Technical Report

Springs

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Oscillating relay tattoo machines consist of a frame, two electromagnetic coils, an armature bar, and two springs. The springs are attached to the armature bar, one spring at the front, the other at the back. The contact point is on the front spring. The back spring mounts the armature bar to the machine frame.

The electromagnets pull the armature bar down, opening the contact points, which interrupts the circuit, turning off the magnets. The back spring then returns the contact to the closed position, once again turning on the electromagnets and repeating the cycle.

One complete cycle includes the duration of time the armature bar travels towards the magnets and back up to the closing of the contact, as well as the complete time the contact point remains closed, until the moment the contact point opens again. One cycle is referred to as an oscillation. The frequency or speed of a machine is measured in oscillations per second.

The distance of travel of the armature bar during one oscillation is measured as the length of stroke of the machine.

The amount of time the contact remains closed, in comparison to the amount of time the contact remains open is measured as a percentage. The measurement of the closed contact time is referred to as the duty cycle of the machine. If the open and closed contact times were equal, the measurement would be 50% of the time closed.

Of all the components of a tattoo machine, the springs are the most important. Tests have been conducted that prove the front spring establishes the speed at which a machine will run, and that the back spring, secondarily, determines the efficiency of the front spring.

The desired speed of a machine is dictated by the application and style of tattooing. The exact speed will differ from tattooer to tattooer, but it is generally recognized that a liner will run faster than a shader. To be used effectively for tattooing, the machine must be fine tuned to work synchronistically with the needle configuration, as well as the tattooer’s hand motion. Line work requires that the machine runs quickly enough that the tattooer can draw a line, and the punctures of the configuration are close enough to read as a clean dense line. Efficient coloring requires that the punctures of the configuration are uniform in spacing. If a machine runs too quickly, or the needles in the configuration are too closely spaced, the skin will be overworked. If a machine runs too slowly, or the needles in a configuration are too widely spaced, the colour will not be solid.

The ability to adjust machines that have inefficient or incorrect spring combinations to the point of making the machine run usably well, has always been dependent on being able to perceive the open and closed contact time, as well as the speed of the machine. The limitations of available spring gauges, and lack of proper meters to read frequency and duty cycle have necessitated this talent, and raised certain individuals in the trade to near mythological status as machine experts and keepers of secrets. Most of these people did this intuitively, with only a vague comprehension of the mechanical principles involved, so their secret keeping was more a matter of ignorance than self-servitude.

The Tests

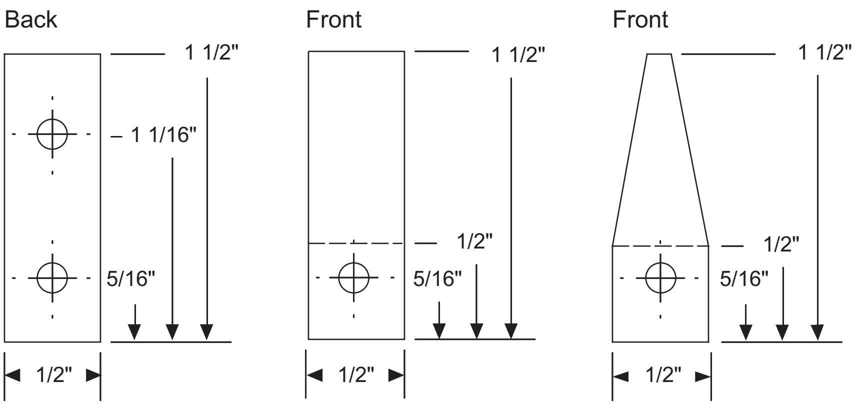
To conduct the tests, springs were made of twelve different gauges of carbon steel feeler gauge stock, from 0.013” to 0.024”. The springs were identical in design, one made of each gauge of feeler gauge stock to ensure the only variation from spring to spring was the hardness, due to the gauge of the stock.

The back springs were 1/2” wide. As each back spring was installed, the mounting bend was adjusted to give 4mm of bottom gap.

The front springs were 1/2” wide. One complete set were tapered from the bend to the contact point. One complete set were 1/2” wide, with no taper. All the bends in the front spring were set at 15°.

All tests were conducted on the same machine frame, with the same electromagnetic coils. One variable voltage power supply, manufactured as a prototype by Eikon Device Inc., was used for all tests. The speed of the machine was measured using a multimeter capable of measuring frequency. The duty cycle of the machine was initially measured using an oscilloscope and later measured using a prototype meter manufactured by Eikon Device Inc.

Test Springs



In the first test, the machine frame was set up with the thinnest gauge back spring, and the thinnest gauge tapered front spring. The contact point gap and the voltage were adjusted until the machine ran as well as possible. The point gap, voltage and frequency were recorded. This was repeated with each of the tapered front springs. The next gauge of back spring was then installed and all the possible front springs were installed, adjusted, and the results recorded. A total of fifty combinations of springs were tested. Spring combinations that were too extreme would not run efficiently. Thin gauge back springs would not work in conjunction with the heavier gauge front springs, and the heavy gauge back springs would not work in conjunction with the thin gauge front springs. This established that certain spring combinations are more efficient than others. In all cases the hardest front springs resulted in the fastest running machine.

The second test was conducted using spring combinations from the initial test that were most efficient. In this series of tests the stroke was measured and recorded showing that as speed increases, length of stroke decreases.

A third test was conducted using the twelve front springs that were not tapered. Results of this test were not recorded as it was not possible to obtain efficient operation of the machine with untapered front springs.

Certain spring combinations had been established as producing a machine that runs efficiently. An oscilloscope was used to identify the duty cycle of the machine. In all cases the measured duty cycle of these spring combinations was from 50% to 60%. Spring combinations that had previously been established as inefficient produced a duty cycle higher than 60% or lower than 50%. This proved that the measurement of duty cycle is a means of obtaining correct spring combinations.

Tests were then conducted to examine the functioning of the machine at various duty cycles. The results of the tests indicated that maximum efficiency of the machine was obtained at a duty cycle of 55%.

A test was required to determine the significance of the angle of the front spring. Four gauges of front springs were chosen with corresponding back springs to achieve a duty cycle of approximately 55%. The test showed that as the angle of the front spring increases, the speed of the machine decreases. Proving that a decrease in mounting angle of the front spring is equivalent to an increase of spring gauge.

Further tests were conducted to measure the effect of the variables of back spring pressure. The bottom gap was set at 4mm. The machine was adjusted and the results recorded. The bottom gap was then set at 3mm, the machine adjusted and results recorded. This test was re-done with a back spring one gauge thinner. The results showed that reduction in bottom gap was equivalent to reduction of gauge of springstock. Tests were conducted using narrower and wider gauge spring stock at a set bottom gap. The results proved that a reduction in width was equivalent to a reduction of gauge in spring stock.

Application

The duty cycle, and frequency of a tattoo machine are affected by, and can be adjusted by four main factors:

1. The contact point gap.
2. The amount of magnetism created by the electromagnets.

3. The hardness of the front spring.
4. The hardness of the back spring.

The Contact Point Gap

The simplest and most obvious adjustment that can be made to a tattoo machine is the adjustment of the contact point. The contact is adjustable to fine tune the gap size of the contact point. Although measurable as a distance, this adjustment is a time relation, not a distance relation adjustment. The duration of time that the contact remains open is controlled by the size of the gap. This time adjustment is made to produce a balance between the time the contact remains open, and the time the contact remains closed.

When the open contact time is increased, the result is a longer distance of travel of the armature bar. The open contact time is the length of time it takes the armature bar to travel from closed contact until it hits the front coil and back to closed contact. This distance is measured as length of stroke. When the length of stroke is decreased, the oscillations per second increase. When the length of stroke is increased, the oscillations per second decrease.

The contact point determines the distance of travel of the armature bar, and fine tunes, in a time relation, the open contact time.

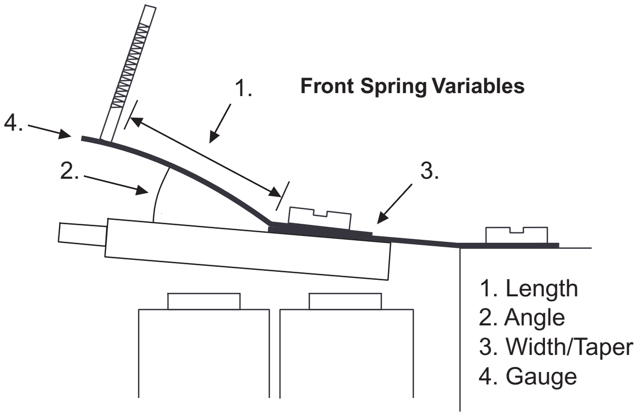
The Electromagnets

The amount of magnetic force created by the coils is a direct result of the amount of voltage running through the electromagnets. More voltage creates more magnetism. The efficiency of the coils is not relevant to how a tattoo machine runs. Some coils require more voltage than others to create the same amount of magnetism.

The Front Spring

The front spring must be chosen to establish the speed of the machine based on the open and closed contact time.The hardness of the front spring determines closed duration. A hard front spring will only stay closed for a short duration of time. To extend the closed contact time, a softer front spring must be used. The softness results in contact, then flexing, then unflexing, and finally opening of the contact. With a longer closed contact time, a balance is created by opening the contact gap, creating a longer open contact time, resulting in a slower running machine. A harder front spring gives a short closed contact time, which will be balanced by a short open time, which will result in a faster running machine.

This can be effected most simply by changing the gauge of the spring stock. Heavier gauge results in a harder spring. The length of the spring also determines its hardness, a shorter spring is less flexible. The angle that the spring is mounted to the armature bar determines hardness as well. A flatter spring is less flexible. Therefore, a front spring mounted at a 10° angle to the armature bar will be harder than a spring of the same length and gauge that is mounted at a 20°angle to the armature bar. These two factors; spring length and mounting angle are the principles at work in running a liner in a “cut-back” style. Both factors increase front spring hardness, thereby shortening contact closed time, and making the machine run faster. The width of the spring also affects spring hardness. A wider spring will be harder. Most front springs are cut so that the width of the spring is less at the contact point than it is at the point that mounts to the armature bar. This taper results in the spring being more flexible at the contact point, where it is narrower. This acts as a buffer, softening the opening and closing of the contact points.



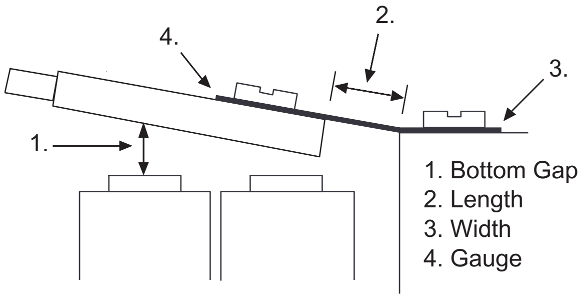
The Back Spring

The amount of pressure the back spring exerts on the front spring and contact point is controlled by four factors:

a) the bottom gap of the armature bar.
b) the length of the spring.
c) the width of the spring.
d) the gauge of the spring.

The back spring connects the armature bar to the frame. The angle that the spring is mounted to the frame establishes the amount of force, or lift, the back spring exerts on the front spring. This can only be measured by the distance between the front coil, and the bottom of the armature bar when there is no front spring on the machine. The greater the distance, the more pressure the back spring exerts on the front spring and contact point. There must be sufficient force applied to the front spring to

Back Spring Variables



make it work efficiently. The width of the back spring also determines hardness. A wider spring will be harder than a narrow one of the same gauge. The simplest method of changing the hardness of the back spring is to change the gauge of the spring. A heavier gauge results in a harder spring. The distance from the frame of the machine to the armature bar is the length of the back spring. A longer spring will be softer, or more flexible than a shorter spring. On most machine frames this is not an easily adjusted distance because the needle bar must run down the center of the tube. There is generally not much adjustability of back spring length.

To achieve a balance between the front and back spring, the springs and the armature bar should be considered as one component. The front spring establishes the speed that the machine will run, and the back spring determines the efficiency of the front spring. The action of one spring will be balanced by the other spring, the result being measurable as a correct duty cycle. A low duty cycle reading indicates that the contact closed time is short, in relation to the contact open time. This can be rectified by increasing back spring pressure using one of the four back spring variables. A high duty cycle reading would be corrected by decreasing the back spring pressure or hardness.

Test #1

Front Spring (in)	Back Spring (in)	Point Gap (mm)	Voltage	Frequency (Hz)	Front Spring (in)	Back Spring (in)	Point Gap (mm)	Voltage	Frequency (Hz)
0.013	0.013	2.5	6.45	87	0.018	0.017	1.0	4.4	120
	0.015	3.0	6.5	92		0.018	1.8	4.5	123
0.014	0.014	2.0	4.8	91		0.019	0.7	4.7	125
	0.016	2.4	5.6	96		0.020	1.7	6.6	130
0.015	0.014	1.5	4.9	97	0.019	0.018	0.75	3.6	129
	0.015	1.2	4.4	101		0.019	0.7	4.6	134
	0.016	2.0	5.2	103		0.020	1.8	6.8	137
0.016	0.015	1.3	4.0	106	0.020	0.019	0.8	5.2	143
	0.016	2.0	5.0	104		0.020	1.3	7.1	148
	0.017	2.0	4.8	109	0.021	0.019	0.9	5.3	147
0.017	0.016	1.5	4.7	117		0.020	1.5	609	150
	0.017	1.0	506	122	0.022	0.019	0.9	4.8	153
	0.018	0.9	4.4	122		0.020	0.6	4.9	158

Duty Cycle Test

Hold Duty Cycle - 50%				Hold Duty Cycle - 55%				Hold Duty Cycle - 60%			
Point Gap (mm)	**Stroke (mm)**	**Voltage**	**Frequency (Hz)**	**Point Gap (mm)**	**Stroke (mm)**	**Voltage**	**Frequency (Hz)**	**Point Gap (mm)**	**Stroke (mm)**	**Voltage**	**Frequency (Hz)**
2.2	9	6.0	112	2	9	6.0	118	1.5	8	6.0	121.5
2.4	10	6.5	112.5	2.3	9.5	6.5	119	1.5	8	6.5	124
2.5	10	7.0	109	2.5	10	7.0	119	1.6	8	7.0	124
2.6	10	7.5	112	2.5	10	7.5	120	1.7	9	7.5	121
2.7	10	8.0	114	2.5	10	8.0	121	1.7	9	8.0	120
2.8	10	8.5	115	2.5	10	8.5	122	1.7	9	8.5	120
3.0	10	9	114	2.6	10	9.0	122	2.0	9	9.0	117.5
3.2	10	9.5	115	2.7	10	9.5	122	2.0	9	9.5	118
3.3	10	10	116	2.8	10	10	122.5	2.2	9	10.0	119
3.5	10	10.5	116	2.8	10	10.5	123				
3.6	10	11.0	116	2.9	10	11.0	124				
				3.0	10	11.5	124				
				3.1	10	12	124				