Dynamic calibration of bridge amplifiers used for periodical force measurement

C. Schlegel, G. Kieckenap, and R. Kumme
Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig
Christian.Schlegel@ptb.de, Gabriela.Kickenap@ptb.de , Rolf.Kumme@ptb.de

Abstract

This contribution describes how bridge amplifiers used in dynamic force measurement can be dynamically calibrated. A special analogue device, called "bridge standard", can be used to simulate a bridge detuning in the mV range as, like it occurs in strain gauge force transducers [1]. The frequency response of the amplifier has to be corrected for the sensitivity of the force transducer. The principle of the bridge standard as well as measurements of different amplifiers will be presented. In addition, the influence of the amplifier frequency response of the parameter identification of the force transducer will be discussed.

Introduction

Bridge amplifiers have a widespread field of applications for several types of sensors. The most precise force calibration performed with strain gauge force transducers in dead weight standard force machines. Nevertheless, static calibrated force transducers are often used in dynamic applications. For that reason, more and more national metrology institutes as well as commercial calibration services establish procedures for dynamic force calibration. Especially at the PTB several different possibilities exist for a dynamic force calibration. There are devices for traceable periodic- and shock force calibrations available [2]. In the periodical force calibration the main output of a calibration is the dynamic sensitivity, which is the ratio between the output signal of the force transducer to the acting dynamic force. To get the real signal of the force transducer, the frequency response of the amplifier has to be known. In the case of piezoelectric force transducers a charge amplifier is used. The calibration of these devices is well known and can be performed with a reference capacity and a precise voltmeter. In the case of amplifiers used for strain gauge transducers, a special device was developed, e.g. at PTB [1]. For this device, recently a traceable calibration was performed with the consequence that up to now also a traceable periodic calibration of force transducers can be provided as an official service.
Currently in the European Metrology Research Programme (EMRP), one promoted research topic is the "Traceable Dynamic Measurement of Mechanical Quantities", which includes work packages about dynamic force, dynamic pressure, dynamic torque, the electrical characterization of measuring amplifiers, and mathematical and statistical methods and modelling [3]. During this program, also a new device for bridge amplifiers based on digital technique will be applied and tested. First comparisons with the analogue device described here showed a good agreement between both devices.

The principle of dynamic calibration

A simplified layout of the device can be seen in Figure 1. The principle is to substitute a force transducer, normally connected to the amplifier, with a kind of calibration Wheatstone bridge. This bridge is a substitute for the strain gauges implemented otherwise on the transducer. To realize a dynamic bridge detuning, U_{Br}, an AC voltage can be coupled, e.g. with a signal generator, inductively in the bridge. The input signal provided by the signal generator is normally in the voltage range; in contrast, the bridge signal is in the mV range. For that reason, the input signal is down-converted before it is coupled into the bridge by a certain circuit. For a calibration, the bridge voltage has to be known, which is also inductively coupled out to a reference output, U_{ref}. All impedances are dimensioned in such a way that U_{Br}=U_{ref}.

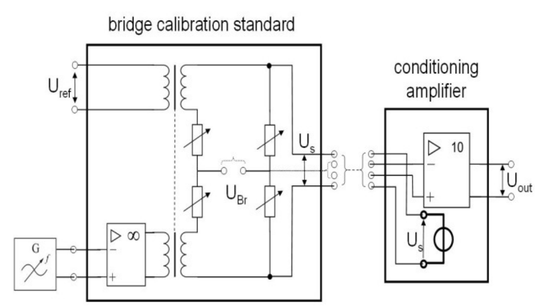

Figure 1. Schematic circuit of the bridge calibration standard, left, and the amplifier under test, right.

The coils responsible for the input/output coupling of the signals are placed on the same ferrite core. A very crucial point is that the bridge supply voltage, Us, is provided by the amplifier, as in the real case, by using a transducer. To guarantee traceability, the complex transfer function from U_{br}/U_{ref} was calibrated in the electrical department of the PTB. According to the uncertainty evaluation which was made for this bridge, relative uncertainties in the order of a view 10^{-4} can be obtained.

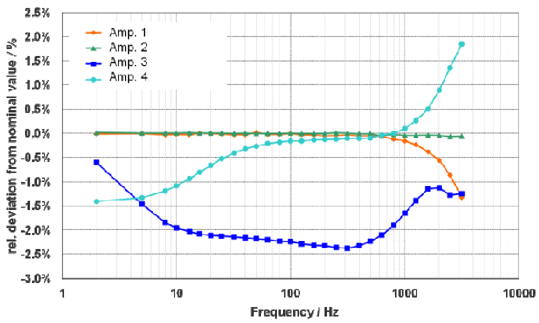

Figure 2 Relative deviation of the amplification factor from the nominal value shown for different bridge amplifiers.

The Figure 2 shows the frequency response of different amplifiers measured with the bridge calibration device. The diagram shows the deviation from the nominal amplification value. It turned out that not all amplifiers which are commonly used for static force calibration can also be applied in dynamic measurement; only two of them have a flat frequency response in the region of interest (10Hz-2kHz).

The influence of the frequency response of the parameter identification of the force transducer

With the aid of a dynamic measurement, also the mechanical parameters of a force transducer, namely the stiffness and damping value, can be determined. This determination is based on a mathematical model which assumes that the transducer can be seen as a damped spring mass system [2]. One way is to analyze the resonance behavior, e.g. measured with a white noise excitation using an electromagnetic shaker system. Thereby the resonance is obtained, e.g. by the ratio of the transducer signal to the acceleration measured on the shaker table. The stiffness can be obtained from the location of the resonance peak, and the damping factor of the force transducer from the full width at half maximum. In Figure 2, a typical resonance peak is drawn at 1 kHz. The calculation illustrates the influence of the frequency response of the amplifier on the resonance behaviour.

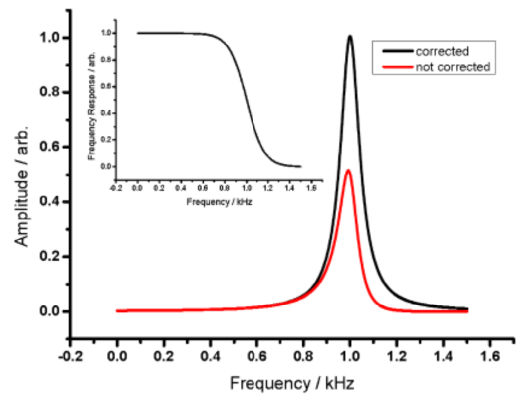

Figure 2 Calculated resonance peak shown for the corrected case (black) and non corrected case (red). The calculated frequency response of the amplifier is seen in the inlet panel.

If the frequency response is not corrected, the resonance frequency might be shifted and the full width at half maximum can be changed. Both values can be influenced thereby in the order of 1-2%.

Conclusion

The calibration of bridge amplifiers used for dynamic force calibration can be performed with a special analogue device containing a Wheatstone bridge. Investigated amplifiers show a quite different dynamic behaviour in the interested frequency range from 10Hz-2kHz. If the frequency response of the amplifier is not corrected, the dynamic sensitivity as well as the parameter determination of the force transducers is falsified. Thereby, additional uncertainty contributions up to a few percent can be in cooperated.

References

[1] R. Kumme, “Influence of measuring amplifiers on dynamic force measurement”, *Proc. 13th IMEKO TC3 Conference*, pp. 25-31, May 1993.

[2] Ch. Schlegel et al., “Dynamic Calibration of Force Transducers Using Sinusoidal Excitations”, *Think Mind Digital Library (www.thinkmind.org), Sensordevices 2011,* Aug. 2011.

[3] www.emrponline.eu