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Interposer for Disk Printer

In an impact printer which selects characters by having a hammer hit type elements as they travel at constant velocity past the print location, a significant design problem results from the requirement that the hammer hit only the selected character. In the usual configuration this requirement limits printing speed because the hammer penetrates the plane of the moving type elements and spends a sufficient time in this plane to risk collision with an adjacent type element. This paper describes, for printers with widely separated hammers, a technique to effectively eliminate the "in-plane" time. A cammed interposer is used to transfer most of the kinetic energy of the hammer to the type element, with the remaining energy being absorbed in strain energy of the interposer. For one printer, this technique resulted in an increase in the printing speed from 15 to 30 characters per second.

Introduction

For many years, high-speed, impact line printers have achieved character selection by timing hammers to strike the type elements as they move at constant velocity past the print location in a direction parallel to the paper [1]. The speed of such printers is limited by the requirement that the hammer hit only the selected character without interfering with the adjacent characters.

In Fig. 1, the type elements are traveling to the left past a stationary hammer. When the selected character approaches, the hammer is moved into the type element plane, driving the selected character against the ribbon and paper. In such a printer, the velocity of the moving type elements must be slow enough to allow time for the hammer to strike a type element, push it in to the platen, and return before the succeeding type element arrives at the hammer location.

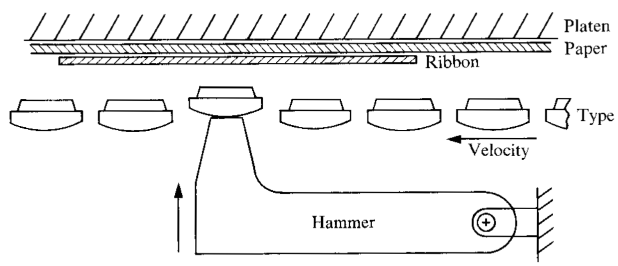

Figure 1 Schematic of conventional printer.

Speed of past printers such as the IBM 3211 has been improved by utilizing very light hammers which travel at very high speed and by utilizing a very small clearance between the type elements and the platen. The incorporation of expensive design features [2, 3] such as a moving platen [4] into the IBM 3211 has permitted a type velocity of about 5 m/s. In disk printers such as the IBM 3610, the close tolerances and moving platen of the 3211 were not used because of cost considerations. Therefore, a method was sought which would cause the type element to impact the platen without having the hammer penetrate the type element plane. The method chosen utilizes relatively massive type elements so that when the hammer strikes the selected type element nearly all of its kinetic energy and momentum are transferred to the type element. After impact, the hammer comes to rest and the type element moves forward to complete the printing operation. This is analogous to a cue ball with no spin axially striking a second ball. The cue ball comes to rest after the impact, and the struck ball leaves with nearly the velocity of the cue ball.

Unfortunately, the real problem is not nearly this simple, and it is shown here that a more practical solution is to introduce an interposer between the impacting hammer and type. In this system, shown in Fig. 2, an interposer is provided for each type element. Both interposer and type element move to the left while remaining in contact. In this case, the hammer energy is transferred to the type element through the interposer, somewhat akin to two adjacent balls being struck by a third. The interposer, analogous to the middle ball, moves very little.

The cammed surface on the interposer will be shown to be desirable to aid the hammer in missing the adjacent type element and to reduce the required hammer velocity.

Impact analysis

The model to be used to analyze the interposer system is shown in Fig. 3. The interposer, support, and the type element are considered to travel at constant velocity v_d in the horizontal direction. The hammer is considered to be fixed in the horizontal direction but to have a vertical velocity v_h prior to impact. The stiffness of the interposer support k_I is small with respect to the axial interposer stiffness k_a, so that support forces on the interposer during impact may be neglected. In addition, the interposer is considered massless. Conservation of momentum in the vertical direction dictates that

$$m_h v_h = m_t v_t' + m_h v_h', \tag{1}$$

where m_h is the mass of the hammer, m_t is the mass of the type, v_t' is the velocity of the type, and the prime indicates values after impact. The change in momentum of the hammer is

$$m_h(v_h - v_h').$$

This is also the vertical impulse which the interposer gives to the hammer. Therefore, the horizontal impulse to the hammer in a frictionless impact is

$$m_h(v_h - v_h') \tan\alpha,$$

and the energy which the interposer introduces into the system due to its horizontal velocity v_d is

$$v_d m_h(v_h - v_h') \tan\alpha.$$

Conservation of energy dictates that

$$v_d m_h(v_h - v_h') \tan\alpha + \frac{m_h v_h^2}{2} = \frac{m_h v_h'^2}{2} + \frac{m_t v_t'^2}{2}. \tag{2}$$

The division of Eq. (2) by Eq. (1) leads to

$$2v_d \tan\alpha + v_h = v_t' - v_h'. \tag{3}$$

The coefficient of restitution e is then defined as

$$e = \frac{v_t' - (v_h' + v_d \tan\alpha)}{v_h + v_d \tan\alpha}, \tag{4}$$

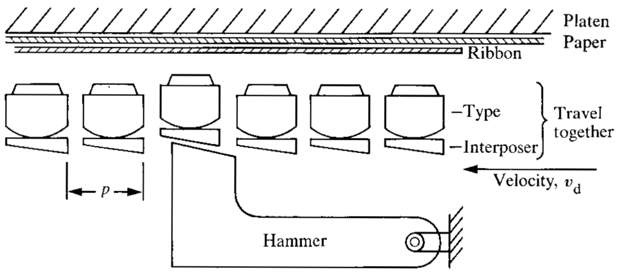

Figure 2 Schematic of printer with interposer.

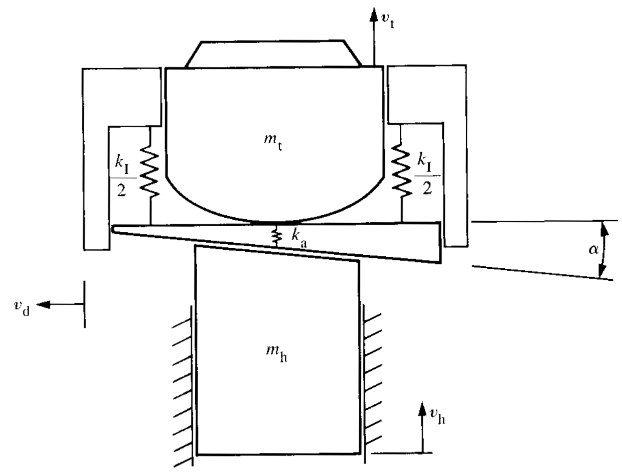

Figure 3 Model at impact.

so that e is 1 if it is an elastic impact with no energy loss and e is zero if it is an inelastic impact in which both the hammer and the type element stay with the interposer.

In the design problem at hand, the kinetic energy required for printing is known to be about 0.0064 J [5–7], and the mass of the type elements is limited to about 0.2 g because of space limitations.

Therefore, the type element mass and type element velocity after impact (8.0 m/s) are considered to be given and fixed and are used to normalize Eqs. (1) and (4) as

$$M_h V_h = 1 + M_h V_h' \tag{5}$$

and

$$e = \frac{1 - V_h'}{V_h}, \tag{6}$$

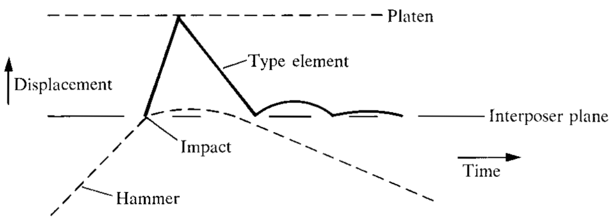

Figure 4 Displacement of hammer and type element in the vertical direction.

where

$$M_h = \frac{m_h}{m_t}, \tag{7}$$

$$V_h = \frac{v_h + v_d \tan\alpha}{v_t'}, \tag{8}$$

and

$$V_h' = \frac{v_h' + v_d \tan\alpha}{v_t'}. \tag{9}$$

Note that the normalized hammer velocity both before and after impact is relative to the interposer surface and that Eqs. (5) and (6) are simply the equations that result from a two-body impact between hammer and type when the type is stationary before impact. Hence, the impact can be considered as a simple two-body impact with the hammer velocity being augmented by the vertical component of the cam velocity, as seen in Eq. (8).

The simultaneous solution of Eqs. (5) and (6) for V_h and V_h' yields

$$V_h' = \frac{M_h - e}{M_h(1 + e)} \tag{10}$$

and

$$V_h = \frac{1 + M_h}{M_h(1 + e)}. \tag{11}$$

From Eq. (10), it is clear that, in order for the hammer to have negative velocity after collision, M_h must be less than e. This appears to be a very straightforward solution to the problem of the hammer penetrating the type element plane. However, in practice, e is significantly less than 1 (about 0.7) because of rotational velocities imparted from eccentric hits, because of wave energy in the hammer, and because of material hysteresis. As seen in Eqs. (8) and (9), the impact can be considered as a simple two body impact with the effective hammer velocity (both before and after impact) being considered to be the sum of the absolute hammer velocity and the vertical component of the cam velocity.

This means that the mass of the hammer would have to be about 0.1 g and the velocity of the hammer about 15 m/s. Even if such a hammer could be made, the impact wear at this velocity would be extreme. Therefore, the appropriate design appears to be to allow the hammer to have positive momentum after impact and to absorb this momentum in the interposer support through the interposer stiffness. We now address the design of the interposer stiffness k_I to ensure that the hammer does not hit the adjacent interposer.

Equation (10) gives the residual velocity of the hammer relative to the cammed interposer surface, so that the maximum interposer penetration can be found by equating the kinetic energy in this moving coordinate system to the strain energy stored in the support of the deflected interposer. Hence,

$$\frac{k_I x^2}{2} = \frac{m_h(v_h' + v_d \tan\alpha)^2}{2} = \frac{1}{2} m_t v_t'^2 \frac{1}{M_h}\left(\frac{M_h - e}{1 + e}\right)^2, \tag{12}$$

where x is the maximum interposer penetration. A conservative requirement on the design is that $x < p \tan\alpha \simeq \alpha p$, where p is the interposer pitch shown in Fig. 2. This ensures that the hammer does not hit the adjacent interposer. If one uses this inequality for x, substitutes into Eq. (12), and solves for k_I, one obtains

$$k_I > \frac{m_t v_t^2}{p^2} \frac{1}{M_h}\left[\frac{M_h - e}{\alpha(1 + e)}\right]^2. \tag{13}$$

Another constraint on the stiffness k_I is that it be sufficiently large to stop the hammer while the interposer cam surface is still in contact with the hammer. Thus, the hammer must remain in contact with the interposer for at least one half oscillation of the hammer interposer system. That is,

$$\pi\left(\frac{m_h}{k_I}\right)^{1/2} < \frac{p}{v_d} \tag{14}$$

or

$$k_I > \frac{m_t v_d^2}{p^2}(\pi^2 M_h). \tag{15}$$

Hence the interposer must be designed to satisfy inequalities (13) and (15) and to absorb the strain energy described by Eq. (12).

The hammer and type element trajectories which result when using the cammed interposer are shown in Fig. 4. The hammer strikes the interposer, giving the type a higher velocity than the hammer, the hammer slows dramatically at impact, the interposer support reverses the direction of the hammer velocity, the type element rebounds off the platen and then strikes the interposer, where the rebound energy is dissipated. The form of this dissipation is described in the paper entitled "An Application of Beam Dynamics to a Damper Design" appearing in this issue [8].

Summary

A supported, cammed interposer has been used to eliminate the "in-plane" time problem common to many printers with moving type elements. Equation (8) gives the required hammer velocity relative to the interposer surface. Since the required hammer velocity is relative to the interposer surface, it is clear that a side benefit of the cammed interposer design is to reduce the required hammer velocity. This results from the fact that the type element takes on kinetic energy from the moving interposer as well as from the hammer.

In the IBM 3610 disk printer, the type velocity was increased from 4 to 8 m/s by using such an interposer [9], and this allowed an increase in printing speed from 15 to 30 characters per second. Expressions (12), (13), and (15) give design requirements for the interposer.

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