Parts Feeding and Materials Handling

Electromagnetic Vibratory Feeders
Introduction

The use of vibration is often used in industry for the efficient conveying and distributing of materials, with high throughput rates of up to several tonnes per hour, the minimum number of moving parts and requiring very low maintenance. It can also be applied to automatic machinery for sorting, orientating and feeding components.

Before the 1990’s the main method used for controlling a vibratory feeder was to vary the input voltage to an electromagnet by using a variable transformer and all other customisation was achieved by time-consuming and labour-intensive methods. Thankfully, the introduction of electronics means that much of the costly, skilled work involved in tuning and testing has been reduced significantly. There is now much more flexibility and ease of inter-connection that can be achieved by using electronic controllers. Perhaps, more importantly with improved electronic technology it is now possible to feed some materials that previously were problematic.

The REOVIB range comprises a comprehensive selection of electronic controllers that have been specially developed for use with vibratory feeders. These can be grouped into two broad categories; phase-angle controllers which use thyristors and frequency controllers using insulated gate bipolar transistors (IGBTs). Phase-angle controllers are used with electromagnets that operate at mains frequency (or twice mains frequency as will be explained later) whilst frequency controllers can be used with magnets that are designed to run at a frequency that is typically between 8 and 300 Hz.

The majority of phase-angle controllers use a front-panel potentiometer for amplitude (throughput) adjustment and are equipped with basic control functions such as remote enable, amplitude-range scaling, voltage stabilisation and soft-starting. However, all frequency controllers and some phase-angle units (collectively called digital controllers) use a microprocessor system for controlling firing pulses and the spare capacity of the microprocessor can be used to run displays, provide fault-finding diagnostics and to store settings. For more sophisticated applications they can provide closed-loop control, whereby the amplitude is monitored and regulated by fitting an accelerometer to the moving part of the feed unit. They can also provide interfacing with computers and PLCs for remote enable and set-point control as well as status monitoring. A large number of controllers can be co-ordinated in a process by using a field bus communication network. Electronic power controllers can be designed so that they always operate safely despite harmful, external fault conditions such as short-circuits or overloads.

REOVIB controllers are designed and built by REO ELEKTRONIK AG based in Solingen, Germany. Together with their sister company REO INDUCTIVE COMPONENTS AG they are able to supply a complete vibratory drive package including the electro-magnets. For the customer this provides the assurance that both key parts of the vibratory system have been tested for complete compatibility and for conformance with relevant standards. Through joint collaboration the two companies have developed a range of unique products for the food, hardware, automation and weighing industries.
The vibratory feeder and electro-magnet

The basic elements remain the same whatever the type of electro-magnetic feeder. Vibrating motion is achieved by using an electro-magnet which is energised with AC or DC half-wave electricity. The coil of the magnet (3) is attached to the base of the feeder (4) and the armature (6) is fitted to the feed tray (1) or bowl (8), which has to be vibrated. The vibrating part is supported from the base by springs (2) which are usually constructed from laminated strips of fibre-glass or steel.

The electro-magnet comprises two elements – the coil (3), which is wound onto high-quality, laminated, electrical-steel, core (5) and an armature (6) which is also made from laminated electrical-steel. The grain-oriented, electrical steel is used to reduce losses and to give a good power to size ratio. On REO magnets the coils are encapsulated for a number of good reasons, such as ensuring a rigid construction, holding the coils firmly in position, protecting against shock hazards and providing a high degree of ingress protection (IP or NEMA rating). In conjunction with nickel plating on the core and armature the encapsulation is a good solution for food quality applications. Also the power cable (7) has an armoured screen for conformance with various safety requirements and this also serves to limit radiated EMC emissions.

As the voltage is increased across the coil so the magnet attracts the armature and pulls the tray downwards. After reaching a peak the voltage decreases so the pull of the magnet reduces and the kinetic energy in the springs return the tray to its rest or equilibrium position. Because of the mass and inertia of the tray it shoots past the equilibrium position and travels as far as the springs will allow it to. The springs will then start pulling the tray back to its equilibrium position again, gradually assisted by the increasing voltage on the coil and the resultant magnetic force of attraction. When the tray reaches the equilibrium point the cycle starts all over again and this repeats at a frequency determined by the applied AC voltage.

It is very important to have a correctly rated magnet. The air-gap, frequency and maximum current are particularly important. Operating the magnet at an incorrect frequency, which is too low, can cause the magnet to overheat. If the frequency of the magnet does not approximate that of the natural frequency of the vibrating system then an excessive current will be drawn and it is very likely that the feeder will not vibrate or will lack power.

The air-gap is the clearance between the magnet and armature when the feed system is in the equilibrium (static) position. This is normally only 1 or 2mm on feeders which operate at mains frequency (50Hz) or above, however it can be up to 12mm on feeders which operate at lower frequencies, say below 15Hz. The air-gap can be set by using a feeler gauge and adjusting the magnet and armature, which often have mounting slots for this purpose, until the setting is correct.
Phase – angle control

Fixed frequency controllers use triacs or thyristors to adjust the amount of power delivered to the electro-magnet and this determines the feed-rate. The technique used is called phase-angle control and employs the ability of the power semiconductor to switch on current when its gate is energised and to automatically switch off again when the current flowing through it falls to zero. Control electronics are used to determine the point on the mains sine wave when a firing pulse is made and to control the amount of current flow by adjusting the timing of each successive pulse.

Whilst phase-angle control is very widely used for general purpose applications it does have a number of limitations. For instance the feeder must be tuned to match that of the mains supply frequency (or twice mains frequency as will be explained later). Therefore tuning a feeder is a skilled operation and can be quite time consuming. It can be seen from the previous diagrams that the waveform is saw-toothed and this causes audible noise which is often amplified by the feeder tray or bowl. Audible noise is cumulative and so when there are several feeders working together the noise-levels can reach a critical level or even exceed those prescribed by health and safety legislation. Therefore if noise levels or tuning are problematic a frequency controller would be more suitable.

The following diagrams are schematic only and are provided to explain the main operating principals of a phase-angle controller.

Diagram (1) shows the trace of the sine-wave created by the mains supply voltage.

Diagram (2) is the output current wave form for a low vibration amplitude setting and the switch-on point (phase-angle) is towards the end of each mains half-cycle. The semiconductor ceases to conduct current after the zero point is crossed.

Diagram (3) shows a smaller phase-angle setting and a longer conduction time, resulting in higher vibrating amplitude.

Diagram (4) represents full conduction with zero phase-angle and so the effective voltage will be almost as high as the mains supply voltage and so maximum vibrating amplitude will be achieved.

An electro-magnet does not differentiate between a negative half or a positive half sine-wave; in either case the coil is energised and attracts the armature. This phenomenon can be used to good effect because by switching one half of the sine-wave only (5), the vibrating frequency is the same as the mains supply frequency (50 or 60Hz); whereas by switching both halves of the sine-wave (6) the vibrating frequency is twice that of the mains supply frequency (100 or 120Hz) – hence the terms half- and full-wave are used. Full-wave control is used when very fine feeding at low amplitude is required, whereas the half-wave control is more applicable to high feed rates and a coarser feeding action.

A selection of phase-angle controllers produced by REO ELEKTRONIK AG
Switched-mode

By using high-speed switching semiconductors such as insulated gate bipolar resistors (IGBT’s) it is possible to switch a DC voltage source on and off with a varying length of on-time for pulses (called pulse width modulation). The technique is known as switched-mode and is widely used in variable-speed drives for motors. When an inductive load such as a magnet is connected to the output of a switched-mode inverter it is possible to derive a current waveform that can be almost sinusoidal, depending on the pulse pattern. This can be used to good effect on electro-magnetic vibratory feeders because it provides a means of varying the power level and the vibrating frequency.

The diagrams on the left are schematic only and are provided to explain the main operating principles of a switched-mode frequency inverter.

Diagram (1) shows the switched DC pulses and in this case the pulse times are relatively short so the resulting effective voltage is fairly low and hence the magnet current sine-wave is low hence the feeder amplitude will also be low.

Diagram (2) shows how by increasing the duration of the pulses it is possible to increase the magnet current and hence the amplitude.

Diagram (3) shows how the pulse lengths are controlled to increase the amplitude of the current sine-wave even more and so increase the throughput of the feed system.

Finally diagram (4) shows how the pulse lengths can be timed in such a way that they can control frequency as well. Hence it is possible to have a variable frequency output that can be changed very quickly, when required.

Variable frequency control offers many advantages:

1) Irrespective of the mechanical frequency of an electro-magnetic feeder it can be used any part of the world without retuning – whether the mains supply is 50Hz or 60Hz the output frequency from the controller will remain the same. This eliminates the need for a generator to test on a supply frequency which is different from the local mains frequency, or a change of spring-packs (larger for a higher frequency or smaller for a lower frequency).

2) The controller frequency can be set to match that of the vibratory feeder which deskills the job of tuning and saves time, especially if the feeder has to be continually retuned to compensate for tooling changes.

3) It is possible to run at much lower frequencies and broadens the scope of applications. For example small sachets of sugar or spices will not feed at 50Hz because their flat surfaces create too much air resistance to allow transportation. However, by running at a lower frequency, say 30Hz, feeding becomes possible. The same applies to all light and flat components.

4) The feeder can be driven at its natural frequency – there is a separate section dedicated to this later on.

5) A feeder which consumes current with a sine-wave form runs much quieter than one which uses phase-angle control, with its characteristic saw-tooth wave-form.

A selection of frequency controllers produced by REO ELEKTRONIK AG
Track control

Often with combined feed systems it is necessary to have a continuous queue of components at a point of presentation, e.g. so that a part is always ready for picking up by a pick and place mechanism or ready to drop into a presented carton. This can be achieved by using a linear feeder which is fed from a bowl feeder for instance.

A sensor is used to regulate the flow of product; it stops the previous feeder from running and overfilling the linear feed track and ensures that the track never runs low. Various types of sensors can be used for the purpose, including through-beam, reflective and proximity types. Apart from mechanical switching systems all of these require a power supply which is provided in a number of REOVIB controllers designed just for this purpose.

To prevent false triggering of the sensor the REOVIB units also have built-in timers which delay the switch-off and -on times. This also provides a certain amount of control over the length of the product queue or buffer.

The diagram on the right shows the operating sequence when track control is used.

1) The proximity sensor detects that components are continuously present and an OFF signal is sent to the controller but the feeder continues to run until a time delay $t_{off}$ has expired.

2) The supply feeder stops feeding after the time delay has expired.

3) The proximity sensor detects that product is continuously absent and an ON signal is sent to the controller but the supply feeder does not run again until a time delay $t_{on}$ has expired.

4) The supply feeder starts feeding again after the time delay $t_{on}$ has expired.

A selection of units incorporating track-control produced by REO ELEKTRONIK AG
Closed loop control

Often it is advantageous to operate a vibratory feeder with a closed-loop control because this gives a much greater degree of stability irrespective of changing conditions such as variations in load, mains supply fluctuations or mechanical differences due to temperature or wear. To achieve this, an accelerometer is fitted firmly to the tray or bowl to measure the acceleration (g) in the direction of movement. The acceleration in g is converted by an electronic circuit within the sensor so that the output is a smoothed DC signal that can be easily used by a comparator within the controller.

Typical accelerometers produced by REO ELEKTRONIK AG

Constant Amplitude Control

When a vibratory feeder is used to convey a heavy product and the product level is high, then the voltage to the feeder has to be increased to cause the product to move. However as the product level drops, the applied power remains the same and so the feed rate of product speeds up.

This problem can be solved by using a controller which has a closed-loop function and a sensor which is fitted to the feed-tray and with sensing orientation in the direction of motion. The sensor measures the acceleration (g) of the tray and maintains this at a constant level by adjusting the voltage. In this way the feed rate is held constant irrespective of the product level or the weight of product carried by the feeder.

Automatic Frequency Control

REOVIB frequency controllers incorporate automatic frequency control (AFC) which means that the feeder does not have to be designed and tuned to run precisely at a given frequency. The controllers have an automatic frequency search function (AFS) which is used in conjunction with an accelerometer (closed-loop control) to find the resonant frequency of a vibrating system. Furthermore, by using automatic frequency control (AFC) the frequency can be continuously adjusted so that the system always runs at resonance, irrespective of the mains supply frequency. The resonant frequency is important because if you try to force a feeder to run at a frequency other than resonance then excessive current will be drawn by the magnet. Therefore the masses, dimensions and springs of a vibrating system have to be carefully designed to ensure that it oscillates at the required frequency.

Conversely, if a vibratory feeder can be run at resonance then it becomes very efficient, the smallest amount of driving force and current is required. Conveyors can be made much smaller if they run at resonance and a considerable amount of energy is saved. Unfortunately, product can have a damping effect on a feeder which reduces the frequency of the system and whilst it might operate at resonance when it is empty, it can go off-tune when it is loaded. For this reason vibratory feeders are often over-tuned so that when they are loaded with product the natural frequency drops to that of mains frequency.

Even if a feeder is tuned manually using the methods described above, it is unlikely to remain at resonance due to changing mechanical or load conditions. An increasing depth of product in a feed tray will cause damping and the resonant frequency to be lower, therefore for optimum and consistent feeding closed-loop control should be used.
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