ASME B89.4.21.1-2020

Environmental Effects on Coordinate Measuring Machine Measurements

AN ASME TECHNICAL REPORT

The American Society of Mechanical Engineers

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FOREWORD

This Technical Report addresses the environmental effects on measurements taken when using coordinate measuring machines (CMMs). In this Report, the considered effects are those due solely to environmental effects, such as temperature and vibration. Operational effects, including items such as fixturing, materials, probe considerations, and the workpiece itself, are not addressed in this document.

The intent of this document is not to provide detailed solutions to specific applications, but rather to address and highlight some items to consider when making measurements on CMMs, with the ultimate objective of reducing the uncertainty in the measurement.

The subject matter itself is extremely broad and complex, making standardized solutions very difficult. As such, how to deal with environmental issues is highly user-dependent and difficult to standardize. The initial concept was to try to develop a standard test, similar to those currently documented in ASME B89.4.10360.2. This was, however, contrary to the concept of making the performance evaluation tests quicker and therefore less expensive to run.

When the CMM is used within rated operating conditions, including environmental conditions as stated by the CMM manufacturer, the performance of the CMM is characterized by its ASME B89.4.10360.2 accuracy specifications. For any combination of environmental conditions that are within the rated operating conditions, the accuracy of the CMM as characterized by ASME B89.4.10360.2 is expressed as a maximum permissible error (MPE) that is assigned by the CMM manufacturer; different MPE values may be assigned to different environmental conditions within the rated conditions. These accuracy specifications apply only to the measurand embodied in the calibrated reference artifact used in the specification, e.g., point-to-point length as measured on gage blocks, step gages, and similar artifacts permitted by the performance testing protocol.

However, if the CMM is used in conditions that are outside its rated environmental conditions, the performance of the CMM is no longer assured. Some guidance for the derating of the CMM performance is given in ASME B89.4.10360.2; however, unless the CMM manufacturer has agreed to a derating method, there is no applicable accuracy specification.

From these discussions, it was decided that the best approach would be to develop a reference document that would elucidate the problems and allow the user of the machine to decide what, if anything, to do about it.

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ENVIRONMENTAL EFFECTS ON COORDINATE MEASURING MACHINE MEASUREMENTS

1 SCOPE

This Technical Report discusses important influences of the environment on dimensional and geometric measurements performed using coordinate measuring machines (CMMs), including influences on both the machine and the workpieces to be measured. This Report discusses the thermal effects related to the use of tactile CMMs, but many of these effects are also applicable to optical and other noncontact coordinate measurement systems.

2 INTRODUCTION AND BACKGROUND

2.1 Operating Conditions

JCGM 200 (ref. [1]) defines rated operating conditions (4.9) and limiting operating conditions (4.10). Machine specifications, typically stated as maximum permissible errors (MPEs), are intended to be applicable to a CMM that is used within its rated operating conditions. These rated operating conditions are the conditions that must be fulfilled for the machine to perform as designed (i.e., meet the MPEs). These conditions include, but are not limited to, environmental conditions. Limiting operating conditions are the extreme at which a machine can be operated without sustaining damage and without degradation of specifications when subsequently operated within its rated operating conditions.

2.2 Definition of Environment

For the purpose of this Technical Report, the CMM environment includes those elements in the machine surroundings that affect CMM system performance; effects of operators are not addressed in this Report. The environmental effects included are temperature and humidity, illumination, vibration, electrical effects, and contamination. These effects are caused or transmitted by surrounding air, building structure, other equipment, supply air, and the electrical system.

For the purpose of this Technical Report, environments are classified as “laboratory” or “shop.” A laboratory environment is controlled in order to perform measurements at an acceptable accuracy level. A shop environment is controlled only to the level required to produce acceptable workpieces. A shop environment may not be acceptable for performing measurement tasks.

2.3 Environmental Effects

The influence of environmental variables on the measurement results obtained using the CMM are classified as environmental effects. The variables are identified in para. 2.2, and their influence can vary greatly among different facilities, or even within one facility. Whereas temperature and humidity may vary depending on the time of day or season of the year, influences such as illumination, electrical noise, and vibration may be fairly constant for a given CMM installation. Contamination, either airborne or on the CMM and workpieces, may be either a steady-state or varying condition. The ability to measure contamination will depend on the nature of the installation and the perceived impact of the contamination on measurement results.

Three main methods are employed to mitigate the influence of the environmental effects, as follows:

(a) Attempt to Remove the Source of the Influence. This may be done by shutting down or moving equipment causing vibration or removing heat sources from the immediate vicinity of the measuring equipment.

(b) Attenuate the Effects of the Influence. Vibration isolators may be used between the factory or laboratory floor and the CMM, or baffles may be installed to block radiation from a heat source that cannot be moved.

(c) Compensate for the Influence. By using knowledge about how a particular influence effects the measurement and sensors to quantify the environmental state, the measurement results can be adjusted to compensate for the environment.

After mitigation, simply evaluate the influence; the uncertainty of measurement can be increased to accommodate the effect of environmental influences where these methods are not employed.