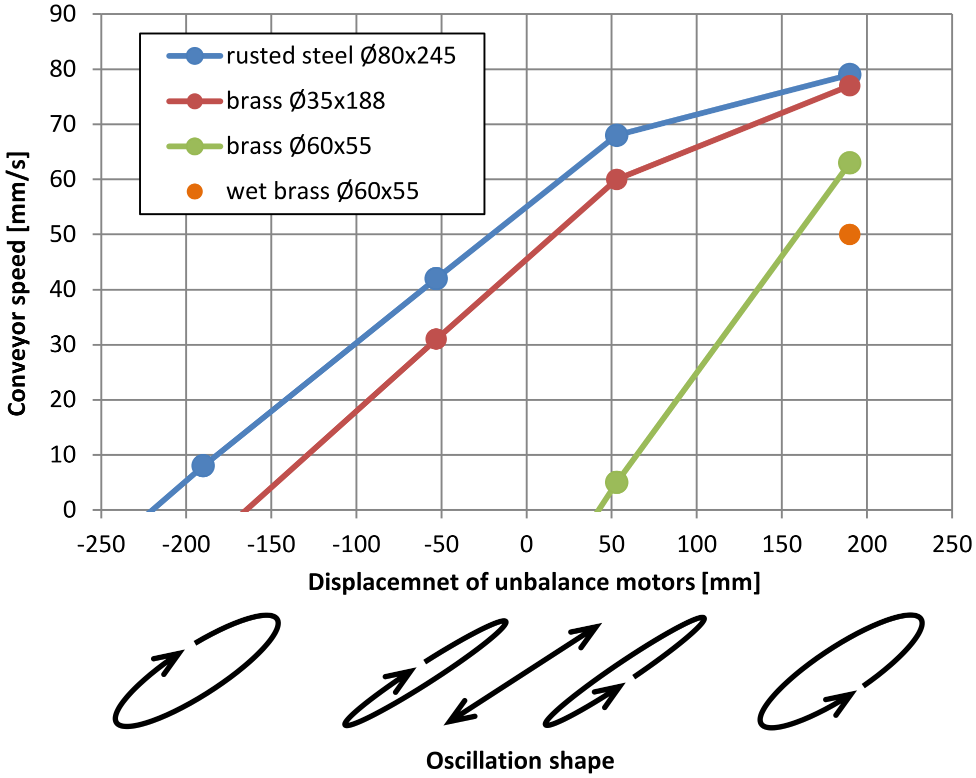

Fig. 5 - Dependence of the feeding speed of different billets on the ellipticity of the oscillation

Measurements have shown that an elliptical oscillation in the right direction significantly increases the feeding speed. With the elliptical oscillation high speeds were also achieved with low-friction materials that do not move forward with linear oscillation. In critical cases the ellipticity of the vibration is crucial for the reliable feeding. Brass billets with a diameter of 60 mm and a length of 55 mm are very unfavorable for feeding as they have a low length/diameter ratio and tend to wobble and swing. With straight oscillation they could not be fed successfully. With elliptical oscillation high feeding speeds were achieved even in wet conditions.

Measurements have shown that even a slight ellipticity of the oscillation caused by a 50 mm displacement of the unbalance motor improves the feeding characteristics. The speed and efficiency of the vibratory conveying can be further increased by optimizing the oscillation ellipticity and angle, as demonstrated by mathematical models and research works [2] and [3] that deal with the optimization of the oscillator shape.

5 Noise reduction

Problems with insufficient feeding speed in linearly oscillating vibratory bowl feeders were often solved by increasing the unbalance or the speed of the unbalance motors which led to exceeding the gravity acceleration, jumping of billets and excessive noise above the pain threshold of 100 dB. The dependence of the noise level of the VZ 1800 vibratory bowl feeder on the vertical component of the acceleration is shown in Fig. 6. The vibratory bowl feeder with elliptical oscillation achieves the required feeding speed with lower acceleration than feeder with linear oscillation, so it can be operated with less unbalance and lower speed of the unbalance motor. This can significantly reduce the noise emission.

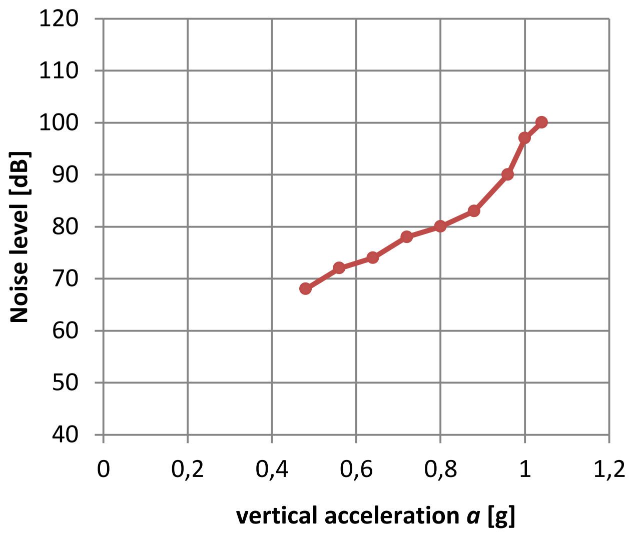

Fig. 6 - Dependence of noise level of the VZ 1800 on the vertical acceleration component

6 Extending the service life

Due to the higher feeding speed the elliptical oscillation conveys the same amount of material with a smaller number of oscillations, i.e. with fewer dynamic load cycles, thus extending the lifetime of the entire vibratory bowl feeder. The effect of the elliptical oscillation on the wear of the track was calculated in a mathematical model that assumes a direct proportionality between frictional losses and wear. The wear of the feeding track was compared when conveying the same amount of material with linear and elliptical oscillation with a 10° tilt of the unbalance motors. With a friction coefficient of 0.3 a 1.6-fold extension of the track life was calculated and with a friction coefficient of 0.2 it was 3.3-fold extension of the life.

The elliptical oscillation also extends the service life of the other parts of the feeder. The vibrating body of the conveyor is a weldment that is exposed to high dynamic stresses and suffers from material fatigue. Fatigue cracks can lead to unexpected downtime. The bearings of the unbalance motors are subjected to high stresses due to the centrifugal force of the unbalanced rotor. The elliptical oscillation makes it possible to shorten the operating time or to operate the vibratory bowl feeder with lower acceleration. In both cases the dynamic stresses on the entire vibratory feeder and its surroundings are reduced.

7 Consumption reduction

According to the mathematical model, the elliptical oscillation reduces friction losses and depending on the friction can be many times more effective than linear oscillation. Assuming that the power consumption is proportional to the frictional losses as well as the wear of the track, the efficiency will increase and the power consumption will decrease in the same proportion as the lifetime is extended. If frictional losses contribute significantly to the total energy consumption, elliptical oscillation could yield interesting energy savings for vibratory feeders with large conveying capacity.

8 Conclusion

The newly developed solution of the elliptically vibrating bowl feeder fundamentally improves the properties of vibration technology and expands application possibilities of the sliding principle in vibratory conveying. The elliptical oscillation makes it possible to completely eliminate the problems of insufficient feeding speed and high noise levels. Elliptical oscillation can increase production capacity where it is currently limited by the vibratory feeder. In cases where the performance of the vibratory feeder with straight oscillation is sufficient elliptical vibration enables operation with less noise and less dynamic stress. According to the mathematical model, the elliptical oscillation reduces frictional losses up to several times and increases the efficiency of vibratory conveying. Although the influence of the oscillation ellipticity on the wear of the track is not yet confirmed by measurements, the lower frictional losses and the smaller number of oscillations required to transport the same amount of material suggest significantly lower wear and longer life of the conveyor track. The elliptical oscillation also enables the design of the spiral track with a steeper slope which results in smaller dimensions and lower production costs of the feeder.

A major advantage of the invention is that it is based on a simple change in the position of the unbalance motors and can therefore be applied to various types of newly designed and already manufactured vibratory feeders without requiring significant changes or increasing production costs. The risks resulting from a minor design change to a proven product, such as a 10° tilting of the unbalance motors, are minimal as the basic design parameters of the vibratory machine remain unchanged. Vibratory bowl feeders or spiral elevators driven by unbalance motors have a wide range of applications and are often an essential element of production automation. Thanks to its ease of use the invention can contribute to higher productivity, lower costs and a smaller environmental footprint in many areas of industry.

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