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Data Article

Impulse excitation technique data set collected on different materials for data analysis methods and quality control procedures development☆

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ABSTRACT

Mechanical properties such as the Young modulus, shear modulus and Poisson's coefficient are very important to define different materials applications, for basic research and for quality control procedures. Impulse excitation technique (IET) is a non-destructive, easy and fast method for characterization of elastic and acoustic properties of materials. The technique consists in sending a mechanical impulse in a sample and measuring the output sound wave. Commercial instruments are widely spread in metal industry, but they are not diffused in academic research centres. Such instruments can be easily self-built at low cost, allowing a much wider diffusion and exploitation in many fields involving materials characterization, since they guarantee high precision and high data reproducibility. For a proper acoustic characterization, necessary to obtain reliable mechanical data, a calibration of the instrument must be performed, for a proper association of the acoustic response to the features of each specific material. In this data article, a data set of impulses, collected on different materials by a self-built instrument

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for IET, named IETeasy, is provided for mechanical properties characterization by a self-built IET tool, and multivariate statistical analysis purposes. The aim is double in the short term: on one hand, providing a verified data set useful to develop, test and verify methods of analysis and tailor the IETeasy instrument on the needs of each specific user; on the other hand, giving a benchmark for any one designing, building and testing his IET home-made instrument. In the long term, since the data base is open, any contribution consisting in data collected by similar self-made or commercial instruments can be added to the data base, with the aim of building a large collection of data, useful for automatic recognition of sound outputs by machine learning or other multivariate or monovariate data analysis approaches, and for instrument performance comparison and alignment.

Specifications Table

Subject	Engineering and materials science
Specific subject area	Materials characterization by acoustic analysis
Type of data	Text files .mp3 files
How data were acquired	IETeasy
Data format	Raw .mp3 Analyzed .txt
Parameters for data collection	Strings distance: 5 cm Collection interval: 8 s to 14 s
Description of data collection	Impulses were collected from the IETeasy instrument, suspending the sample on PA6 strings with a distance of 5 cm and a collection interval of 8 s to 14 s. Audio signals were collected using Audacity software on a Raspberry Pi 4 with a Raspbian OS 5.4.51.
Data source location	Institution: Universitá del Piemonte Orientale City/Town/Region: Alessandria Country: Italy
Data accessibility	Repository name: Mendeley Data Data identification number: https://doi.org/10.17632/srfp7x6wxm.1 Direct URL to data: https://data.mendeley.com/datasets/srfp7x6wxm

Value of the Data

- The data set is a collection of replicated impulses sampled on fifteen different materials, spanning from pure metals, to alloys, to polymers. Data are provided in three different formats: .mp3 audio file for direct wave data processing, two-column .txt files for monovariate or multivariate data analysis and the values of magnitude of .txt files processed by Fast-Fourier Transform (FFT) for the analysis of the resonance frequencies of the materials. These data can be used with multiple purposes: instrumental precision evaluation, accuracy of outputs with a comparison with data reported in scientific literature (collected using professional instruments [1–5]) and multivariate analysis for classification.
- Data can be used for developing new quality control methods, or to make the existing ones more robust, for a fast and easy on-line analysis in productive processes and in research laboratories.
- Analyzing these data can promote the spread of open-source and cheap self-assembled IET instruments, that can result in two principal advantages: the expansion of the present data set, which reflects in more robust analyses and potentialities in machine learning, and the

evolution of this technology in the open source model. Widespread in-situ quality control can help reducing scraps in production, help reducing environmental impacts, while improving the value of the production itself.

1. Data Description

The present data set was gathered by collecting ten measurements on each of the analyzed material. It can be found in the repository on Mendeley Data linked in the specification table, and it is organized as described in the following tree diagram:

```
root/
├── Audio data
│   ├── AISI 304 steel
│   ├── AISI 316 steel
│   ├── Aluminium 6082
│   ├── B10 bronze
│   ├── B12 bronze
│   ├── BrAl alloy
│   ├── C45E steel
│   ├── Copper
│   ├── CW614 brass
│   ├── Fe37 drawn
│   ├── Nylon 6
│   ├── Polizene
│   ├── Pom-C
│   ├── Teflon
│   └── X150 steel
├── Text data
│   ├── AISI 304 steel
│   ├── AISI 316 steel
│   ├── Aluminium 6082
│   ├── B10 bronze
│   ├── B12 bronze
│   ├── BrAl alloy
│   ├── C45E steel
│   ├── Copper
│   ├── CW614 brass
│   ├── Fe37 drawn
│   ├── Nylon 6
│   ├── Polizene
│   ├── Pom-C
│   ├── Teflon
│   └── X150 steel
└── Fourier-transformed data
    ├── AISI 304 steel
    ├── AISI 316 steel
    ├── Aluminium 6082
    ├── B10 bronze
    ├── B12 bronze
    ├── BrAl alloy
    ├── C45E steel
    ├── Copper
    ├── CW614 brass
    ├── Fe37 drawn
    ├── Nylon 6
    ├── Polizene
    ├── Pom-C
    ├── Teflon
    └── X150 steel
```

Table 1
Analyzed materials and sample parameters.

Sample	Length (cm)	Depth (cm)	Thickness (cm)	Mass (g)
6082 aluminium	9.900	5.985	0.985	157
AISI 304 steel	9.900	10.050	0.820	636
AISI 316 steel	10.045	5.000	1.035	400
Fe37 steel	9.900	7.990	0.795	488
X150 steel	9.950	10.225	1.065	826
B10 bronze	10.000	8.250	1.250	905
B12 bronze	10.000	8.325	1.345	996
BrAl	9.855	6.460	0.680	319
C45E steel	10.010	9.230	1.015	735
Copper	10.650	9.200	1.010	824
CW614 brass	9.825	7.600	0.810	507
Nylon 6	10.245	10.350	1.035	120
Polizene	10.195	7.7650	1.015	75
Pom-C	10.315	10.150	1.065	154
Teflon	10.290	10.235	1.115	230

Each level-2 directory indicates the file format contained in children folders: .mp3 audio files, .txt raw files, .txt FFT pre-processed files. Each level-3 directory, instead, indicates the corresponding analyzed material, which is described by Table 1 in the following section. Audio files are 8 s to 14 s long with IET pulses placed at about half-length, in order to collect the whole acoustic signal. Quality settings of the audio file are MONO 32-bit float with sampling rate of 48,000 Hz. In Figs. 1–3, measurements on the materials are reported as both wave form and FFT processed profiles. Due to the high on number of data (fifteen different samples and ten measurements for each sample), only the first measurement for each sample is reported in the graphs. In Fig. 1(a) the average spectra calculated on the ten measurements for each sample are reported for comparison. All polymeric samples show absolute sound intensities that are up to twenty times lower than those belonging to metal samples. Moreover, no important peaks are present above 10,000 Hz. In panels Fig. 1(b)–(f), different steels are showed. Shape and duration of the sound wave in the figures are very different for each material, in particular between Fe37 steel and X150 steel, that both have a pulse duration of about 1 s, but a very different damping shape. The characteristic frequencies and magnitudes are different as well from one sample to another. AISI 304 steel and AISI 316 steel, which are very similar in composition, being both part of the AISI 300 steel series, show very different profiles, with the AISI 304 being richer in peaks and with a natural resonant frequency at lower values than AISI 316 steel. In Fig. 2 data collected on other alloys are reported. In these data, a longer sound wave than steels can be observed, with BrAl alloy, lasting more than two seconds. Differences are also marked in the frequency domain with a large variety in peak number and positions. B10 and B12 bronzes show very similar patterns, with a shift of peaks at higher frequencies for B2 bronze. In Fig. 3 the sound waves and the spectra of four polymers are reported. As previously observed, the magnitudes are lower than those belonging to metallic samples. Profiles also tends to be much more noisy. Differences can also be observed in the waves of the miniatures, which are much shorter and irregular than those showed in Figs. 1 and 2. For each of the analyzed samples, length, depth, thickness and mass are reported in the following section, as required for the calculation of some properties such as Young modulus.

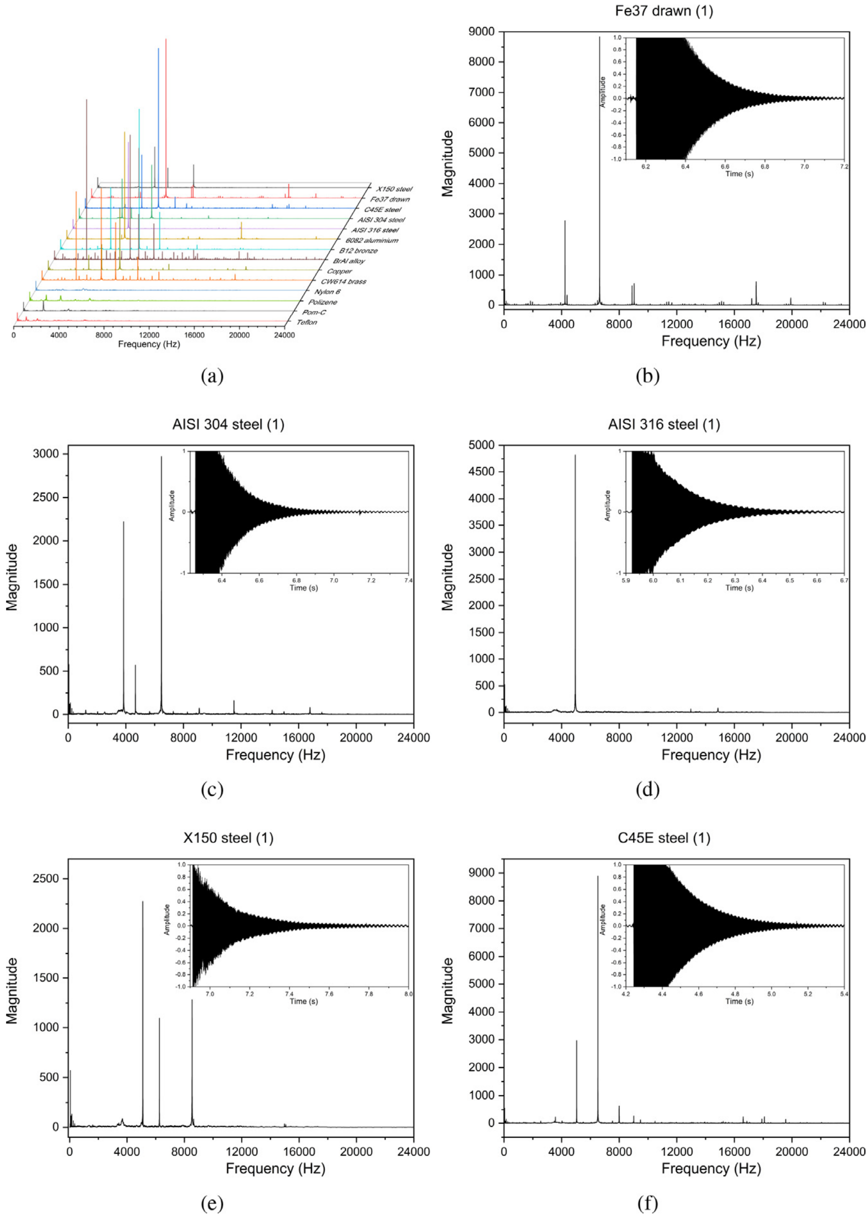

Fig. 1. In Fig. 1(a) the collection of the average spectra of the fifteen analyzed materials is reported. The reported spectra were calculated on the ten measurements for each sample. In Fig. 1(b)–(f) each sound wave (shown in the inset) and the corresponding frequency pattern are reported for different steel alloys.

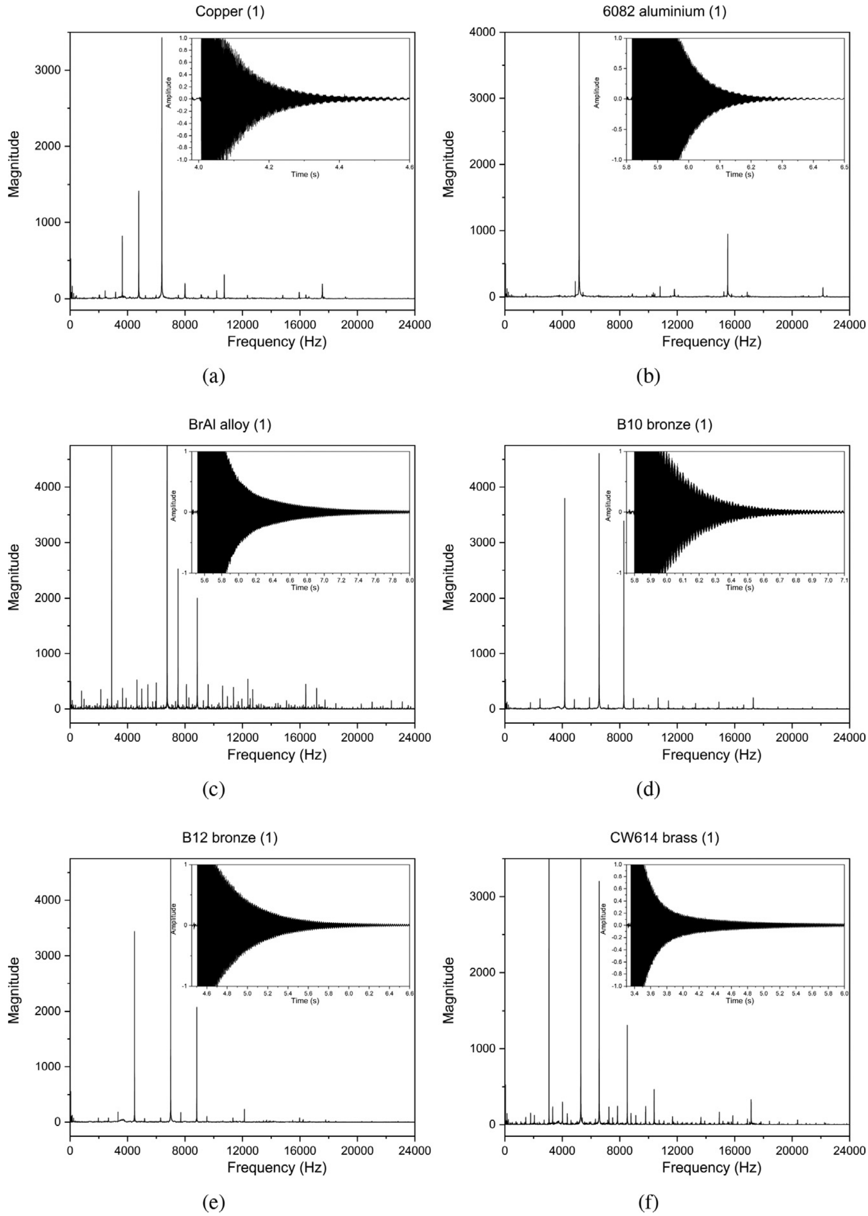

Fig. 2. The reported spectra were calculated on the ten measurements for each sample. In Fig. 2(a)–(f) each sound wave (shown in the inset) and the corresponding frequency pattern are reported for different copper or aluminium-based alloys.

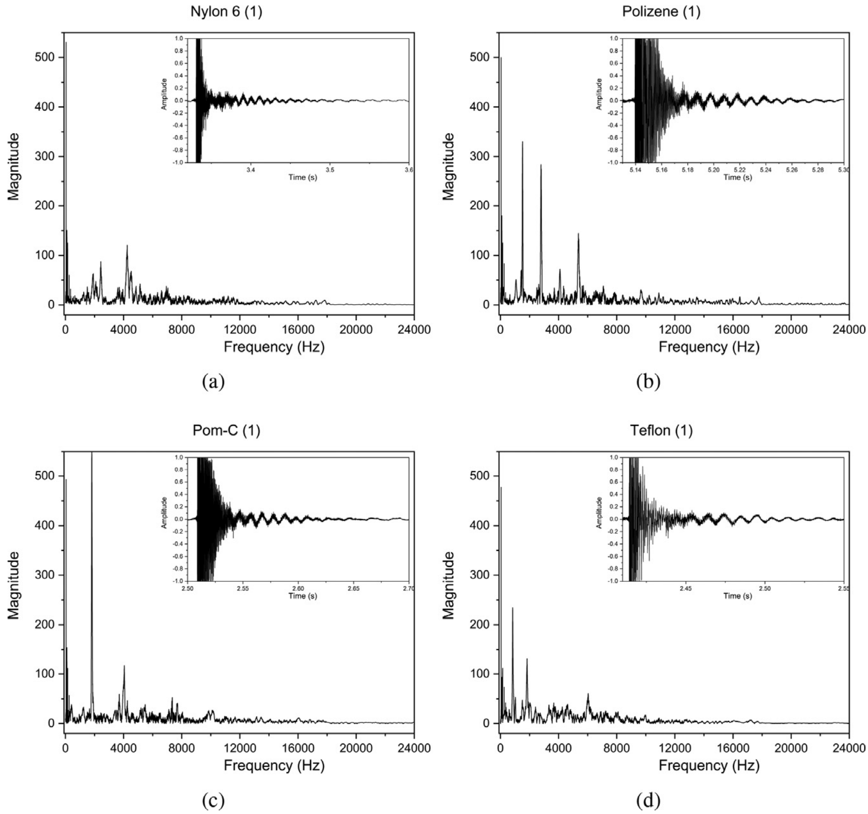

Fig. 3. The reported spectra were calculated on the ten measurements for each sample. In Fig. 3(a)–(d) each sound wave (shown in the inset) and the corresponding frequency pattern are reported for different polymers.

2. Experimental Design, Materials and Methods

2.1. Materials

Analyzed materials were purchased by HobbyMetal, (Giulianova, Italy) which provided samples with mass and dimensions as described in Table 1.

2.2. Data collection

Data were collected by the IETeasy instrument [6] placing the sample on the strings distanced by 5 cm and releasing the percussion mallet. The acoustic output is collected by a microphone that faces the top of the sample, as detailed in the supporting article. The whole setup was connected to a Raspberry Pi 4 which uses Raspbian 5.4.51 as operating system. Audio .mp3 files were recorded using Audacity 2.4.2 [7] open-source software and then converted in .txt raw files with SoX [8]. Raw files were then processed by fast Fourier-transformed on Origin 2020 [9] to obtain the signal in the frequency domain. Two column data (frequency vs. magnitude) were then exported in .txt files.

CRediT Author Statement

The instrument was assembled by NM and ML. Data collection was performed by NM. All the authors analyzed the data, edited the manuscript and approved its final version.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

CRediT Author Statement

Nazareno Massara: Data curation, Methodology, Writing – original draft, Writing – review & editing; **Enrico Boccaleri:** Conceptualization, Writing – original draft, Writing – review & editing; **Marco Milanesio:** Formal analysis, Funding acquisition, Supervision, Validation, Writing – original draft, Writing – review & editing; **Mattia Lopresti:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing.

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