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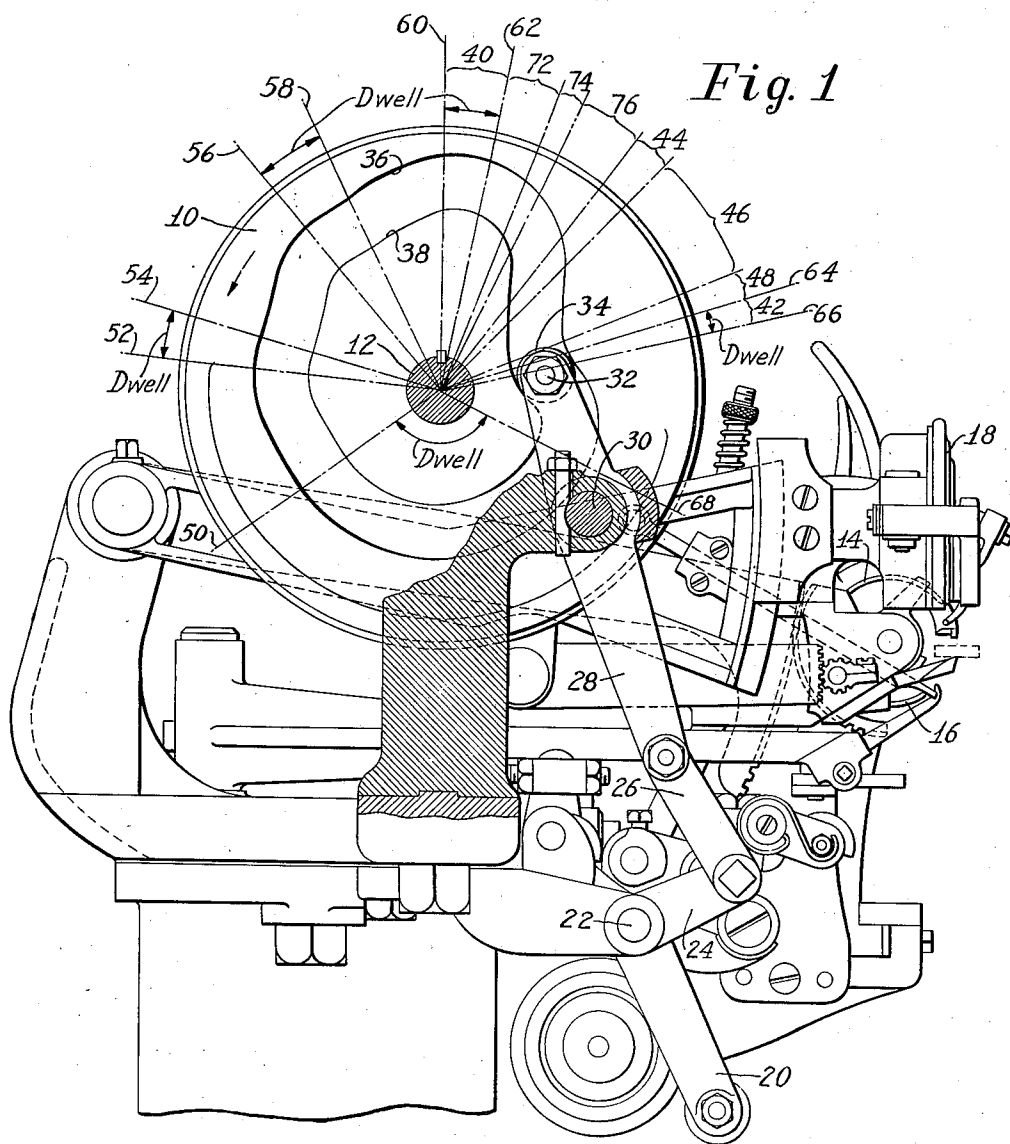
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CAM OPERATED MACHINE

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CAM OPERATED MACHINE

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2 Claims. (Cl. 74—53)

The present invention relates to machines operated by slotted or grooved cams and is herein illustrated as applied to a lockstitch outsole shoe sewing machine of the type described in the patent to French and Meyer No. 412,703.

The object of the invention is to provide new and improved slot-forms for actuating cams in a machine of the class referred to by means of which the machine will operate more quietly, at a higher speed, and more reliably than heretofore.

In any machine operated by an open type of cam having a spring pressed follower, impact during movement of the cam may be produced by too sudden a change in the velocity of movement imparted to the follower by the cam. The impact between the follower and the cam increases with the square of the change in velocity, so that difficulty of this nature is directly reduced by lowering the speed at which the machine is operated. It is the usual practise, in order to increase the speed of machines operated by such cams, to modify the form of the cam so that the follower will start and stop more gradually, the inertia of the follower being more slowly overcome.

In any machine operated by the closed or slotted type of cam, in which the follower is guided without being yieldingly forced against either side of the slot, a certain amount of lost motion between the parts must be provided to prevent excessive friction. Impact of the follower against the slot sides of a closed cam may be produced by a number of causes in addition to starting or stopping the follower movement too suddenly. Speed of rotation of a closed cam may not be a direct factor in effecting sudden change in velocity of the operated parts as the follower shifts its pressure of engagement from one side of the cam slot to the other, but impact may take place with considerable force even below speeds at which a machine equipped with an open cam of the same form may operate with relatively no noise. The causes of impact in a closed cam may also change while the machine is operating so that even though the cam slot is of a shape which is advantageous for one set of operating conditions, it will be ineffective in preventing undesirable impact under other normal conditions of machine operation.

Accordingly, the present invention contemplates the provision in a sewing or similar type of machine, in which an actuating cam is provided with a continuous slot for guiding a follower, each individual movement of which has such

a character that the degree of impact caused as the follower shifts between engagement of the slot sides will occur with certainty along a predetermined portion of the cam where the impact will be maintained below a predetermined minimum limit with changes in speed of operation, friction in the machine, and amount of work performed by the machine.

Other features of the invention consist of certain novel and improved constructions and arrangements of parts, hereinafter described and particularly pointed out in the claims, the advantages of which will be readily understood by those skilled in the art.

In the accompanying drawings, Figure 1 is a view in side elevation with certain parts broken away and shown in section, of a sewing machine equipped with cams embodying the features of the present invention, and Figure 2 is a diagrammatic illustration of the form of cam slot movement employed in the machine shown in Figure 1.

The machine illustrated in Figure 1 of the drawings is a lockstitch outsole shoe sewing machine of a type more fully described in the patent above referred to, and comprises operated parts and a series of cams, one of which is indicated at 10, keyed to a cam shaft 12 rotatably mounted in the machine. The operated parts include a curved hook needle 14, a curved awl 16, a shuttle 18, a take-up 20 and other stitch forming and work feeding devices. The operated parts are moved through individual cycles of operation in proper timed relation to form a seam in the work, the movement of each part being controlled by suitable continuous cam slots formed in the cams.

As an example of one set of operated parts, the take-up 20 is illustrated as being in the form of an arm fixed to a shaft 22 rotatable in a bearing on the frame of the machine. The take-up shaft 22 is oscillated by an arm 24 secured to one end of the shaft and connected by means of a link 26 to one arm of a cam operated lever 28 journaled on a fixed stud 30. The other arm of the lever 28 carries a short shaft 32 on which is rotatably mounted a cam follower roll 34 positioned between the sides 36 and 38 of a cam slot formed in the cam 10. The operated part 20, the arm 24, link 26, lever 28 and the cam follower roll 34 comprise a moving mechanical system having certain physical characteristics of mass, elasticity and friction, the mass being represented by the inertia of the parts according to their manner of movement. The degree of impact in the moving system, due to change in velocity of the follower at any point in the rotation of the cam 10 for a

given speed of the shaft 12, is proportional to the mass of the moving system, but impact from this cause may be reduced, as previously explained, by simply reducing the acceleration of the follower at the beginning and end of its movement.

Another cause of impact in the mechanical system results from clearance between the sides of the slot and the follower 34, and in the bearings and connections of the mechanical system. Due to this clearance, a certain amount of lost motion is possible, permitting a momentary departure in velocity of the operated parts from that velocity prescribed by the shape of the cam slot. During the brief period in which the operated parts move from one limit of their lost motion to the other, they act as a separate mechanical system independently of the cam, according to their individual physical characteristics, and in so doing, may set up a series of more or less sharp impacts which may be increased in intensity along certain parts of the slot, or may cause undesirable oscillations between individual members of the system at unexpected times.

According to the present invention it is possible to so form the cam slot that impact due to the physical characteristics of the mechanical system may be made to occur along one portion only of the cam where the force creating the impact is reduced to a minimum limit.

In a sewing machine, any operated part, such as the take-up 20 and the connecting links between the operated part and actuating cam follower have a certain amount of mass and elasticity which can be measured. The elasticity, together with the mass of the parts, may cause the mechanical system including the parts to oscillate at a fixed frequency. For any elementary unidirectional movement of the cam follower 34 between the cam slot portion 40 and any other portion 42, as indicated diagrammatically in Figure 2, a certain force or pressure is imparted to the follower 34 during the first part of the movement by engagement with one side 36 of the slot, thereafter the force is diminished to zero and sufficient force applied in the opposite direction by the other side 38 of the slot to again bring the follower 34 to rest. The moving force may be diminished progressively almost to zero at a relatively high rate near the time the velocity of the follower in the line of follower movement reaches its maximum value and becomes uniform, at which time the follower may be guided by a portion 44 of the slot somewhere near the middle of its movement. If the moving force is diminished at too high a rate, the elasticity of the moving system will cause a rebound of the follower, characterized by a rapid engagement with alternate sides of the slot. It is, therefore, essential in order to prevent this rebound, that the moving force be diminished only as fast as the mass and elasticity of the moving system will permit the follower 34 to conform with the motion imparted by the cam. The length of time required for diminishing the force along portion 44 is, therefore, chosen to at least equal one half the natural time period of free oscillation of the mechanical system. To increase the factor of safety, this time period may be doubled without adding greatly to the total time required for the entire movement between 40 and 42. For all practical purposes, the amount of mass and elasticity of the operated parts may be assumed to be substantially constant in a machine of the type illustrated and, in any event, not to vary to such an extent as will cause exagger-

ated impact effects under any operating conditions of the machine.

After having reached the end of portion 44 of the slot with the elastic tension of the operated parts and the pressure on the follower nearly relieved, the condition in the mechanical system approaches the point where there is very little pressure of the cam roll 34 against side 36 of the slot and the follower soon thereafter may begin to move away from the side due to the inertia and friction of the moving system. After the follower moves with uniform velocity, the only factors acting to prevent the moving system from continuing to move at uniform velocity, are the decelerating effects of friction inherent in the bearings and pivotal connections of the system, together with the resistance of the work performed. The effect of friction and work resistance thus tends to cause the follower to hug the same side 36 of the slot somewhat beyond the point where uniform velocity is reached. These factors may be grouped together under the head of total friction, but may vary from time to time according to the condition of the bearings and the type of work being performed.

The limits of variation in total friction, can be evaluated and compared with the negative accelerating force of the cam by resolving the frictional forces into equivalent velocity reducing pressures or decelerating effects. The decelerating effects on the cam follower of friction as compared with the velocity reducing pressure or negative accelerating effect of the cam slot for any one particular set of operating conditions in the machine, therefore, determines the point at which the cam follower becomes disengaged from the side 36 of the cam slot. Between the sides of the cam slot, the follower moves along a path corresponding to the path of a body being uniformly decelerated, the rate of deceleration being regulated by friction. The free movement or crossover of the follower requires but a brief period unless the shape of the succeeding cam slot portion 46 is formed exactly to coincide with the follower movement as determined by the particular friction values existing at the time. In case the cam slot portion 46 should be so formed, this shape would coincide with the follower movement for only one speed and for only one value of friction in the machine, any other values of speed or friction acting to cause forcible impact of the follower with side 38 of the slot, which impact would increase proportionately with the departure from said speed and friction value.

In the form of the invention shown, the rate of decrease in pressure on the follower or in negative acceleration produced by the cam slot is abruptly reduced, as indicated at 45 (Fig. 2) between slot portions 44 and 46 from the high rate of decrease along portion 44 to a relatively low rate of decrease, the negative acceleration still being somewhat less than the deceleration due to minimum total friction, so that with the smallest possible amount of total friction in the system, the follower will still be in engagement with side 36 of the cam slot at the beginning of portion 46. Thereafter, as the pressure on the follower is decreased at a low rate, a point will be reached where the negative acceleration equals the deceleration of friction and the pressure on the follower is reduced to zero. The follower will then leave side 36 and engage side 38 of the slot. As the value of total friction in the machine increases under different operating conditions, the follower will remain in engagement with the first side 36 of the slot for a longer

time. By properly extending the length of the slot portion 46 in which the pressure or negative acceleration of the cam slot is reduced at a low rate, the velocity of the follower with respect to the slot, which velocity causes the impact at the end of the cross-over period, may be made substantially less than heretofore considered possible for any range of friction values. The rate of acceleration change between the portions 44 and 46 being made abrupt, as distinguished from being gradual or progressive, insures that the cross-over will occur with certainty only along portion 46 of the slot.

The degree of impact produced by the follower striking the side 38 of the cam slot after the cross-over may also be made substantially uniform throughout a definite range of friction values in the machine, by reducing the pressure or negative acceleration of the slot movement at a uniform rate along slot portion 46. By proportioning the curvatures of slot portion 46 at the beginning to effect a pressure below and at the end to effect a pressure above the decelerating forces of friction in the system, the follower will, therefore, always shift from one side of the slot to the other with uniform impact for any values of friction existing under different normal operating conditions in the particular mechanism.

After the follower has definitely engaged the second side 38 of the cam slot, the rate of velocity decrease or the negative accelerating force of the cam may be gradually reduced along a follower slot portion 48 to a point where it equals the average decelerating effect of friction, after which the negative accelerating effect of the cam slot on the follower may be instantly reduced to zero at the end of the portion 48, in case the succeeding portion 42 of the cam slot is in the form of a dwell. Instead of dropping to zero, other accelerating forces may be imparted to the follower without actually bringing the follower more nearly to rest, since the decelerating effect of friction is substantially equal to any other force imparted to the follower along the portion 42 of the cam slot, and no oscillatory engagement between the slot sides will be produced. The rate at which the negative acceleration of the slot portion 48 may be reduced is limited, as in the cam portion 44, only by the elasticity and mass of the parts.

Briefly, therefore, the present invention consists in first reducing the negative accelerating pressure of the cam slot at a high rate and then abruptly reducing the rate of negative acceleration change, to a relatively low rate at the beginning of the portion 46 of the cam slot after the pressure of the follower on one side of the cam slot is nearly relieved so that the follower will surely cross over from one side 36 of the cam slot to the other 38 along portion 46. The preliminary portion 44 of the slot in advance of portion 46 acts progressively to release substantially the tension in the operated parts, so that the mechanical system moved by the follower will not have set up within itself a series of sustained oscillations to interfere with the actual period of cross-over. By this arrangement, cross-over with a minimum impact may be assured. The only other limitation which may desirably be observed is in maintaining the maximum pressure angle or inclination of the cam slot below a reasonable limit, and preferably below the usual 30 degree angle. With such limitations the shapes of all the cam slots of a sewing machine of the type referred to, may be modified with marked improvement in operation of the machine both as to du-

rability and as to increased speed of operation over that heretofore possible.

A more detailed and specific description of the manner of applying these limitations to the cams in the machine illustrated will now be given.

Referring more particularly to Figure 1, it is apparent that the cam slot is divided into a series of consecutive elementary movements in the direction in which the follower is capable of being actuated, each for the purpose of transferring the follower between positions at different distances from the cam shaft 12. The elementary movements may terminate in dwell portions in which the cam slot is concentric with the shaft 12, or they may terminate more abruptly in portions which cause movement in other directions. Obviously, no motion is imparted to the follower along the dwell portions, so that once movement of the follower has been stopped, no special consideration is required until another movement is begun. The elementary movements of the cam slot are, therefore, selected to the exclusion of the dwell portions, and the cam 10, as shown, is divided roughly into five such elementary movements. These movements are contained between radial lines 50 to 68, inclusive. The parts of the cam slot included within the cam segments 50 to 52, 54 to 56, 58 to 60, 62 to 64, and 66 to 68 comprise the elemental movements of the cam, the remaining parts of the cam slot being dwells. The characteristic shape of each elemental movement, as will be described, is made substantially similar to that of another, all corresponding points of each being made proportional to the extent of movement required and to the time or angular displacement in the cam between the limits of movement. The elementary movement included within the radial lines 62 to 64, is selected as an example of how each movement may be formed, according to the present invention.

The diagrammatic illustration of the characteristic shape to be applied to the movement 62 to 64 is shown in Fig. 2, and is divided into a series of unequal portions by vertical lines 70. The spacings in a vertical direction correspond to the movement in a radial direction on the cam, and the spacings in a horizontal direction represent the relative time or amount of angular rotation required for the movement, the space portions between the vertical lines being so chosen as to substantially separate the times in which different characteristics of the moving mechanical system connected with the follower are effective in reducing the impact along those portions. The portion 40 of the cam slot may be assumed to be a dwell, and the cam follower 34 is illustrated with an exaggerated amount of clearance between the sides 36, 38 of the slot so as to more clearly illustrate the features of the invention.

While the follower 34 is operated upon by the dwell portion 40, it is impossible to determine the relative positions of the follower and the slot sides, so that in starting a given motion, a portion 72 of the slot is formed with a very gradually increasing velocity, and the degree of acceleration, as indicated in the corresponding lower part of Fig. 2, starts from zero and is increased at a low uniform rate. At the end of the slot portion 72, the follower 34 is definitely in engagement with the slot side 36, the total amount of movement within this portion being made greater than the clearance or lost motion of the operated parts, and the maximum acceleration being such as to

reduce to a minimum the impact of the follower against the slot side.

After the follower has definitely engaged the side 36 of the slot, the force of acceleration may be increased more rapidly along a portion 74 until the greatest direct pressure which it is desired to apply to the follower is reached. The increase in acceleration is illustrated as being uniform, but may be made to vary at any desired rate until the end of the portion 74. The length of time required for this movement, however, should be sufficiently long to prevent oscillation of the operated parts, as previously described in connection with portions 44 and 48.

At the end of slot portion 74 there is arranged a portion 76 of uniform acceleration and uniformly increasing velocity terminating at such time as the inclination of the slot approximates the greatest pressure angle which it is desired to employ.

The velocity of the cam during the next portion 44 reaches a maximum as the accelerating force is being rapidly reduced. Until the zero acceleration point is reached, the cam follower remains against the same side 36 of the cam slot that it originally engaged during start of the motion. However, the cam follower will continue in engagement with the side 36 of the slot beyond the point where acceleration of the follower ceases due to the retarding force on the follower of friction in the moving system. The force or pressure against the follower, therefore, may be rapidly reduced slightly beyond the zero point by the slot portion 44 until the spring tension of the parts is substantially relieved.

When the pressure of slot-side 36 against the cam follower is reduced to zero, the follower will begin to leave the slot side 36 and move along an unrestrained path until engagement with the other side 38 occurs. After the portion 44 is terminated, the rate of change in negative acceleration is decreased abruptly so that it increases more slowly along the succeeding slot portion 46. When the point 77 in the portion 46 is reached, where the negative acceleration force of the cam is greater than the minimum decelerating force of friction on the operated system, the follower may begin to cross from one side of the slot to the other. The minimum decelerating force of friction is determined with the bearings cleaned and oiled while no work is being performed.

To cause the follower to surely cross over to the side 38 of the slot negatively accelerated movement produced by the cam portion 46 is increased at the slow rate, above referred to, until a value of negative acceleration force is reached at a point 78 which is greater than any decelerating effect produced by the maximum total friction including full operating load resistance of the mechanical system. With small values of friction, the follower will cross over from side 36 to side 38 just beyond the point 74 and, with large values of friction, the cross-over will take place later. The follower will, therefore, always shift from one side of the slot to the other along the slot portion 46.

The next portion of the cam slot is arranged to reduce the negative acceleration force to zero, and since the motion shown in Figure 2 terminates in a dwell portion 42, the portion 48 is characterized by a negative acceleration decreasing more rapidly than the rate of increase in negative acceleration of the previous slot portion in order to reach the point of zero acceleration quickly. Since the cam follower already has

crossed over and the velocity is being reduced, the rapidity with which the negative acceleration is increased thereafter causes no further shift of pressure from one side of the slot to the other. This rapidly decreasing negative acceleration terminates at a point where the negatively accelerated movement is approximately equal to or greater than the average deceleration produced by friction in the moving system. When this point is reached, the negative acceleration is instantly decreased to zero, and no oscillations or substantial impacts of the follower occur between the slot sides because the amount of energy stored in the moving system is effectively absorbed by the frictional force without impact.

If any other motion is to be imparted to the cam follower directly at the beginning or at the end of the movement just described, in place of the dwell portions 40 or 42, respectively, an adjacent slot portion of the proper shape may be connected directly to the portion 74 or 46 without reducing the negative acceleration entirely to zero, and since the follower is already in engagement with the respective side of the slot, the acceleration may be applied rather abruptly to move the follower in the opposite direction.

By preventing the follower from leaving one side of the cam slot while the acceleration is being reduced to zero at the end of each motion unit, and then by reducing the negative acceleration to a predetermined minimum, the impact between the follower and the slot may be diminished to a point where it is not troublesome for the maximum speed at which the cam shaft is rotated. With the slot proportioned as described, the impact of the follower will not increase with a reduction in speed of the machine, so that the impact may be kept below a predetermined degree at all speeds.

The amount of elasticity or measure of resilience in the moving system may, for all practical purposes, be assumed as constant, since this characteristic does not change with different operating conditions. One limiting value of negative acceleration for each portion 74, 44 and 48 of the cam slot, therefore, will be sufficiently low for any speed of cam rotation below the maximum. However, the friction may change from time to time and with different kinds of the work being operated upon.

In considering the effect on impact of changing values of total friction in the machine, it will be assumed that the intensity of impact is dependent upon the maximum velocity of the follower relatively to the sides of the cam slot as it crosses from one side to the other of the slot. The velocity is also governed by the amount of lost motion in the mechanical system which permits an abrupt change in velocity between the parts. This lost motion may be considered uniform throughout the follower movement, since it is composed of a number of factors which tend to result in a rather definite average.

In order to illustrate the motion of the follower during the time it crosses from one side 36 of the cam slot to the other side 38, the velocity and acceleration curves of Fig. 2 may be referred to. All vertical distances between the cam slot and the zero ordinate 79 represent areas under the curve of velocity, and all vertical distances between the velocity curve and its zero ordinate 80 are equal to areas between the acceleration curve and its zero ordinate 82. This is as a result of constructing these curves in the proportions required by the equations of actual physical

movements of the slot sides in the line of follower movement.

The vertical distance p represents the amount of equivalent lost motion in the mechanical system, indicated for purposes of illustration as being wholly between the follower 34 and the cam slot portion 46 at the point where the follower contacts with the side 38 after having crossed from the side 36 of the slot. It is apparent that this lost motion is substantially uniform throughout portion 46. The cross-over occurs in a period of time t during which the follower moves along a free path m in the form of a parabola, and departs from the curve of the cam slot by the amount p . The distance p is, therefore, equal to the distance after a time t between points along the path of a freely moving body affected only by friction which describes a parabola and along the side of the cam slot in the form of a cubic curve, respectively, from the point of tangency of these curves. The impact is produced by the difference of velocities of the follower and slot side at the end of period t after having travelled the distance p .

The difference between the velocity curve r of the follower and the velocity curve of the cam slot at the end of the time period t is indicated at v and is a measure of the intensity of the impact with which the follower engages the side 38 of the cam slot. The difference of acceleration which causes the difference of velocity v is represented in the acceleration diagram by a , which is the difference in acceleration force, at the end of period t , between the constant decelerating effect f of friction on the follower and the negative acceleration of the cam slot which is made to increase at a uniform rate.

The expression of the distance p vertically between the parabola m and the cubic cam curve after the time period t from their point of tangency takes the form

$$p = \frac{ut^3}{6}$$

Where u is the rate of acceleration change of the cam slot and, correspondingly, the expression of the distance v vertically between the straight line v and the parabolic velocity curve of the cam slot takes the form,

$$v = \frac{ut^2}{2}$$

Substituting v into the expression of p ,

$$p = v \frac{t}{3}$$

But, since v and t , according to the next to last equation, vary together in the same direction, p being a constant because it is known that the lost motion is uniform, there is but one value each for v and t which satisfies the last equation. Therefore, v remains the same at any point along the slot portion 46 and the velocity and impact of crossover for a slot having a cubic curve remain uniform with changing values of friction. The only effect of changing frictional values is to cause the follower to cross from one side to the other of the slot earlier or later along the portion 46, the length of time required by the cross-over period remaining the same.

In the sewing machine cam illustrated, the relative length of time allotted to the cross-over slot portion 46 is the largest in each elementary motion unit. The tension releasing slot portions 52, 44 and 48 are of sufficient length to produce the desired effect as quickly as practical, and the

lengths of the remaining slot portions 50 and 53 are more or less arbitrary and may be increased or decreased to a reasonable extent in providing for more efficient operation of the other portions. It has been found that the relative proportions, as illustrated in Figure 2, between the vertical lines, are effective to provide unusually quiet operation at higher speeds of the machine than heretofore considered possible.

In applying the motion unit of Figure 2 to the various elementary motions required in the machine, the individual portions of each unit are laid off proportionally as angular displacements along the elementary motion of the cam, as shown in Figure 1, and the displacement radially of the cam is adjusted to equal the displacement required by the elementary cam motion, the intermediate points of displacement being proportioned accordingly. In some instances it may not be necessary to apply the motion unit of the invention to all of the elementary motions in the machine, but only to those in which the greatest displacement of the follower takes place, and in those where undesirable impact is definitely located.

The description given above is based upon the presumption that the amount of lost motion in the mechanical system is substantially constant, but in certain cases the amount of lost motion may increase with the movement of the follower. This increase of lost motion, however, may be compensated for along the slot portion 46 by causing the negative acceleration of the cam slot to increase at a non-uniform rate, and in case this change in lost motion may be caused by angular deviation of the slot, the rate of increasing negative acceleration would, as a result, be increased slightly to compensate for the change of lost motion from the inclined part of the slot portion 46 to the dwell portion where the lost motion would be smallest.

The nature and scope of the present invention having been indicated, and a machine embodying the features of the present invention in their preferred form having been specifically described, what is claimed is:

1. A machine of the type described having, in combination, an operated part, a cam follower and connecting links comprising a mechanical system of inherent mass, elasticity and friction, and a cam in the machine having a continuous closed slot in which there are a number of elementary unidirectional movements imparted to the follower loosely engaging the slot as the cam is rotated, at least one of the movements being effected at its beginning by cam slot portions for increasing the velocity of the follower by pressure of one side of the slot, at its end by slot portions for decreasing the velocity of the follower by pressure of the other side of the slot, and between its beginning and end by two successive slot portions in the first of which the initial pressure on the follower decreases progressively at a relatively rapid rate, limited only sufficiently to prevent complete interruption of pressure, in the second of which the pressure decreases at a relatively low rate for a sufficient length of time to cause the pressure on the follower against the first mentioned side of the cam slot to be entirely relieved and transferred to said other side of the slot and between which two portions there is an abrupt change in rate of pressure decrease to insure transfer of follower pressure only along the slot portion of low decreasing pressure rate.

2. A machine of the type described having, in

combination, an operated part, a cam follower and connecting links comprising a mechanical system of inherent mass, elasticity and friction, and a cam in the machine having a continuous
5 closed slot in which there are a number of elementary unidirectional movements imparted to the follower loosely engaging the slot as the cam is rotated, at least one of the movements being effected at its beginning by cam slot portions for
10 increasing the velocity of the follower by pressure of one side of the slot, at its end by slot portions for decreasing the velocity of the follower by pressure of the other side of the slot, and between its beginning and end by two successive slot portions in the first of which the initial pressure

on the follower decreases progressively at a relatively rapid rate, limited only sufficiently to prevent complete interruption of pressure, in the second of which the pressure decreases at a relatively low uniform rate for a sufficient length of
5 time to cause the pressure on the follower against the first mentioned side of the cam slot to be entirely relieved and transferred with uniform impact for all values of friction in the mechanical system to said other side of the slot, and between
10 which two portions there is an abrupt change in rate of pressure decrease to insure transfer of the follower pressure only along the slot portion of low decreasing pressure rate.

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