

PERCUSSIVE TOOL NOISE AND VIBRATION CONTROL

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ABSTRACT

Investigations are now being conducted to quiet the noise and reduce the amount of hand-arm vibration produced by chipping hammers.

Chipping hammer noise comes from four sources: workpiece, chisel and housing excitation and air exhaust pulsations. Reduction of workpiece noise has proven difficult, expensive, and detrimental to productivity. Both external and internal damping methods can reduce noise from chisels; external dampers, however, are vulnerable to damage. Air exhaust noises can be reduced by mufflers. Reduction of housing noises involves adding a barrier-type material to the outer surfaces of the housing or isolating the inner barrel from the outer housing.

Chipping hammer vibration results from resonances in the structure of the chipper, from recoil, and from chisel rebound. Recoil may be reduced by isolating the barrel from the handle or through an air reservoir technique. Vibration isolators have been under study for some time, but there has been difficulty in incorporating isolation in a tool suitable for production. Methods of chisel vibration reduction include damping the chisel or putting an isolating sleeve between the chisel and the hand which guides it.

Even with the above measures of noise and vibration reduction, levels will still be above those of other metal removal tools. Casting production changes to permit the use of quieter tools and automation of finishing operations are future ideas for solving the problem. For the present, investigations will continue into producing quieter, lower vibration, and more productive chipping hammers.

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INTRODUCTION

Chipping hammers have been used in foundry cleaning operations for many years. These tools often remove metal faster and easier than other types of hand-held power tools such as grinders. In the past, high sound and vibration levels have been tolerated as the price paid for higher productivity. Recent government noise regulations and studies of hand-arm vibration have led to

new interest in quieting and reducing vibration of this tool. Investigations now being conducted will lead to a new generation of quieter, lower vibration chipping hammers that can be used until alternative methods are developed.

The basic design of pneumatic chipping hammers has not changed since the turn of the century. A cross-section of a chipper is shown in Figure 1. A free running piston is driven in a cylinder by air pressure. At the end of its power stroke, the piston impacts a chisel imparting its kinetic energy to the chisel to do work. In its return stroke, the piston is kept from hitting the top of the cylinder by a cushion of trapped air. The flow of air into the cylinder is controlled by an air pressure activated valve, thereby controlling the operating cycle duration.

CHIPPER NOISE

Experimental investigations of sounds from chipping hammers have determined four main sources of noise. These are listed below in order of importance to the overall sound level:

- a. Workpiece noise.
- b. Chisel or steel noise.
- c. Air exhaust noise.
- d. Case or housing radiated noise.

Noise Evaluation Methods

Before considering individual chipper noise sources, the method of evaluating each of the pneumatic tool noises will be described. Sound was measured according to ANSI S5.1-1971. This test standard calls for measurement at five microphone locations one meter from the tool, as shown in Figure 2. The five A-weighted pressure sound levels are logarithmically averaged to yield a single descriptive sound pressure level. The measurement room should have absorbant walls and ceiling and be large enough so that a 6dB drop can be obtained at distances of two meters or greater from the tool. The floor must be reflective; i.e., made of concrete.

Each of the tool noise sources was evaluated by muffling or eliminating the other sources when measurements were taken. For example, chisel noise was evaluated with the chisel impacting on a steel I-beam totally immersed in sand to eliminate workpiece noise. The air exhaust was piped out of the room and the housing was covered with polyurethane lead septum foam to eliminate those two sources.

Workpiece Noise

The impact of the chisel on the undamped casting excites the workpiece to vibrate at its natural frequency. Airborne sound radiates from the surface of the casting to the operator's ear. The sound level of this ringing can often exceed 120 dBA. The actual sound level depends on the size, damping, and shape of the radiating surface. Reduction of this noise source has

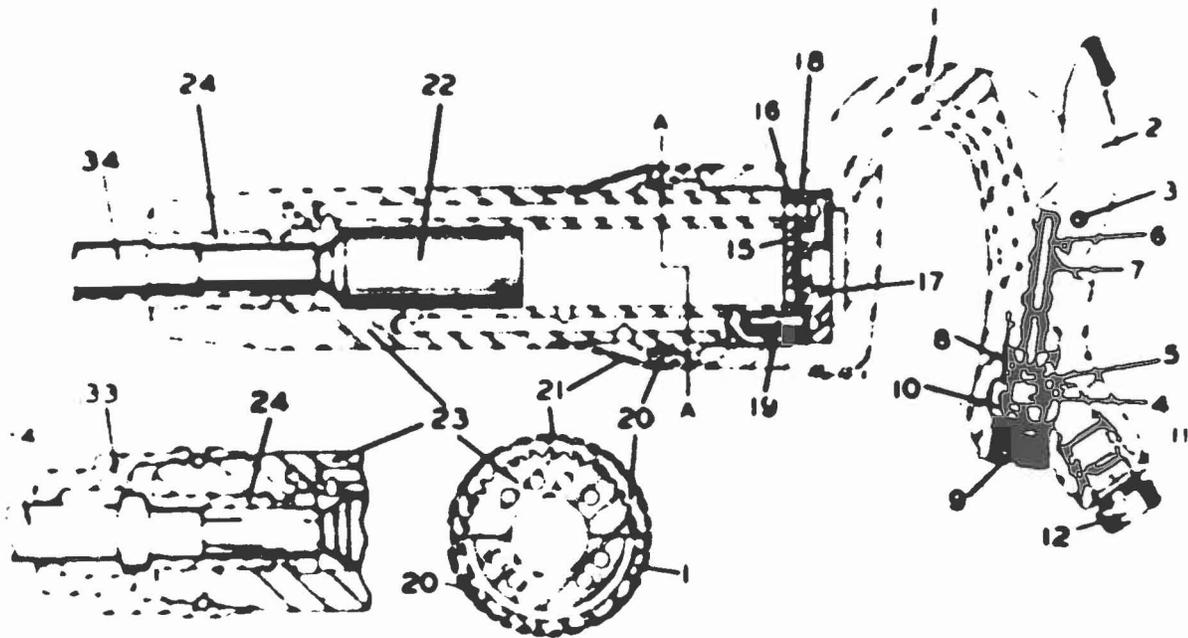
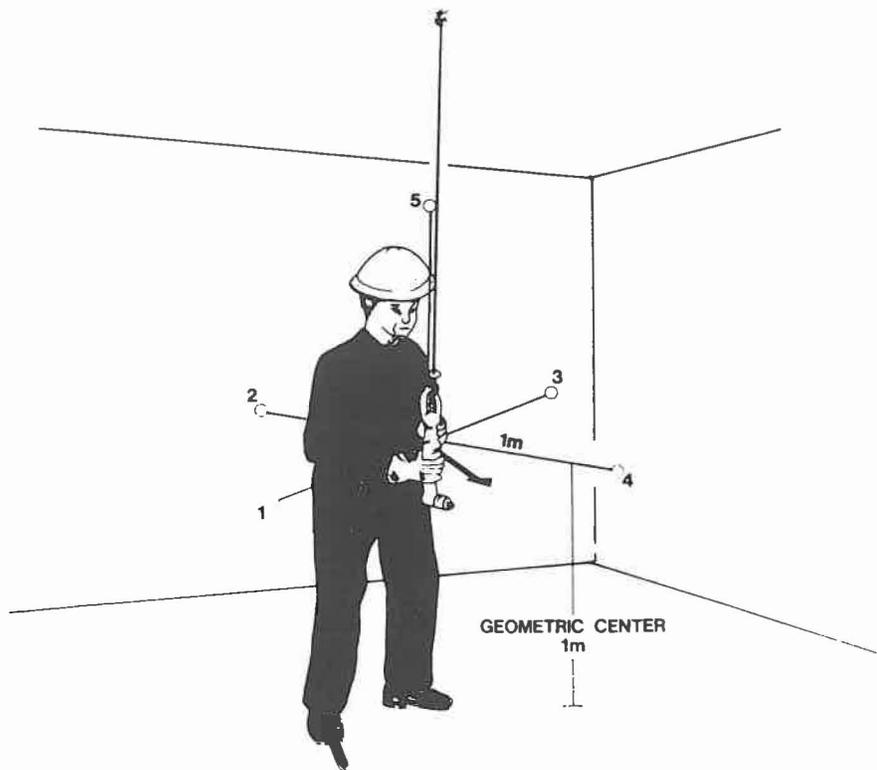


Figure 1. Cross section of typical chipping hammer.



ROTARY AIR MACHINE RUNNING FREE

Figure 2. ANSI S5.1-1971 microphone positions.

proven difficult, expensive, and detrimental to productivity. The major noise control method is to add damping to the casting. This involves immersing the casting in a damping media such as water or sand. Immersion can be a rather arduous procedure with large castings, especially in high volume operations. Small castings are usually rotated in many directions during cleaning operations. Each time the casting is rotated, it has to be immersed again. Therefore, cleaning time is increased. Other noise control methods, such as covering the workpiece with a low transmitting blanket, cannot be used effectively in many cases due to the complicated contours and sizes of castings.

When workpiece noise is high, the other noise sources have little effect on the overall sound level. However, if the workpiece noise is sufficiently damped, the other chipper noise sources become prominent.

Chisel Noise

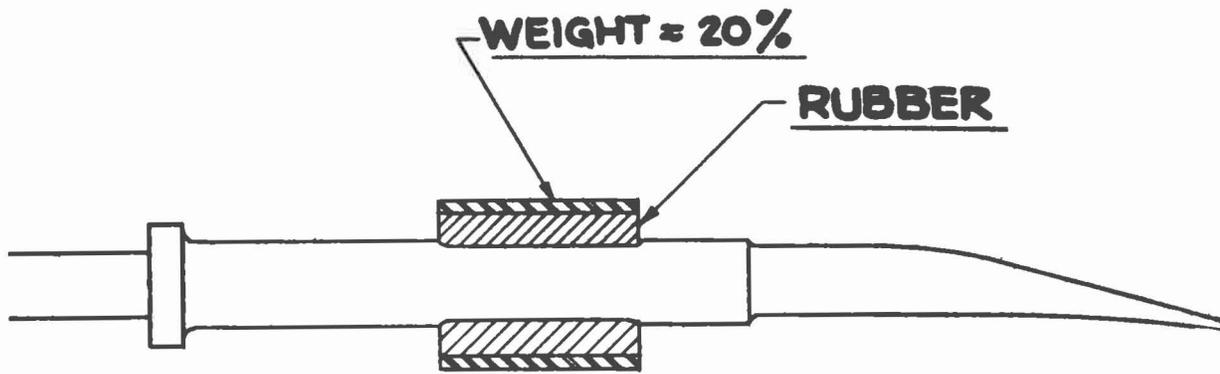
The chisel may be considered a cantilever-hinged beam. When the chisel is struck by the piston, both longitudinal and flexural modes of vibration are induced. Short 10-30cm (4-12 inch) chisels are used in most foundry operations. These chisels have relatively high natural frequencies. In many cases, the longitudinal model frequencies are above the audible range. In addition, longitudinal modes are poor sound radiators. Therefore, the audible chisel ring is due mainly to flexural vibrations. It has been observed that chisels with large exposed areas (longer chisels) yield higher sound levels than shorter chisels. Long chisel ring can generate sound levels as high as 110 dBA while shorter 10cm (4 inch) chisels generate sound levels as low as 100 dBA.

The most frequently used method of reducing chisel noise is to add external damping to the chisels. Most of the dampers consist of a layer of rubber between the chisel and a protective outer shell as shown in Figure 3. External dampers such as this are vulnerable to the heavy abuse of a typical foundry operation. In addition, high temperature will lead to rapid deterioration of the rubber layer.

A second method of damping chisels is to use internal damping. Ingersoll-Rand utilizes a Lanchester damper, otherwise known as an unturned dynamic absorber in its patented "muted chisel", as shown in Figure 4. A mass suspended by a viscous fluid or by air is free to move in a bore within the chisel. The inertia of the mass puts a force on the chisel that is out of phase with the vibratory forces. This damps out chisel ring and reduces chisel noise. The muted chisel reduces chisel noise by 10 dBA from that of a conventional chisel of the same size.

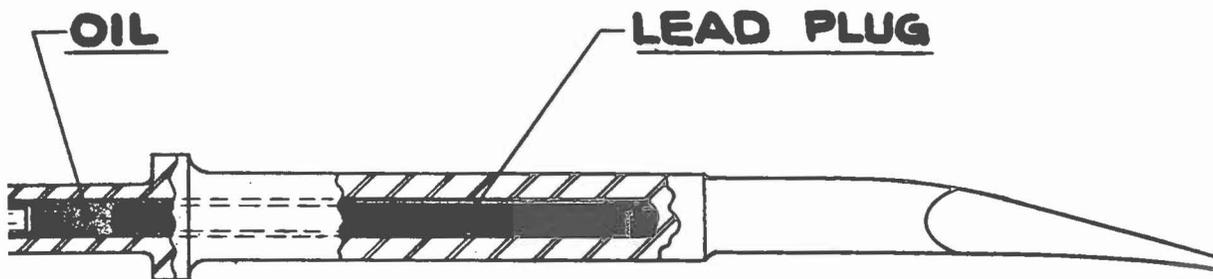
Air Exhaust Noise

Exhaust noise of chippers is caused mainly by the pressure pulses released to the atmosphere each time an exhaust port is opened. This noise consists of a series of discrete tones that are of "firing" frequency and its harmonics.



EXTERNAL DAMPING (PATENT NO. 3856107)

Figure 3. Chisel with external vibration damper.



INTERNAL DAMPING (I-R PATENT NO. 3861494)

Figure 4. Cross-section of "muted" chisel.

The fundamental tonal frequency is generally below 42 Hz because most large chippers operate at 2500 blows per minute or less. Since A-weighting gives more emphasis to high frequencies, the effect of exhaust noise on the total A-weighted sound level is smaller than that of the outer high frequency noise sources. However, the large frequency spread between low frequency exhaust noise and the other high frequency noise sources makes the exhaust noise easily distinguishable. Subjectively, the chipper sounds quieter if the air exhaust is muffled. Air exhaust noise ranges from 95 dBA to 105 dBA and muffling can reduce this noise by 5 to 10 dBA, as indicated in Figure 5. However, when the other chipper noise sources are present, muffling only reduces the total noise by 1 to 2 dBA.

Case or Housing Radiated Noise

When noise from the previously described sources is sufficiently reduced, case radiated noise must be considered before the sound level can be reduced further. Sounds generated internally by impacts of the piston on the chisel are transmitted through the housing and radiated to the atmosphere. In addition, the housing is also excited at its natural frequency and radiates sound. The sound level of this noise ranges from 95 dBA to 100 dBA. Reducing this noise involves adding a barrier-type material to the outer surfaces of the housing or isolating the inner barrel from the outer housing.

In a foundry operation with the tool working on a damped workpiece, the sound level was reduced from 115 dBA to 110 dBA with the noise reduction methods described; i.e., exhaust air noise piped away, muted chisel, non-resonant workpiece, and non-transmittal case sheath; while in a paper box stripping operation, the chipping sound level was reduced from 105 dBA to 90 dBA. The lower levels in paper box stripping were due to the total lack of workpiece noise and the added damping effect of the paper on the chisel.

CHIPPER VIBRATION

Chipping hammer vibration has been found to be caused by resonances in the structure of the chipper, from recoil, and from chisel rebound. Recoil and rebound create vibrations along the axis of the tool that are transmitted through the throttle handle to the hand. In many cases, the operator holds the throttle handle with one hand while steadying and grinding the chisel with the other. This grinding hand is subjected to the flexural vibrations of the chisel. Investigations have shown that most cases of vibration-induced white finger (VWF) occur on the hand grinding the chisel, while problems further up the hand-arm system occur from holding the throttle handle; i.e., chipper's elbow.

Vibration Measurement Problems

There are problems involved with evaluating chipping hammer vibration. Most general purpose accelerometers have natural frequencies around 25 k Hz. The impacting associated with chipper operation generates vibration with frequencies that can exceed 30 k Hz. Therefore, the forced vibration at the accelerometer's natural frequency puts high loadings on the delicate

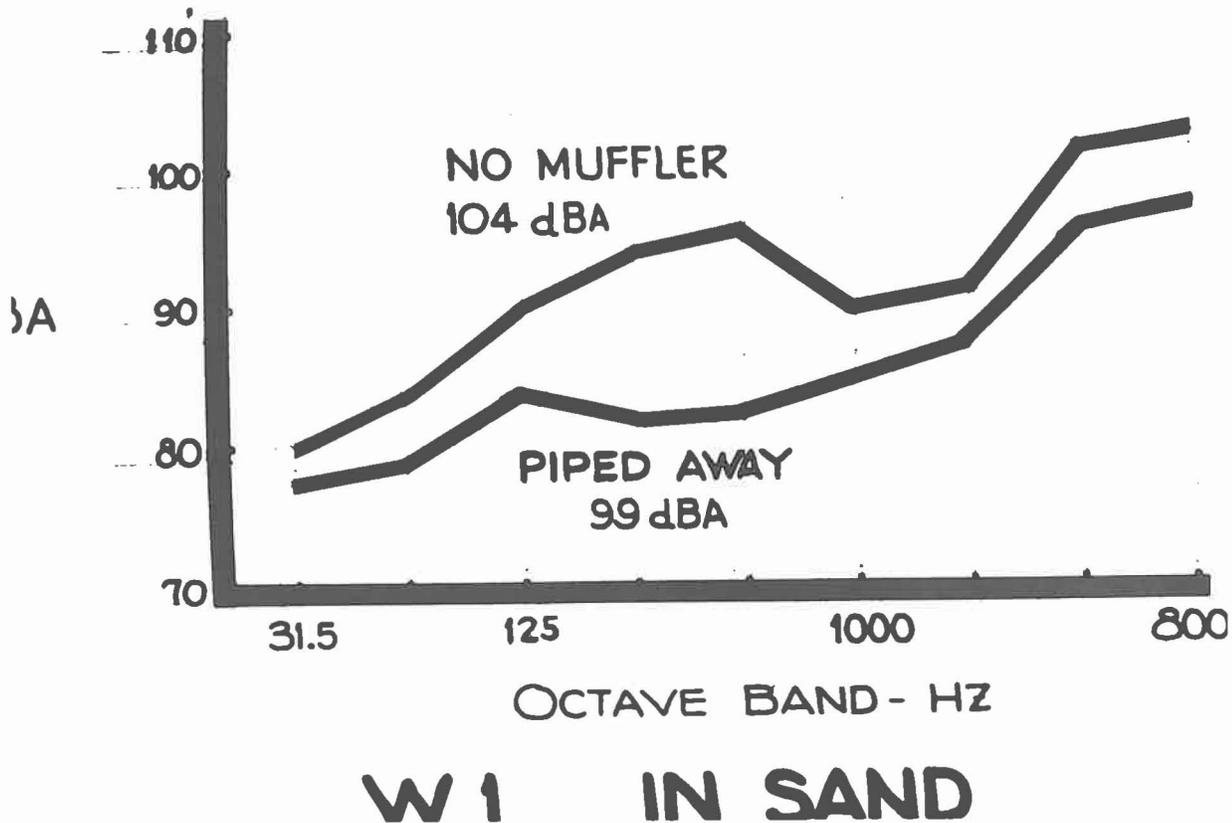


Figure 5. Sound spectra of chipping hammer with and without muffler.

internal parts of the transducer. This can lead to erroneous data and destruction of the accelerometer.

The European Committee of Manufacturers of Compressors, Vacuum Pumps, and Pneumatic Tools (PNEUROP) has been investigating the use of low pass mechanical filters between the chipper and the accelerometer to allow the use of general purpose accelerometers in chipper vibration measurement. The mechanical filter consists of a piece of rubber sandwiched between the steel mounting plates. The filter allows the useful data in the 0 - 1000 Hz range to be measured while filtering out the high frequencies that could damage the accelerometer.

An alternative method is to use a shock accelerometer that has a high natural frequency above 60 k Hz and, sometimes, internal damping. The shock accelerometer works well when mounted solidly to the throttle handle. However, it has been demonstrated by Reynolds that even shock accelerometers cannot withstand high frequency vibrations when mounted solidly to the chisel. Therefore, a fixture for holding the accelerometer has been developed to measure chisel vibration. The fixture is held in contact with the chisel by the operator's hand, as shown in Figure 6. This setup yields an accurate measure of the vibrational energy transfer from the chisel to the hand and provides protection for the transducer.

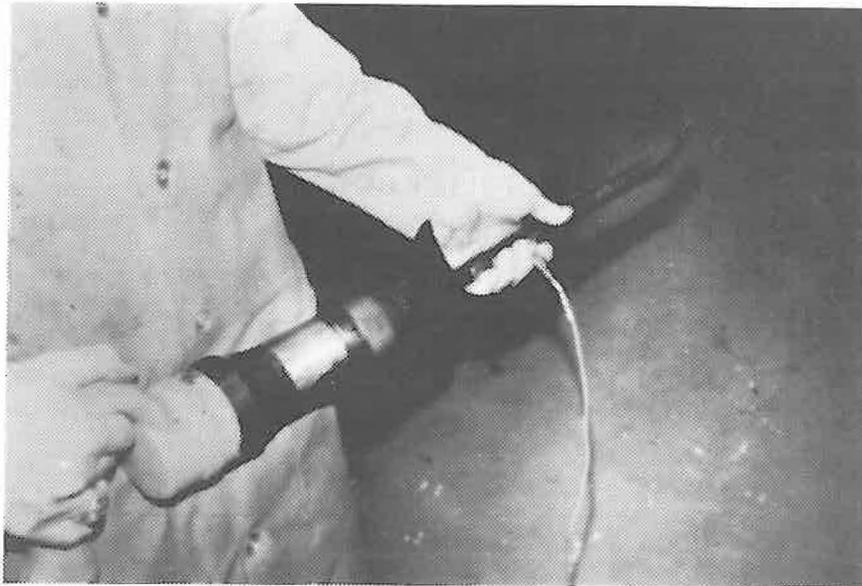


Figure 6. Measuring chisel vibration with a shock accelerometer in fixture.

Recoil Vibration

Recoil is caused by the acceleration of the piston within the barrel. The accelerations change the pressure of the gas in the barrel imposing a force on the tool in the opposite direction to the accelerations. The recoil may be reduced by isolating the barrel from the handle or by having a large reservoir of air in communication with the air in the barrel, such that the pressure changes will be smaller.

Vibration Isolators

Isolators for use in chippers have been under study for some time. However, there has been difficulty in implementing this system in a production tool. The vibrational frequencies of interest are below 1000 Hz. The natural frequency of the isolator system should be below 10 Hz for the isolator to be effective in protecting the hand-arm system. A chipper weighs less than twenty pounds; therefore, the isolator stiffness has to be less than 200 lb/in for an isolator resonant frequency of 10 Hz. At low spring rates, under certain working conditions, instability can be induced in the isolator system. Relatively large oscillating motions between the handle and the barrel make it difficult to control the chisel. Chisel control allows an experienced operator to produce a continuous chip which yields a high metal removal rate and a smooth finish. Therefore, instability leads to a reduction in productivity and degradation of surface finish. Adding damping to the isolator reduces the instability but also reduces the effectiveness of the isolator. An experimental tool with a damped rubber isolator is shown in Figure 7. This isolator was effective in reducing high frequency vibrations, but had little effect on low frequency vibrations.

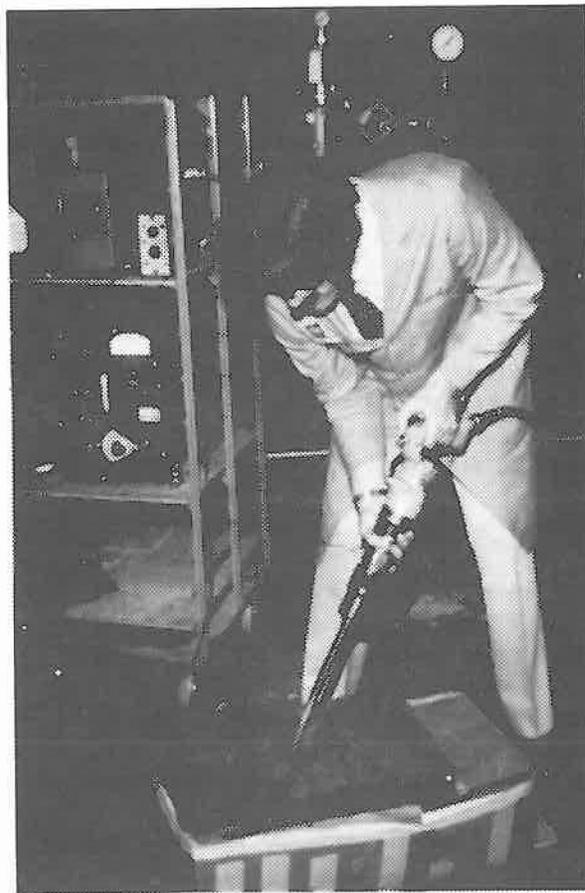


Figure 7. An experimental tool with a damped rubber isolator working in a non-resonant media.

Attempts have also been made to use a dynamic absorber to reduce axial vibrations. However, the limited space available for the secondary mass travel required the use of a secondary mass comparable to the mass of the tool itself to be effective. Doubling the weight of the chipper was, of course, unacceptable.

Some operators have observed a reduction in vibration when mass was added to the tool. This effect can be demonstrated by the equation below:

$$X = \frac{F/K}{1 - \frac{W^2}{K} M}$$

- where
- X = Displacement
 - F = Imposed force
 - K = Spring constant of hand-arm system
 - W = Forcing frequency
 - M = Mass of chipper

It can be seen that as the mass increases, the displacement decreases. In fact, a dynamic absorber acts as an increased equivalent mass. In both cases the added weight is unacceptable.

Rebound Vibration

Chisel rebound is common in foundry operations. The chipper bounces off the workpiece and impacts the front end of the chipper. This axial vibration can be reduced by isolating the barrel from the handle or by isolating the front end from the barrel. The problems associated with isolating the handle from the barrel have already been described. When isolating the front end of the chipper a performance problem is introduced. The small masses involved require an isolator with a low spring rate. When the operator bears down on the work, the front end will be moved rearward reducing the travel of the isolator and reducing the stroke and, therefore, the power of the chipper.

Methods of chisel vibration reduction include damping the chisel as described previously or by putting an isolating sleeve between the chisel and the hand. However, a sleeve adds width and length to the chisel and reduces what chipper operators call "feel". The muted chisel reduces vibration by the level of 6 to 10 dB in the frequencies of interest.

ALTERNATIVES TO CHIPPING

The methods of noise and vibration reduction described above are some of the latest being considered for chipping hammers. Even with the use of these measures, the sound and vibration levels will still be above those of other metal removal tools. Therefore, it may be necessary to seek alternative procedures in casting design to reduce exposure or to allow other types of metal removal tools to be used productively. These alternatives could include new designs of metal castings that would reduce amounts of flashing to be removed. Molds could be designed so that cleaning operations with quieter tools, such as grinders, could do the work instead of chippers. In addition, some cleaning room operations could be automated to remove the workers from the high noise and vibration regime. However, these techniques will take a long time to be initiated. In the short term, chippers will continue to be used for cleaning operations. Therefore, investigations into producing quieter, lower vibration and more productive chippers will continue.

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