Powertrain Part and Assembly Defect Detection and Discrimination

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The sequence of process steps for machining of powertrain mating surfaces and the critical features on those surfaces are subject to leaving any of a substantial variety of potential surface defects on the finished part. Engine blocks, cylinder heads, automatic transmission valve bodies and transmission cases, and certain other precision parts and downstream assemblies may:

- Be produced with defects caused by the specific material removal actions of the various machine and their tools and associated fixturing elements, or
- Have defects brought to the part surface that were originally internal defects from a sub-optimal casting process or raw material composition deficiency, or
- Incur defects (damage) caused to the part surface during fixturing, clamping, or other handling steps or equipment mis-adjustment or failure, or
- Have contaminating particles of various types applied and not reliably removed in spite of nominal cleaning and drying operations.
- Have parts left off of, mis-applied, misconnected, or left unattached on engine, transmission, or overall powertrain assemblies.

The categories of surface dimensional defects that can, and often do, exist at the end of a powertrain machining line and prior to part assembly include:

- Surface porosity
- Burrs
- Scratches
- Gouges
- Dings
- Residual metal chips
- Residual non-metallic "dirt" particles from transport or other handling components.
- Absence of a specified feature
- An incompletely machined feature
- An incorrectly located individual feature (relative to some specified datum)
- Offset (incorrect location) of an entire set of specified features
- Incorrect machining of a specific individual specified feature
- Incorrect machining of all of the features that employ a given specific tool
- Excessive surface waviness indicative of a broken or overly-worn CNC tool.
- Incorrect assembly of components due to interchanging of parts
- Incorrect assembly due to missing components
- Incorrect assembly due to mis-location or mis-orientation of components

The root causes of defects are highly variable and specific to each powertrain line's equipment complement and process settings. Very significantly, the root cause of any particular defect type will determine whether it is:

- A random event that is not more likely to occur on a part just because it happened on the immediately previous produced part, or
- An event that will recur almost always after it first occurs, or
- A condition that reflects a slower change in a process that is drifting out of control until it starts to produce defects with increasing frequency.

The probability, likely root cause(s) and physical nature of any defect(s) of concern will determine the appropriate strategy to be followed to reduce their occurrence to the minimum possible frequency. That strategy may call for infrequent or frequent or 100% inspection of parts for defects. It may also call for examination of the entire surface of a finished powertrain part or assembly. Alternatively, it may only require examination of certain features or areas of a part. If the manufacturing objective includes minimizing the costs and productivity losses from production of scrap, the logical remedy is to detect defects as soon as they start to occur. If the objective is also to minimize the wasted cost of further processing or use of a defective part having random defects, then 100% inspection for those random defects must be considered.

20th-century attempts to detect defects in precision machined surfaces have resorted to methods ranging from manual visual inspection to basic mechanical and optical gauging techniques. The limitations and failures of these methods have been recognized for many years. Specifically, they are often:

- Too slow to detect repetitive defects before numerous further unacceptable parts have been produced, and
- Too incomplete and inaccurate to detect an adequate percentage of defects that occur, and
- Too primitive in their discrimination ability to sort out one defect type from another so that proper remedial action could be taken for each, and
- Unable to discriminate certain surface phenomena that are not defects at all, from those that are defects, therefore producing excessive false detections.
- In the case of human visual inspection, unreliable in detecting actual infrequent defects due to the well-known human factors of boredom, distraction and fatigue.

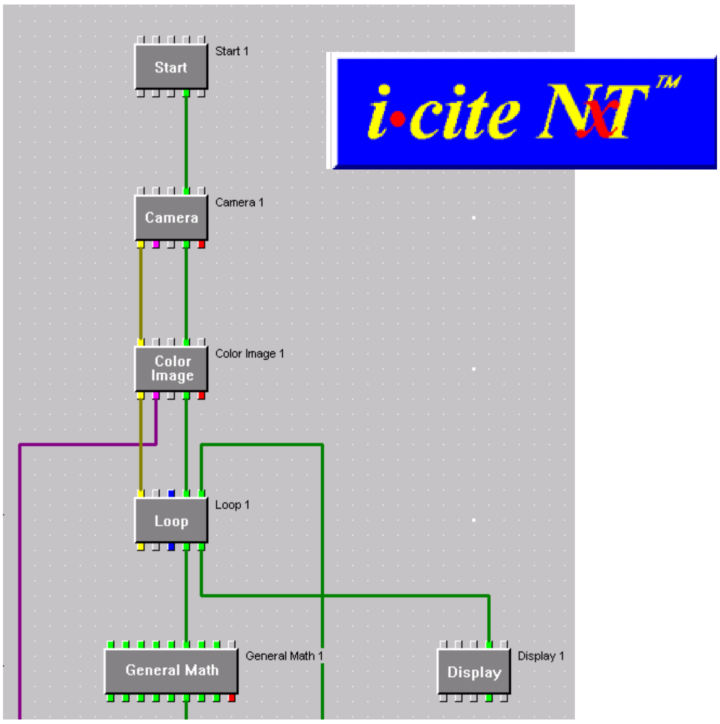
Fortunately in the current era, high-definition, high-speed, 3-dimensional holographic and multi-stereo vision automation finally enable reliable defect detection and defect type discrimination to be automatically performed on precision powertrain parts and assemblies and other types of manufacturing at whatever inspection rate is required.

Accurate automated defect detection requires the employment and integration of all of the following key technological ingredients:

- Part or assembly illumination that enhances and distinguishes the fundamental characteristics that highlight or clarify the differences between different types of defects, as well as the differences between defects and non-defect surface phenomena (such as a mere 2-dimensional blemish or spot).
- Sensing devices and configurations that can exploit the observable images created by the illumination of the parts and assemblies and capture 3-dimensional information with sufficient spatial and spectral resolution.
- A repertoire and configuration of algorithm components that incorporate enough knowledge, sensitivity and generalization ability to robustly produce correct defect detection and discrimination decisions. These decisions must be produced across the wide range of different defect and non-defect instances that occur. While exhibiting that capability, this algorithm suite must be executable at speeds required by the manufacturing operating environment.
- An application definition and development environment that enables the total vision solution – illumination, sensors and algorithms - to be implemented and integrated for a new application, and enhanced as new information is obtained, within a minimal amount of elapsed time and skilled manpower.

The Coherix machine vision and metrology technology platforms have been developed and deployed to meet these realistic manufacturing requirements across multiple industries internationally. The ***i-Cite™*** machine vision application development and execution platform is widely used in the food processing, semiconductor, heavy manufacturing and other industries for detection of defects and measurement of features of objects at rates up to 15,000 parts per hour. The ***ShaPix®*** interferometric metrology and defect detection platform is employed in the automotive and the precision machined parts manufacturing industries to measure and detect defects in featureless surfaces on both small and large machined parts.

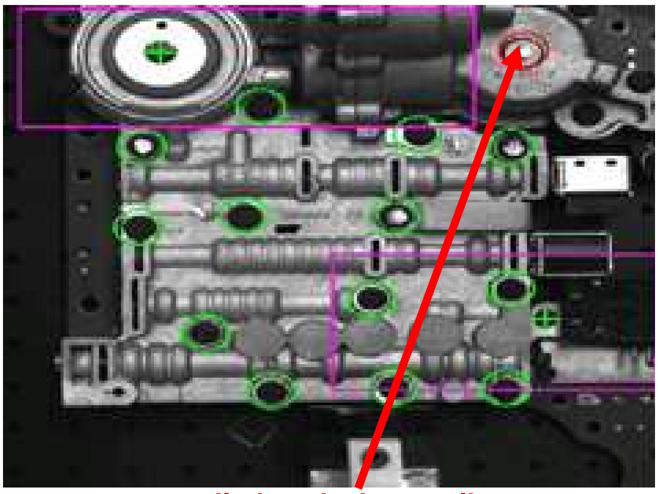
The ***i-Cite*** platform enables a machine vision solution to be created in hours to days using an icon-based graphic algorithm configuration paradigm. In this development environment , algorithm components are viewed, selected and interconnected as a set of functional processing “chips” as illustrated in the figure below. ***i-Cite’s*** large repertoire of “chips” provide for configuring the hardware, the communications, the processing, the display and the control actuations of a complete machine vision application solution. Solutions may entail a wide range of functionalities and total solution complexities. Without requiring any programming whatsoever, the resulting algorithm can then be executed at real-time rates in the same ***i-Cite*** operating environment.



i-Cite Graphic Vision Algorithm Construction Illustration

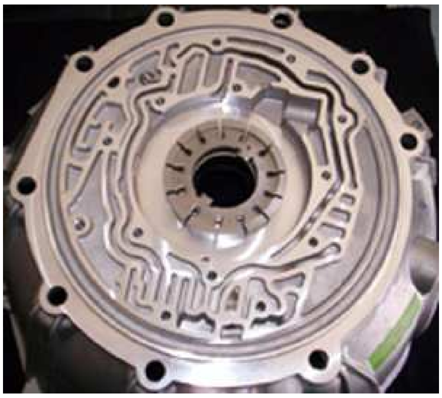
Vision system solutions built on the ***i-Cite*** platform are used for defect detection based upon 3-dimensional shape and size measurements, color variations, 3-dimensional relationships among part features and critical components, completeness of assembly, and the presence and correctness of imprinted codes and labels, just to name a few examples. Measurements down to the micron level are employed when required to develop accurate inspection decisions

An *i-Cite*-based Completeness of Assembly Inspection Solution

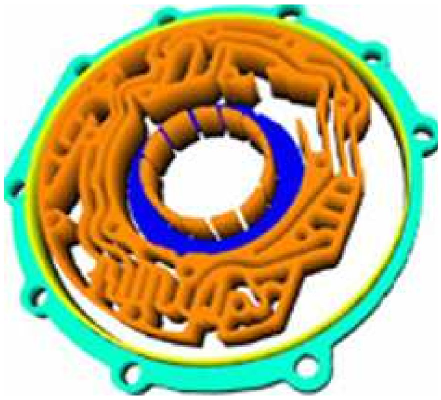


Failed – Missing E-Clip

The ***ShaPix*** holographic interferometry platform measures the 3-dimensional flatness, waviness, and other characteristics of machined nominally-planar surfaces to the micron level. It detects and measures dimensional features located in those surfaces.



The face of a pump housing with four surface planes required to be parallel



Where the application requires the power of both of these two platforms to accomplish part defect detection or inspection for dimensional correctness, they can be combined into a single integrated system solution.

Together these Coherix vision and metrology platforms provide unmatched capability for high-definition 3-dimensional measurement, together with defect detection and inspection, to ensure product quality and accurate process control.