Introduction To Impulse Hammers

Introduction

A transfer function of a mechanical system describes its dynamic behavior in response to an applied stimulus (excitation). There are six major transfer functions used in mechanical systems analysis.

These are:

Dynamic Mass (Force/Acceleration)
Mechanical Impedance (Force/Velocity)
Dynamic Stiffness (Force/Displacement)
Compliance (Displacement/Force)
Accelerance (Acceleration/Force)
Mobility (Velocity/Force)

(Note that each of these transfer functions is itself a function of Force.)

Each transfer function describes the dynamic behavior of the mechanical system in a different fashion and each involves the ratioing of the output response to the input stimulus. Response can be measured most conveniently with accelerometers placed at important points throughout the structure under test. Spectrum analyzers perform the necessary mathematical ratioing on input and response signals to produce, almost instantaneously the desired transfer function.

The input stimulus (forcing function) may be applied to the structure by various methods. One common way to excite structures is by use of an electrodynamic or hydraulic shaker. A force sensor attached to the armature driving the test object may be used to define input force amplitude and a signal generator controls frequency. When the test object is too large to be excited in this fashion, or when it is physically impossible to do so, there is another method to consider.

An alternative method available to excite a structure without the complication and expense of a shaker system, involves striking it with a calibrated dynamic impulse hammer. A force sensor mounted in the head of the hammer transforms the input force pulse into an analogous waveform that contains the necessary amplitude and phase information to completely describe the forcing function. Impact tip material stiffness helps determine the frequency content of the input forcing function by controlling the impact pulse duration. By defining the frequency and amplitude of the forcing function, impulse hammers present a fast, simple way to excite structures in a well defined fashion.

Spectrum analyzers in conjunction with hammer systems (with accelerometers) can instantaneously plot transfer functions greatly simplifying testing and saving valuable man hours. A branch of mechanical system analysis called Modal Analysis, uses software to further refine the frequency response data to describe in detail each mode (resonance and anti-resonance) of the structure.

The Impulse Hammer

The dynamic impulse hammer has two primary functions:

1. It must excite the test structure with constant force over the frequency range of interest and,
2. It must produce an analog voltage pulse which is an exact representation of the input impulse (F.t) both in amplitude and phase.

A piezoelectric impulse hammer consists of a head assembly containing a force sensor and a handle with rubber grip, interchangeable head extenders and several different impact tips (steel, aluminum, hard plastic and soft plastic). Figure 1 illustrates the construction of one of several models of Dynapulse™ hammers produced by Dytran, the model series 5800B. The two other Dynapulse hammers are the series 5801B and the model 5850B.

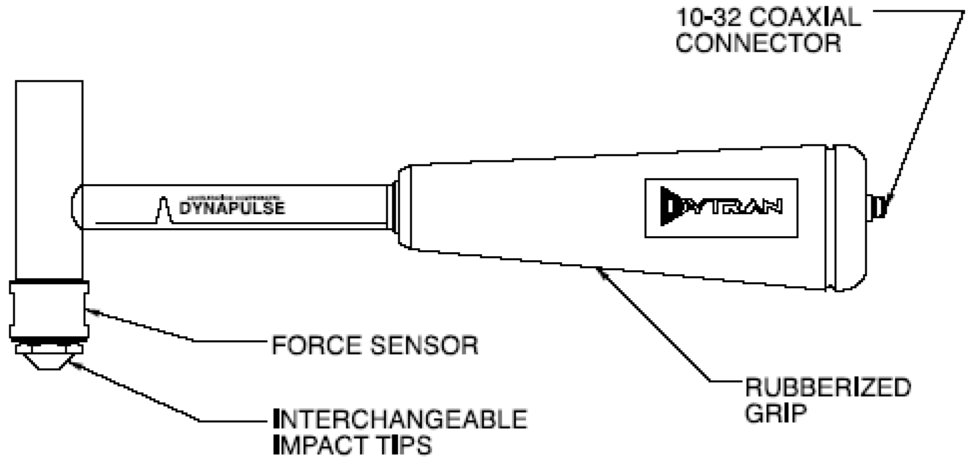

Figure 1: Impulse Hammer Structure

Dytran Dynapulse™ impulse hammers utilize an exclusive acceleration compensated quartz force sensor to ensure that hammer self-resonances do not produce spurious “noise glitches” in the hammer output signal spectrum. The high rigidity of the force sensor combined with acceleration compensation produces a clean, smooth output signal which is an exact representation of the forcing function, both in amplitude and phase.

The Low Impedance Voltage Mode (LIVM) force sensor is permanently mounted to the front surface of the hammer head with electrical connections conveniently routed through head and handle, terminating in a BNC connector located at the end of the handle. This streamlined concept in design was pioneered by Dytran and has become the industry standard.

Tailoring The Force Pulse

Since structures vary greatly in size, mass and dynamic response, input forces with widely differing characteristics are required for proper excitation. For example, small low-mass objects in general, will have higher response frequencies and thus will require higher frequencies of excitation at lower force levels. Heavier structures with lower frequency responses (resonances) require lower frequency excitation at higher input force levels.

Using these general guidelines, the user can combine various head extenders which alter the hammer head mass) and selected impulse tips (provided with hammer systems) to create different impulse waveforms. A spectrum analyzer is usually used to verify the input force spectrum produced by the various tip and extender combinations.

Fourier analysis shows that faster rise time pulses with short pulse duration contain the highest frequencies so use the metal (aluminum or steel) impact tips and no head extender for quickest rebound to produce impulses with the highest frequency content.

Figure 2 is a typical result from a Dytran series 5800B hammer as seen with a spectrum analyzer.

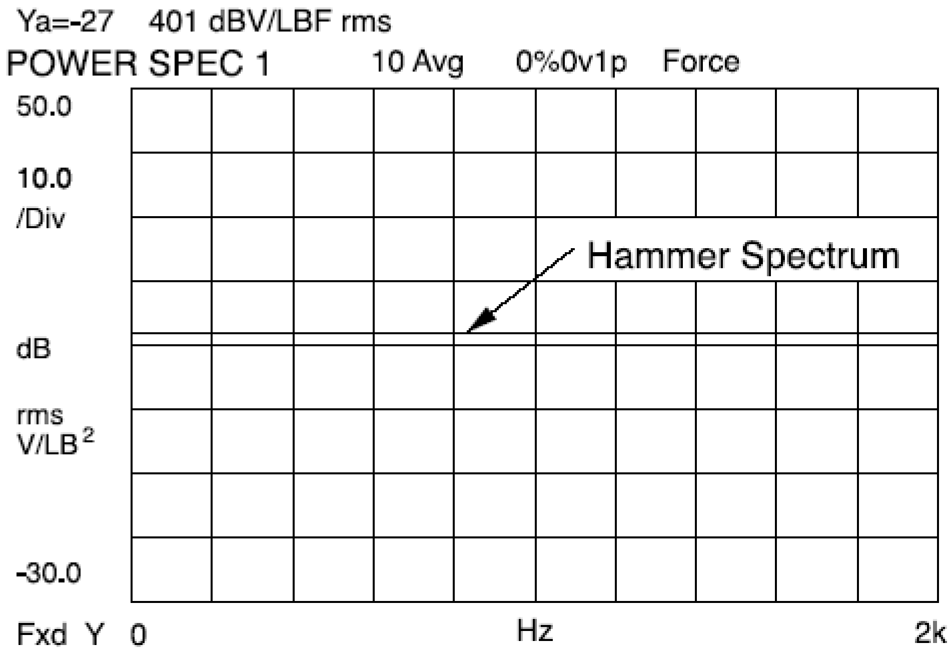

Figure 2: Impulse Spectrum, Aluminum Tip, No Extender

To decrease the high frequency content of the input excitation, increase head inertia by adding a head extender and use a softer impact tip to increase the rise time and pulse duration. This will further lower the frequency content of the excitation.

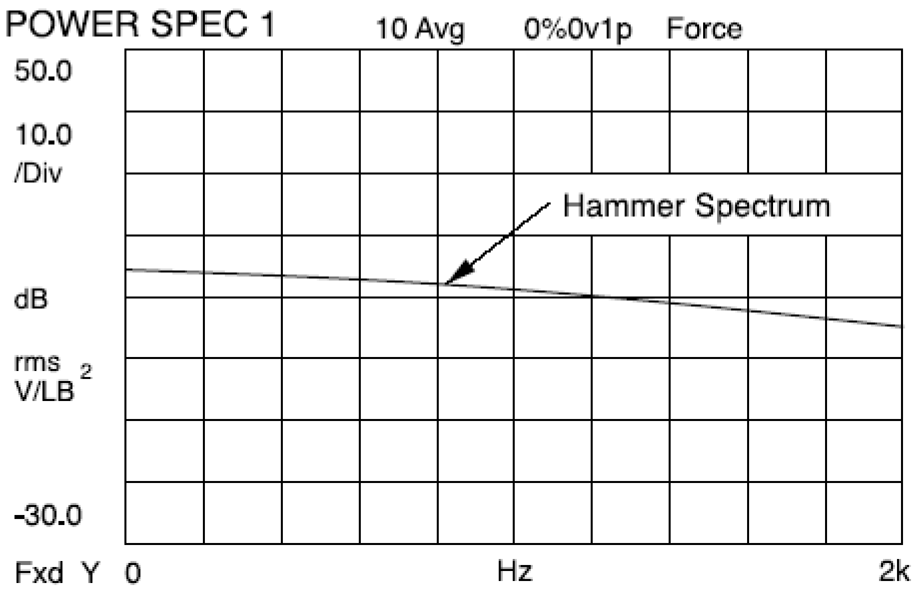

Figure 3: Impulse Spectrum, Hard Plastic Tip, One Head Extender

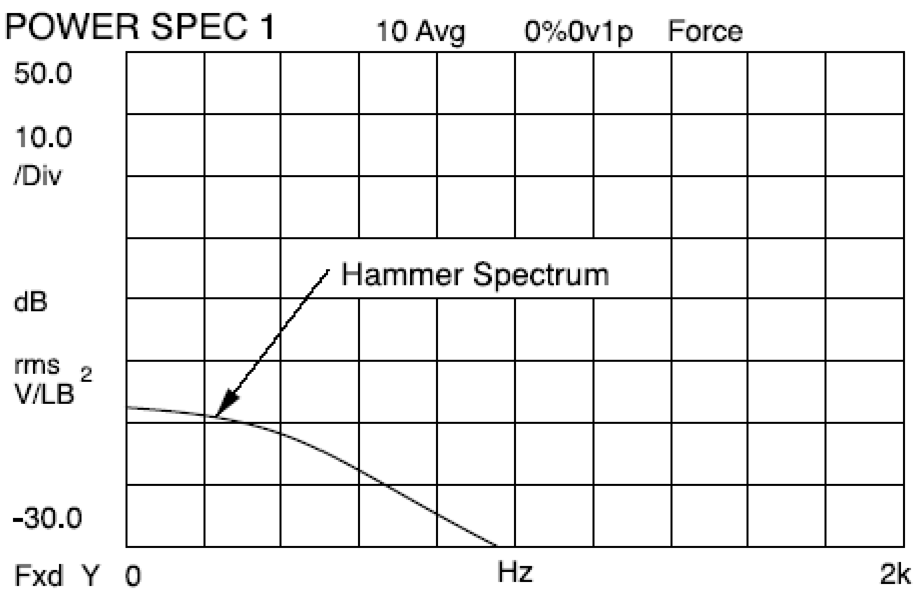

Figure 4: Impulse Spectrum, Soft Plastic Tip, One Head Extender

Figure 5 is an expanded view of the analog voltage pulse (time base) produced by a 5801B using a hard plastic impact tip and no head extender. The pulse duration is .640 mSec.

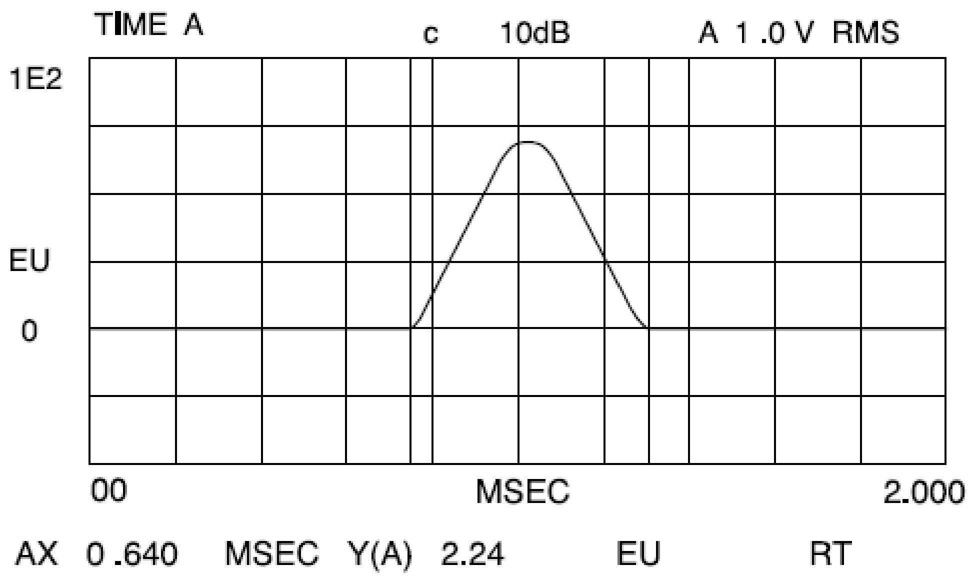

Figure 5: Hammer Pulse, No Extender, Hard Plastic Tip

Figure 6 is an expanded view of the pulse with added mass by use of a head extender with the same impact tip as in Figure 5, above. Notice that the pulse duration is longer.

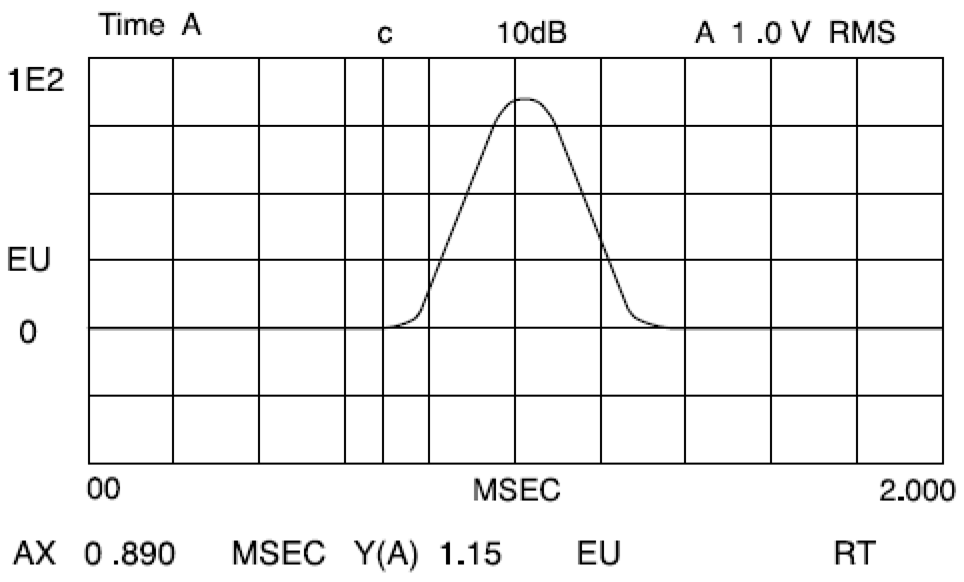

Figure 6: Hammer Pulse, One Extender, Hard Plastic Tip

Coherence plots will enable the user to determine if the structure is being properly excited at all frequencies of interest. Various Impact tip materials and extender mass can be substituted to achieve close to optimum excitation.

System Interconnection

Figure 7 illustrates how an impulse hammer system may be used in conjunction with a spectrum analyzer. A computer operating in concert with the analyzer may be added to perform modal analysis, a software based extension of mechanical system frequency response testing.

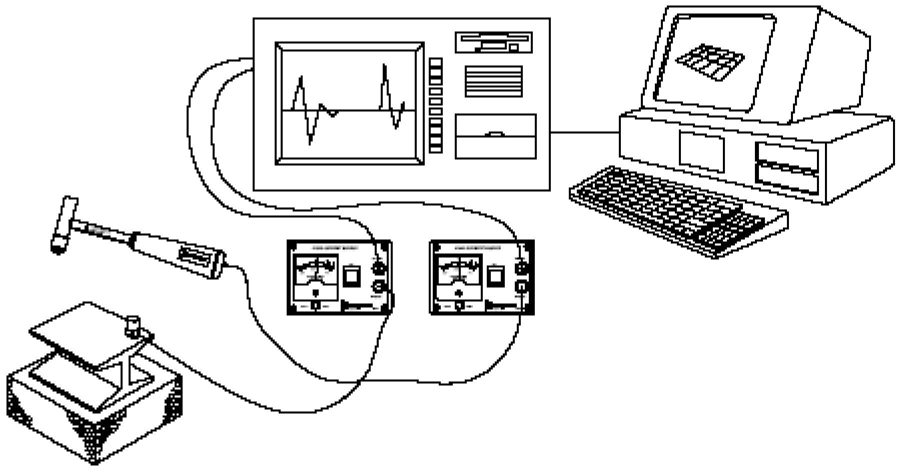

Figure 7: Typical Impulse Hammer Analysis System

Hammer Selection

All Dytran hammers feature internal impedance converting IC amplifiers for convenient LIVM operation. Hammers may be purchased separately or as hammer kits which include accelerometers, power supplies, cables, several tips and head extenders. The complete Dytran hammer line consists of seven different hammer configurations, from the very miniature 5800SL to the large 12 lb. sledge hammer model 5803A, to excite a wide range of test objects and structures from tiny turbine blades to viaducts. All Dytran hammers come supplied with NIST traceable calibration certificates at no extra cost.

The following summary will help in determining the best hammer for your application:

Model 5800SL: This miniature “Super Light” hammer was designed to excite very light compliant structures such as small turbine blades and disc drive read heads. Model 5800SL has a very high tip stiffness and low head mass making it ideal for very high frequency excitation of small structures. A removable head extender is supplied with each instrument. The impact tip, made from hardened steel, is not interchangeable. Sensitivity is 100 mV/lbf.

Model Series 5800B: The first in the Dynapulse™ series, model 5800B has a 100 gram head mass and is available in five force ranges from 10 to 1,000 lbf. full scale. Interchangeable impact tips and a 40 gram head extender are supplied. Acceleration compensation ensures a smooth frequency spectrum free from anomalies. This hammer is recommended for general purpose use on bearing housings, brake rotors, I-beams, plates and other small structures and machines.

Model Series 5801B: This general purpose Dynapulse™ hammer series is available in three force ranges, 500, 1000 and 5,000 lbf. Series 5801B hammers have a 150 gram head which can be increased to 210 grams and 270 grams with the two head extenders available. This hammer is recommended for engine block castings, auto frames, airframes, machine tools, etc.

Model 5850B: The patented Dynapulse "Multi-Range" hammer offers versatility to dynamics laboratories where structures of varying size and weight are to be tested. A three-position toggle switch located in the handle allows the user to select sensitivities of 1, 10 and 100 mV/lbf. The switch summons three different ranging capacitors to change sensitivity and adds no electrical gain to the circuit ensuring that the three ranges share the same low noise level. The model 5850B effectively replaces three dedicated range hammers. Dynapulse acceleration ensures smooth "glitch free" response. This hammer comes with three impact tips and two head extenders to allow tailoring of the impulse. The very wide dynamic range of this hammer provides adequate excitation of a multitude of structures from small to large.

Model 5802A: This lighter sledge hammer (3 lb head) can be equipped with any one of four interchangeable plastic impact tips of varying stiffness and can be used to excite low frequencies in concrete castings, storage tanks, pipelines, towers, etc.

Model 5803A: Our heaviest hammer at 12 lbs, this instrumented sledge hammer has been used to shake buildings, bridges, dams and foundations.

Model 5805A: This is the lightest of the sledge hammers at 1 lb and was designed to be used on smaller structures than the 3 lb 5802A.