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JOINT UNIVERSITY-INDUSTRY EXPERIMENTS IN SOUND RADIATION FROM A FORGING HAMMER

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Introduction

A production forging hammer produces 500 to 20000 blows during an eight hour workshift, each blow creating a true peak sound level of 120-155+dB_p and an A-weighted rms level of 100-130 dBA(fast) at the operator's ear. Since a hammer may have an operating life of forty years, noise reduction must be applied not only to new hammers but also toward retrofits for the thousands of hammers already in the field. Investigations of hammer noise have been underway since before 1970, beginning in Germany (1), then in England (2,4) the USA (3) and Sweden (5). The bulk of this work has been aimed toward identification of noise mechanisms and development of treatments which do not impair productivity.

This paper briefly summarises some results of a project conducted jointly by the US Forging Industry and Michigan Technological University. Begun in 1973, one of its purposes was to identify the sources of hammer noise and evaluate prospects for reducing these sources. Experiments were conducted in facilities provided by a US hammer manufacturer (Chambersburg Engineering Company) using a CECO model 60 FD forming drop hammer.

Noise Prediction by the Forging Hammer: General Features

The typical four-piece forging hammer depicted in Fig 1 is a simple but efficient structure with massive, rather loosely-connected components. The ram's motion provides the work energy; the anvil provides inertial backing for the blow; the columns (which normally rest on the anvil) maintain a stand-off distance and guide the ram toward the workpiece; the yoke maintains column spacing and provides lift/drive for the ram. The entire assembly rests on timbers and/or rubber isolation placed on a concrete foundation.

Experiments cited in (1-5) and those conducted in this study show that the hammer is excited not only by the vertical forging force but also by a nearly-random sequence of impact forces applied at the ram-column and anvil-column interfaces when the ram and anvil bounce against the columns.

The energy of the ram is converted not only into useful plastic deformation of the workpiece but also into rebound kinetic energy, flow work on the air and elastic energy in the structure. The stored energy is dissipated during the ensuing structural vibration either through conversion to heat by internal damping, by radiation as sound or by conduction into the ground. Four mechanisms for producing hammer noise have been identified: a) expulsion of air from between dies, prior to impact; b) rigid body acceleration as the ram and anvil are struck; c) transverse expansion as the billet is struck and d) structural ringing as a result of the blow itself and the impacts at the interfaces.

The first three mechanisms induce transient sound of short duration. Since the corresponding acoustical energies are small, the associated equivalent levels

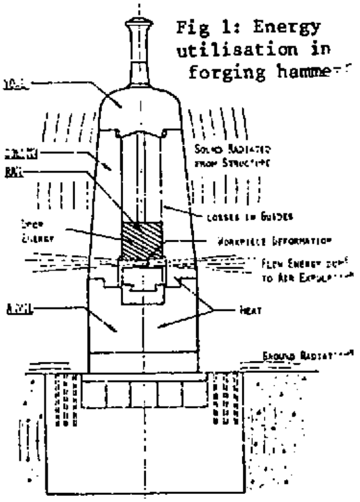


Fig 1: Energy utilisation in forging hammer

are not usually of interest in countries whose standards are based on total energy (these peak pressures are of some concern in the USA). Structural ringing, on the other hand, produces sound of relatively long duration and relatively high total acoustic energy. Therefore the control of structural ringing has been the object of most studies of hammer noise.

Specific Results, related to the CECO 60FD Hammer

The Chambersburg hammer is relatively small by industry standards, with 2000 lb ram (4400 kg), 15 to 1 anvil-ram mass ratio and 8100 J maximum blow energy. To achieve maximum blows, 9 inch (23cm) diameter flat faced dies were used with no intervening workpiece. The hammer was tested under die-to-die impact, both with and without protective shrouding. The protective shrouding consisted of 6 psf (142kg/m^2) lined and isolated sections sealed around the ram, anvil and guide zone. The columns remained uncovered throughout the tests, while other structural elements were covered as required for source identification. Ordinary and coherent spectra were also analysed to obtain supplementary evidence in the identification process.

The force-history during die-to-die impact was a half-sinusoid with peak force directly proportional to the impact velcity v_0 (Fig 2). This proportionality is in agreement with classical theory but the magnitude F_{max} and the duration τ of the contact force are governed more by the stiffness of the dies than the properties of the ram and anvil. Formulae developed at $^{(2)}$ assuming rigid ram and anvil connected by a massless die of stiffness K, produce reasonable approximations to force history and duration, provided the die stiffness is less than half the ram stiffness.

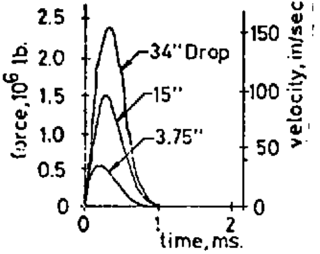


Fig 2: Blow histories for die-to-die impact

Peak sound pressure levels were measured during die-to-die impacts, at positions along two verticals, located 42cm and 133cm respectively, in front of the hammer. The peak pressures were found to increase in proportion to the blow magnitude F_{max} (or impact velocity v_0) and followed distribution patterns which could be predicted using equations developed for a colliding sphere$^{(4)}$. The theoretical predictions and measurements are shown in Fig 3.

The contributions of structural elements were assessed using sound attenuation data (Fig 4) supplemented by coherent-spectrum displays. As Fig 4 shows, the peak levels were typically reduced by at least 6 dB when only the columns were left exposed, while reductions of only 4 dBA were realised in the rms levels (dBA fast). Since the shrouds themselves were applied with great care, the results imply that the columns experience structural ringing sufficient to

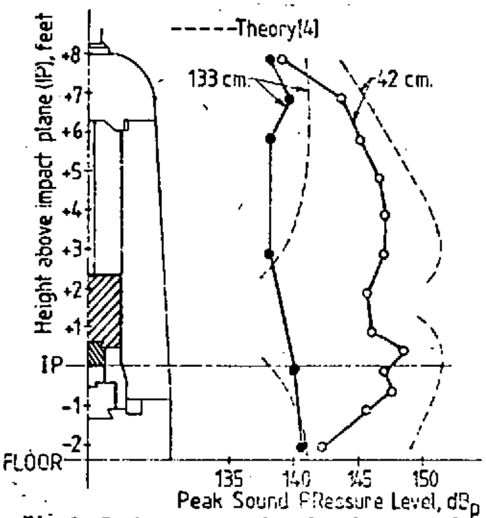


Fig 3: Peak pressure levels along vertical traverses at 2 distances from hammer; comparison made with theoretical results in (4). Impact velocity=4.1m/sec.

contribute rms sound levels only 4 dB below the combined level.

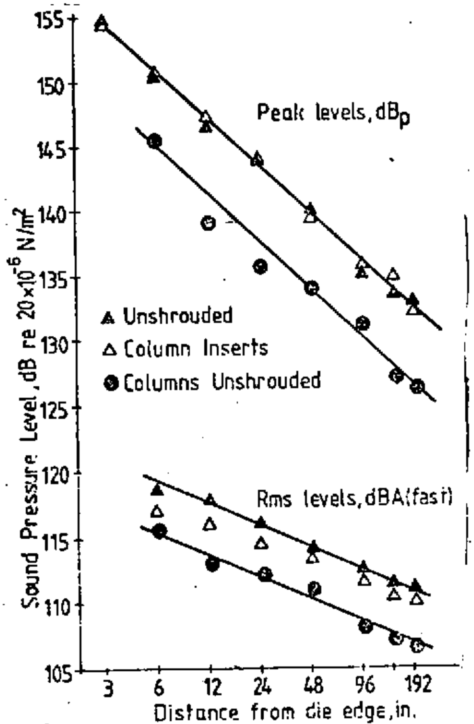
Insertion of resilient inserts in the column-anvil interface produced no changes in peak levels and small but distinct (1 dB) changes in rms level. Moreover the spectrum of the radiated sound was always found to be somewhat broader (DC-4kHz) than the spectrum of the hammer blow (DC-2kHz). Since no non-linear behaviour is evident, the apparent discrepancy arises from the occurrence of impacts at the structural interfaces during and afte the blow itself. This information, corroborated by coherence data, indicates that the columns are excited through the column-ram interfaces, ie. through the guides, and that column motion induced by these forces is responsible for a significant fractio of the total sound energy.

Horizontal traverses in the hammer's impact plane (Fig 4) reveal that the peak levels decrease at a higher rate (4-5 dB/doubling) than the rms levels (2-3 dBA/doubling). This difference in rate is attributed to the fact that the peak levels originate from the relatively smal ram-die region while the structural vibration is distributed not only over the ram and anvil but also the columns, from which sound is radiated in a roughly cylindrical pattern.

An additional interface was induced in the structure by a slight loosening of the die key in the ram. Although no change was noted in peak acceleration or peak pressure levels, a 4 to 8 dBA increase in rms level was achieved (Fig 5), indicating a significant effect of this interface on the ringing of the structure.

Results and Further Work

The combination of shielding and coherency analysis used in these experiments has shown that sound energy radiates in significant quantities from not only the ram and anvil but also the columns, which are excited by impacts at the ram-column and anvil-column interfaces. The peak levels radiated to the operator can be estimated reasonably well from existing theoretical work, but the estimation of radiated acoustical energy is not yet feasible without supplementary measurements It is still necessary to develop an effective estimator of vibration energy distribution in a loosely-interconnected structure under transient loading, befor the available acoustical knowledge can be brought to bear on this problem. Field techniques, perhaps based on coherence methods, must also be developed to investigate hammers under production conditions.



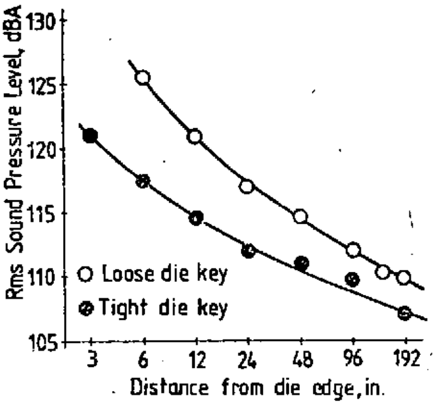


Fig 5: Effect of loose die key on rms sound levels. Anvil shrouded and column inserts in place. Impact velocity = 4.1 m/sec

Fig 4: Effects of Shrouding on peak and rms levels. Impact velocity =4.1m/sec, readings taken in the impact planes.

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