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CheckMate & ISO 9000

Overview

Origin has had a number of requests for "validation" of CheckMate software with respect to ISO 9000 and QS 9000. This document discusses the roles of various CheckMate products in product verification and monitoring of process performance and their impact on ISO 9000/QS 9000. Suggestions for processes to validate the various CheckMate software elements are given. Examples of results obtained using such procedures are given where available. Details of Origin's software development, testing and support policies and procedures are provided.

Origin Software Products

Origin is a software development and marketing company.

CheckMate Programming

CheckMate Programming's role in part verification and process performance monitoring is to produce a CMM program which instructs the CMM to measure and evaluate specified part features.

The CMM program output by CheckMate could be "taught" on the CMM or entered in an ASCII text editor if the programmer had the necessary knowledge of the nominal dimensions of the part. In this way CheckMate Programming is equivalent to other methods of CMM part program generation. All methods, including CheckMate, rely on the CMM's internal algorithms for determining part characteristics.

Some examples of these part characteristics are

- plane attitude, offset and form (flatness)
- circle location, diameter and form (roundness)
- cylinder location, diameter, attitude and form (cylindricity)
- etc.

Similarly CheckMate and other methods of part program generation rely on the CMM's internal algorithms for part alignment.

CheckMate Programming neither enhances nor replaces the CMM's internal algorithms. CheckMate does not control the CMM motion nor does it alter the accuracy of the CMM in any way. It simply gives a set of instructions for the CMM to perform. It resides totally off-line from the CMM, usually on another computer.

CheckMate Programming does differ from other methods of part program generation in that nominal locations and dimensions do not need to be entered (typed-in) during program creation. They are extracted from a CAD model.

Any concerns about inaccuracies caused by CheckMate must then be related to the accuracy of the CAD model imported into CheckMate. On occasion Origin's customers test the validity of the IGES translation into CheckMate. The procedure used is as follows:

- points are generated in the native CAD system either on or offset from surfaces
- these points are exported along with the surfaces in IGES format

- the IGES file is translated and loaded into CheckMate
- the points are projected normal to surface to produce a new set of points
- the locations of the points are compared
- ideally, the IGES file is loaded back into the native CAD system for a similar comparison

Recently such a comparison was done with a Catia generated IGES file, the results are shown below:

CMM4	4.9996
CMM6	5.0000
CMM9	4.9998
CMM11	4.9995
CMM12	5.0003
CMM13	4.9996
CMM19	4.9997
CMM20	5.0000

The table shows the distance between a given point and a CheckMate generated point on a surface. The given points were generated at a 5.0000 mm offset from their respective surfaces in the native CAD system. In all cases the deviations are all sub-micron and would therefore be un-measurable on all but the most precise CMM's.

CheckMate Reporting

CheckMate Reporting's role in part verification and process performance monitoring is to read text reports produced by CMM's and produce new graphical and text reports from that data.

Like CheckMate Programming, CheckMate Reporting relies on the CMM's internal algorithms for the evaluation of feature characteristics. Feature form and size are taken from the CMM report and always remain unaltered.

Further calculations that CheckMate Reporting can be perform on feature positions follows:

- the reported center of a hole or slot can be projected up the feature axis to the nominal feature plane,
- the position of a hole, cylinder or slot can be evaluated with bonus (i.e., at maximum material condition) in the plane defined by the feature axis,
- any measurements can be displaced up or down the feature axis/vector by a theoretical material thickness to produce ISM (inside of material) or OSM (outside of material) reports,
- sideways deviation (hit error) of a surface or edge measurement can be removed knowing the feature vector,
- a surface or edge measurement can be reported with all deviations shown in one axis as if the CMM were locked on two axes and drove to the target point down the third axis with a zero diameter probe, again knowing the feature vector.

These simple alterations of the reported feature position are all derived from the feature axis/vector as determined by CheckMate Programming from the CAD model. These calculations can be disabled and all reported will show the feature positions exactly as they appeared in the CMM report.

CheckMate Reporting's statistical calculations as used for process performance monitoring are all derived from the formulas in the Fundamental Statistical Process Control Reference Manual produced by General Motors, Ford and Chrysler working under the auspices of the Automotive Division of the American Society for Quality Control Supplier Quality Requirements Task Force, in collaboration with the Automotive Industry Action Group with the following exception:

According to the Fundamental Statistical Process Control Reference Manual, the process capability indices (Cp and Cpk) are calculated from the estimated standard deviation derived from R-bar. Because this estimated standard

deviation is only defined for subgroups of 2 or more samples, Cp and Cpk are not defined for subgroups with a size of one. Despite this fact, Origin customers have still requested an evaluation of Cp and Cpk for subgroups with a size of one. To satisfy this demand we quote the process capability indices (Cp and Cpk) with the values of the process performance indices (Pp and Ppk). The latter values are defined for a sub-grouping of any size. For all other subgroup sizes except one, Cp and Cpk are calculated in accordance with the formulas in the Fundamental Statistical Process Control Reference Manual.

CheckMate Reporting's Surface Analysis' role in part verification and process performance monitoring is to analyze manually collected center-of-ball CMM readings against the CAD model.

The center-of-ball readings are collected on the CMM using the CMM's resident software including any error correction algorithms. These points are exported in a data file to be analyzed by CheckMate off-line. CheckMate does not alter the CMM's function in any way.

The center-of-ball points are projected to the CAD model to determine part deviation taking into account the probe diameter.

The accuracy of results produced by CheckMate Reporting's Surface Analysis depends on the accuracy of the imported CAD model and the surface projection algorithms used. These are precisely the same concerns that arise with CheckMate Programming. Please see the section on CheckMate Programming above for a discussion of these issues.

The validity of CheckMate Reporting's Surface Analysis can be checked with a DCC CMM. The projected data from the manual measurements can be used to create a CheckMate CMM program rather than simply a report. Executing this program on the same part should produce a report the same as the one produced by CheckMate Reporting's Surface Analysis within the limits defined by the reproducibility of the CMM's used.

CheckMate Analysis

CheckMate Analysis SoftFit's role in part verification and process performance monitoring is to augment the "gate keeper" role of the CMM inspection software residing on and controlling the CMM. CheckMate Analysis SoftFit is most often used for "trouble shooting". When a part or process has gone out of specification CheckMate Analysis can be used to determine the root cause of the problem.

SoftFit alters the coordinate system of the actual measurements with respect to the nominal target features to minimize deviations. The proprietary fitting algorithms used by SoftFit were developed by General Motors of Canada in a joint project with the National Research Council of Canada and mathematicians from the University of Guelph (Ontario Canada).

A utility exists within CheckMate Analysis to check the validity of any SoftFit derived coordinate system. CMM reorientation instructions can be created that will instruct the CMM to alter its coordinate system so that it matches the coordinate system derived by SoftFit. Re-measuring the part in this coordinate system should produce a report similar to the report produced by CheckMate Analysis without re-measuring. Tests have shown this to be the case within the limits defined by surface curvature and surface finish.

CheckMate Analysis can be used in part verification in the determination of tolerance conditions for GD&T call-outs which include only a partial datum reference frame. Often position and/or surface profile tolerances are defined only with respect to a primary datum. This allows a "best fit" to be performed in the plane of the primary datum in an attempt to bring the part into specification.

This type of "best fit" is normally not handled by CMM software's internal algorithms, and so must be performed by external software algorithms like SoftFit. Unlike CMM software "best fit" algorithms which determine geometric features from data points sets (planes, lines, circles, cylinders, etc.), we at Origin know of no industry standards for evaluating "whole part" best fits. Using CMM reorientation instructions, any SoftFit derived coordinate system can be evaluated by re-measuring the part in the altered coordinate system.

SoftOrient

SoftOrient's role in part verification and process performance monitoring is to replace a hard fixture's role in part alignment. Either a fixture becomes completely unnecessary or a simple fixture which holds the part inaccurately, or

by non-datum features can be used. SoftOrient emulates a hard fixture and alters the CMM coordinate system so that the part appears in an orientation as if it were being held by a precision holding fixture at datum locations.

SoftOrient uses the same proprietary fitting algorithms used in CheckMate Analysis SoftFit.

In a sense SoftOrient is self-validating. After SoftOrient alters the CMM coordinate system, the CMM program used to collect data for SoftOrient can be rerun. The deviations in this report show the accuracy of SoftOrient which is limited only by surface curvature and surface finish.

Because SoftOrient replaces the function of hard holding fixtures a gauge R&R study can be performed with SoftOrient just as with any hard fixture. We performed such a study to compare SoftOrient with a certified hard fixture. The procedures documented in the Measurement Systems Analysis Reference Manual produced by General Motors, Ford and Chrysler working under the auspices of the Automotive Division of the American Society for Quality Control Supplier Quality Requirements Task Force were used for this study. The results for an average over ten gauge points are shown below:

	Hard Fixture:	SoftOrient:
R-bar all operators	0.069	0.008
X-Diff	0.066	0.002
Rp	0.294	0.156
%Cont EV	28.1	6.9
%Cont AV	16.4	0.0
%Cont R&R37.4	6.9	
%Cont PV	55.5	93.0

The results show that not only does SoftOrient match the performance of a hard fixture, it surpasses it particularly in its ability to remove operator variability. The above gauge R&R was based on a single iteration of SoftOrient after a single measurement. A customer study was performed using multiple iterations of measurement and SoftOrient. The reproducibility of measurements the hard fixture in this particular study was 0.006", for SoftOrient it was 0.000006" limited only by the repeatability of the CMM.

Origin Software Policies and Procedures

Software development and testing

Origin Software is developed in the C programming language using the structured programming and object oriented programming paradigms were appropriate. Source code is backed up on a regular basis and is stored in three different physical locations.

Software versions are tracked by a major release number followed a sub release "point" number and a revision number, for example, 3.1 x003. An expanding database listing enhancements and bug fixes is maintained with the source code by the chief developer.

New software is "alpha" tested by the software developers on standard "proof of performance" parts. After successful alpha testing, software is used internally by Origin application engineers and in CheckMate training classes for further test out.

After this process "beta" software is released to Origin's beta sites for further testing.

Individual users may receive immediate partial software updates on a "need be" basis, usually related to output to and input from their particular CMM. These interim updates are not released to all customers until the software has

been fully tested. All customers are brought up to date at “point” releases (for example 3.0 to 3.1) and major release (for example 3.1 to 4.0).

Software support

Software support requests (enhancement requests and bug reports) are logged into a data base. The requests are prioritized as immediate, high, medium or low urgency depending on its impact on the customer’s operation. Any requests dealing with a reported inaccuracy in any calculations performed by any Origin product are given an immediate status.

Hard copies of the request are sent to the support coordinator and the appropriate application engineer(s) or developer(s). The support request is handled as appropriate. Customers are variously informed

- of a user error and instructed on the correct procedure for using the software function in question;
- of a “work around” for the problem encountered, the problem is passed on to the development staff as a medium priority item;
- that a software update will be produced to handle the problem, the problem is passed on to the development staff as a high or immediate priority item, these updates are usually delivered electronically to the customer via modem or the internet;
- that an enhancement will be produced, the request is passed on to the development staff as a low priority item.

As software is updated in response to a support request, the software revision number is incremented. Any other customer affected by a software update are informed, affected customers are usually defined by the type of CMM they employ. At “point” and major releases all customers are brought up to date.

Summary

Origin’s software products do **not** affect the control or accuracy of the CMM in any way. Origin’s software products have been shown to be accurate to the point where errors introduced by Origin software are undetectable on all but the highest precision CMM’s. Even then, the errors introduced by Origin’s software are a small fraction of the tolerance specification of any part feature measured with CMM technology.

Released (i.e., non-beta testing versions) Origin software products have been shown to consistently give satisfactory and correct results in day to day operations in the CMM laboratories of many customers over the past eight years.

As a company, Origin has the necessary policies and procedures in place to ensure the continued enhancement and reliability of its software products and support.