Case History:

Improved Robotic Scoring Method

SUMMARY

An automotive equipment supplier was burdened with an inefficient method of teaching high-tolerance robot paths for Passenger Airbag Scoring equipment. An alternative method of producing and implementing Skin Scoring Path Locations for robot was investigated using RobotWorks. The new method was tried on one customer job with ***excellent results***. This proposed method was then retrofitted to an existing second job, again with excellent results.

DISCUSSION & DESCRIPTION

The latest trend in automotive manufacturing of Instrument Panel ("IP") Assemblies is to "score" or partially cut the IP skin in order to weaken it. This weakening is essential to Passenger Air Bag ("PAB") deployment. The Supplier produced robotic equipment to move a knife blade along a 3-Dimensional path and cut the score line. The path was taught in a variety of manual methods. The existing control algorithm used by the Supplier was to attempt to compensate the position of the cutting blade off of the surface of the Fixture Plate Insert. This method did not work very well and cost the Supplier in terms of high scrap rates, extensive equipment setup time requirements, high field service support requirements, and lost customers due to dissatisfaction.

Because of critical scheduling requirements, the Supplier sought an alternative method of producing customer prototype parts in a short period of time. The alternative was to use RobotWorks to generate robot locations.

Instrument Panel Skins are held with vacuum on a form-fitting 3-dimensional fixture conforming to the instrument panel contours. Skin is approximately 1.5 mm thick. Skin must be scored to achieve customer-specified Remaining Wall Thickness (RWT). This RWT dimensions for this application is 0.4mm ±0.10mm. Cutting blade must be held normal to Fixture Plate surface at all points during the cut.

FIGURE 1: Intier Job# IN-068A (J61J) Scoring Fixture. Figure shows robot with precision pointer attached, teaching Fixture Coordinate System points. The Fixture Insert was designed to have three locating features machined into it to be used at teaching points.

THEORY

A ***new theory*** of developing a set of Cartesian path locations was investigated.

- Fixtures are made with physical features that allow repeatable teaching of high-precision points in space relative to the Robot World Coordinate System.
- These points are used to create a Fixture Coordinate System in the Robot Coordinate System.
- CAD models of the fixture and path data are used by an offline robot programming software package to create robot locations.
- The use of a local Fixture Coordinate System isolates point teaching errors and allows calcaulation of path points. All that is necessary to develop the robot scoring path would be to accurately teach three locations in the Robot World Coordinate System. This allows calibration of the physical part to the CAD part.

- Thermal changes and blade wear changes can be accomodated during the course of a production run by re-calibrating the Fixture Coordinate System and measuring the cutting blade length.
- This proposed method uses the strength of a robot system, which is to move to a taught location with a repeatability tolerance.

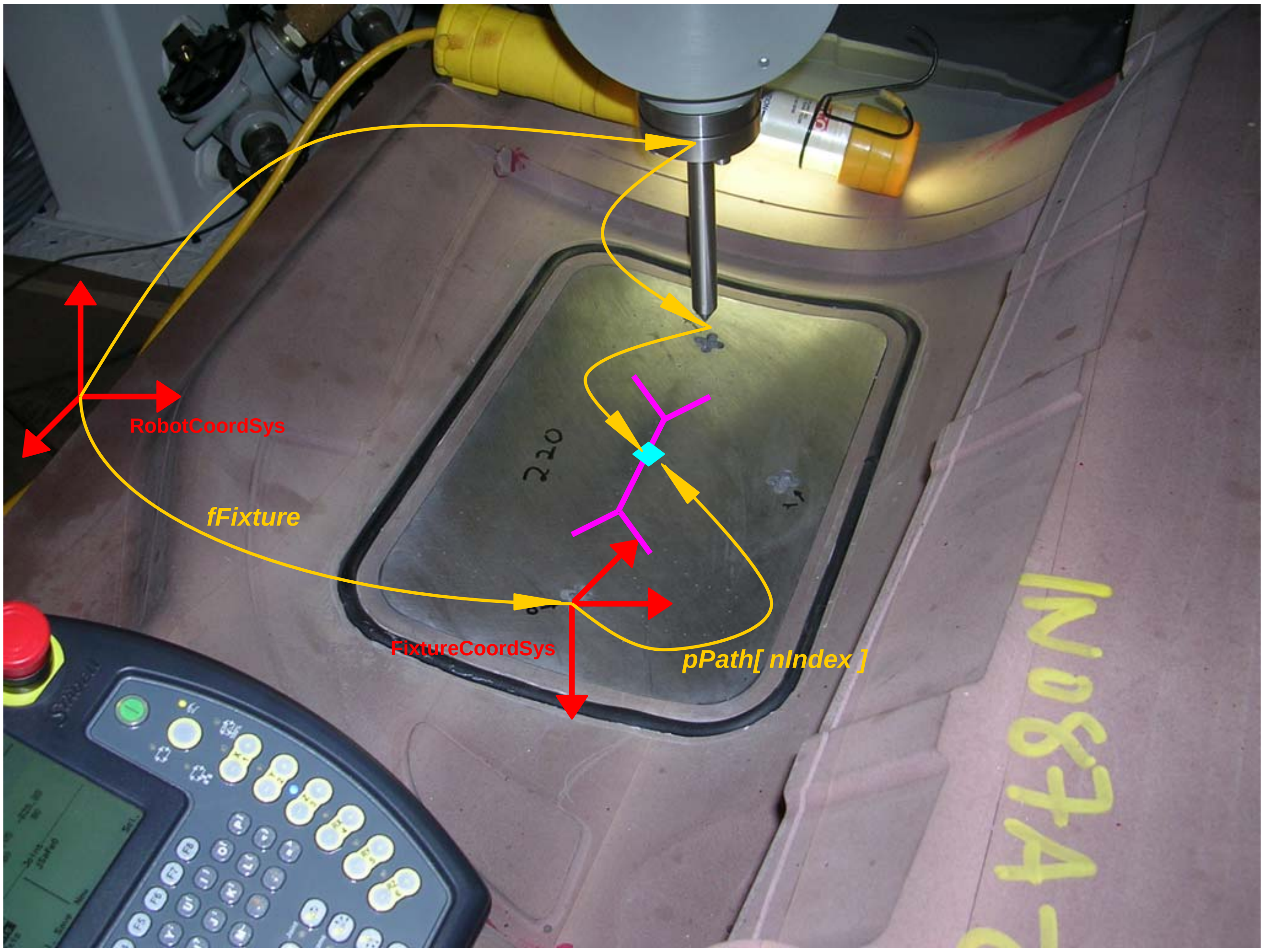


Figure 2: Path location transformations. This is the principle for the proposed method. The Fixture Coordinate System is taught from three arbitrary features located directly on the Fixture Plate Insert.

SOLUTION

- RobotWorks (www.robotworks-eu.com) robotics path software was used to create the robot points necessary to drive the robot on this complex high-tolerance 3-dimensional path.
- A CAD file of the fixture plate was imported to SolidWorks from a Parasolid format export from Unigraphics.
- The scoring path is a complex seven-segment "H-Shaped" cut for effective airbag deployment. Teaching these seven segments would require an estimated 30 hours of teaching and adjustment time by inexperienced Wixom personnel. This path was supplied as an IGES format file and imported to SolidWorks as a SolidWorks part.

- Construction of the Fixture Plate was modified to add three cruciform slot features on the Fixture Plate surface. These slots provided ***sharp, repeatable corner points***. These corner points would be used to calibrate the Robot World location of the fixture in CAD Space. Proper calibration would be necessary for accurate path point creation. An abitrary Fixture Coordinate System was created using these corner points in both CAD and Robot World. This would allow the creation of robot path points relative to a teachable coordinate system.

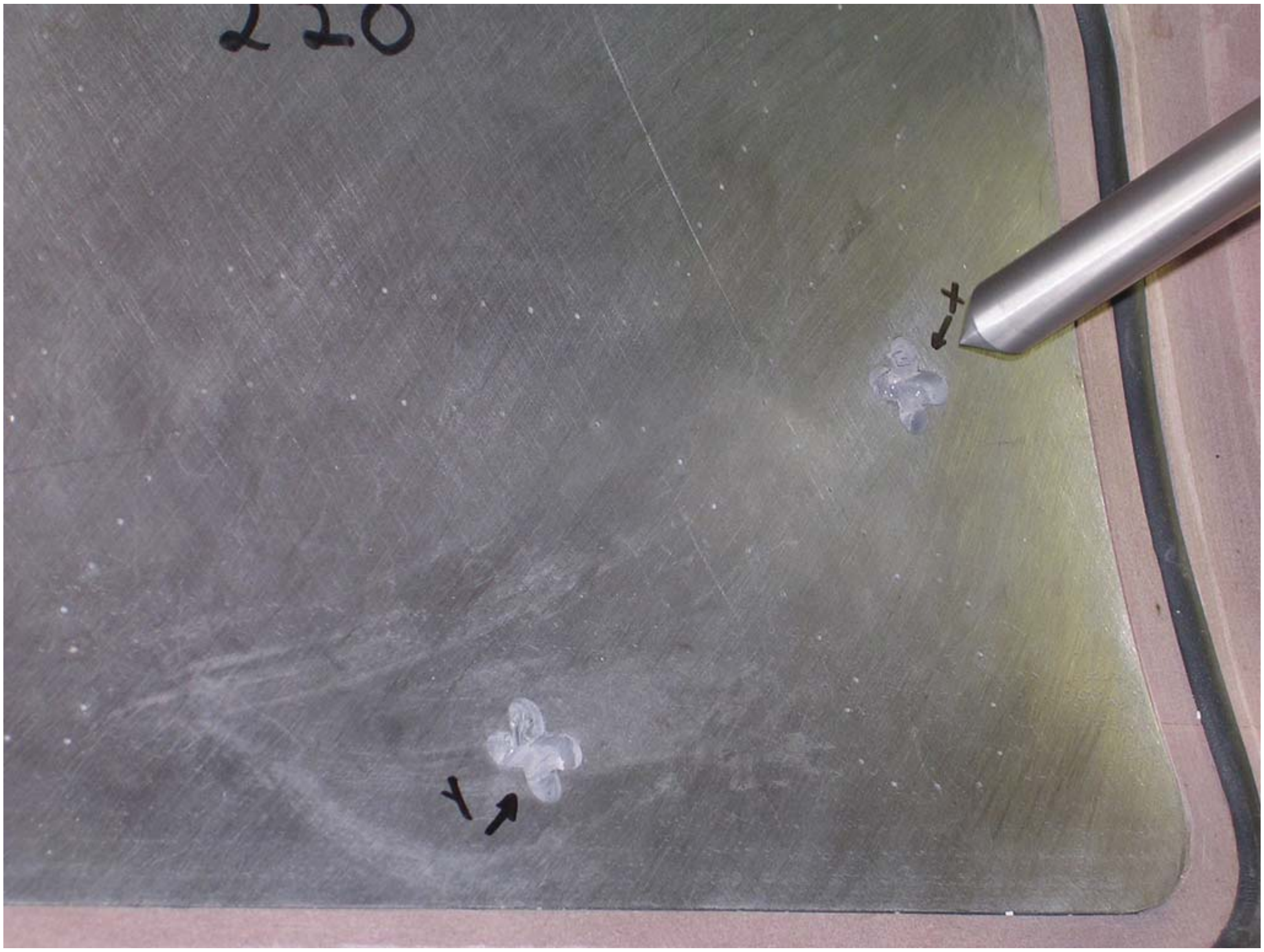


FIGURE 3: Closeup of cruciform features. One of the corner points of each feature is arbitrarily selected and used to teach a Fixture Coordinate System point.

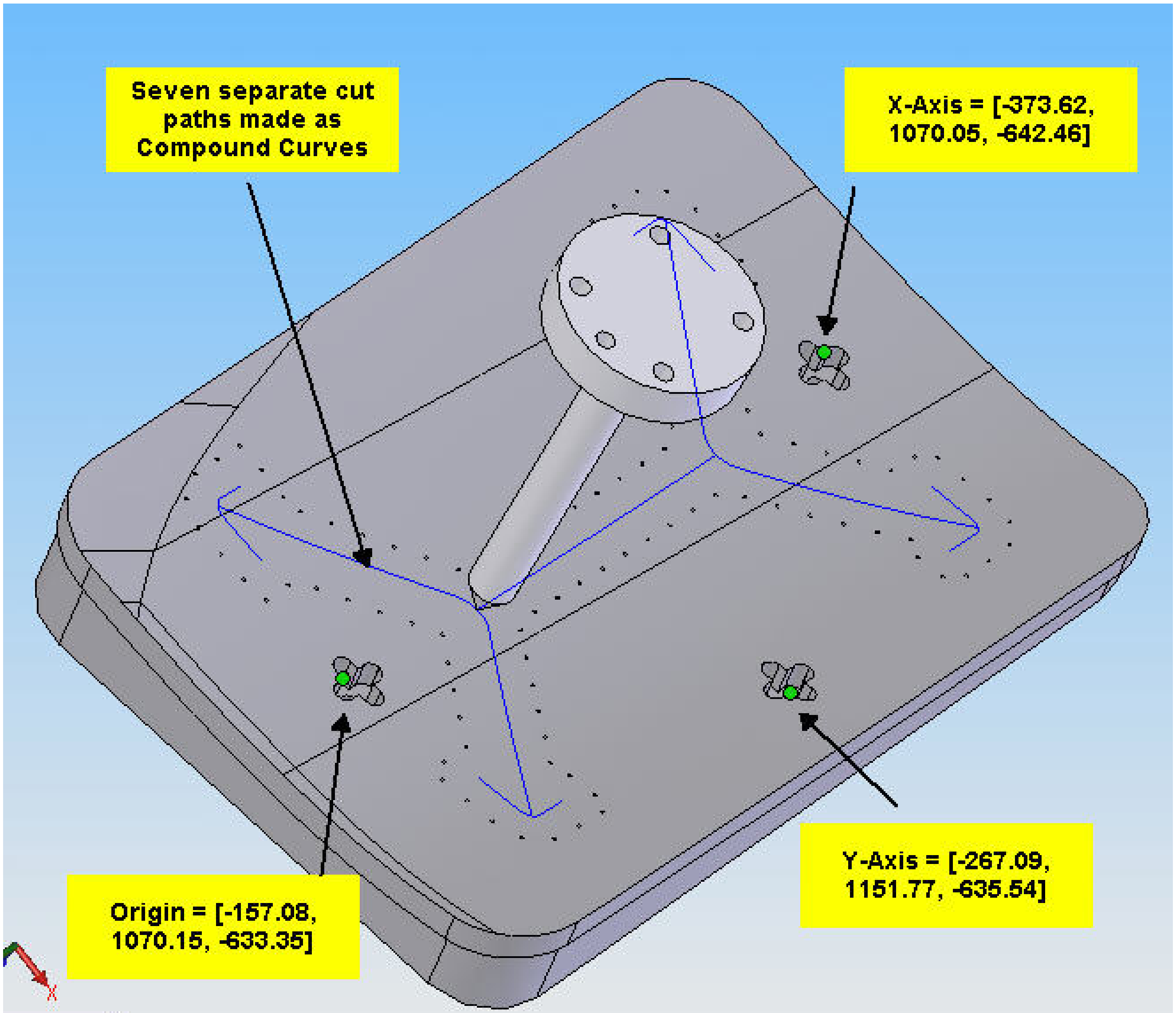


Figure 4: CAD representation of Fixture with Coordinate System location features. The location and orientation of the Fixture Coordinate System is ARBITRARY.

METHOD

The method of importing CAD parts, and developing into a path is given in **APPENDIX 1** at the end of this document.

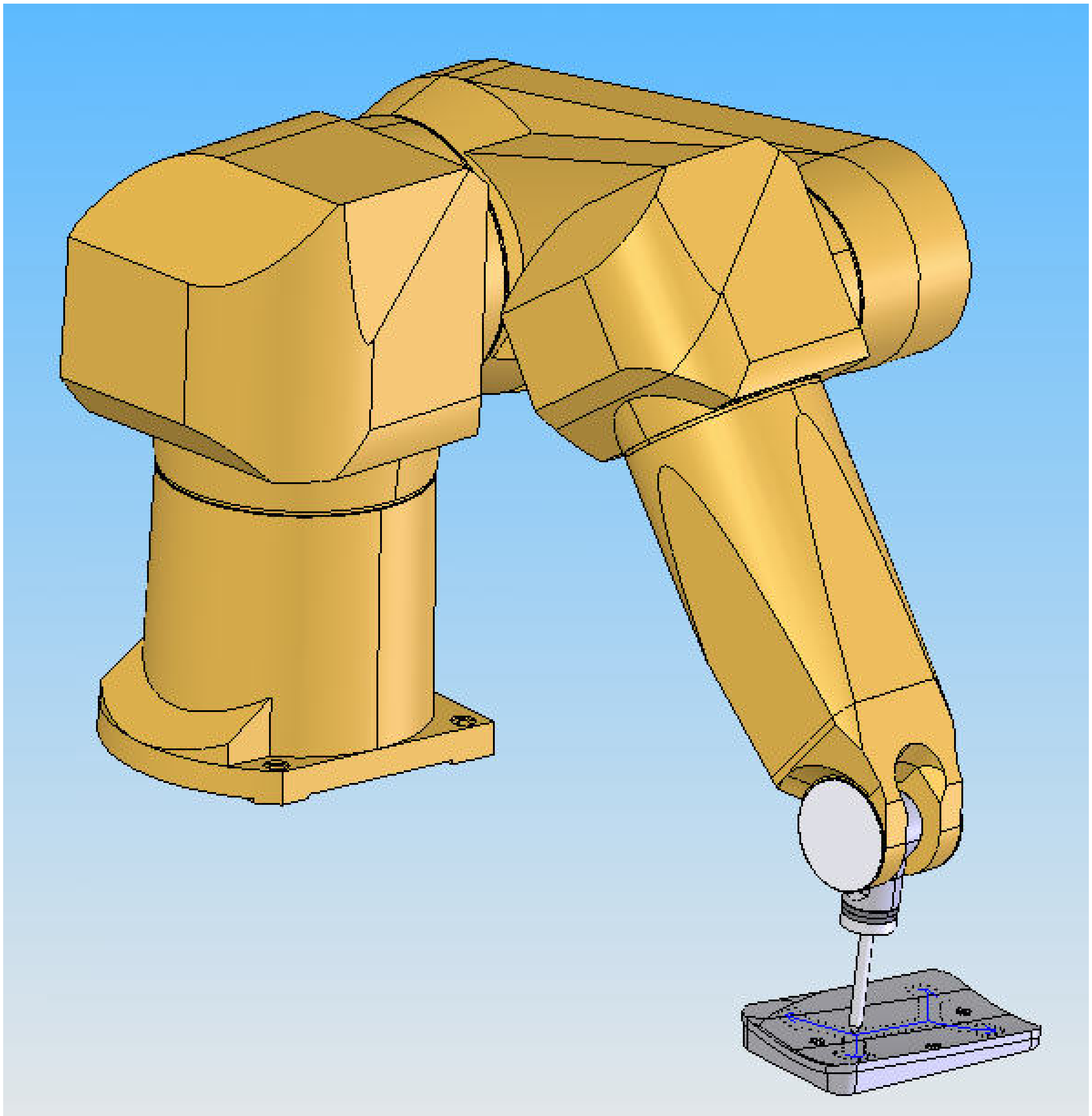


Figure 5: CAD representation of schematic workcell. This is a quick method of determining reach and suitability to task before teaching & programming is started. RobotWorks automatically determines if sufficient reach is available for the application.

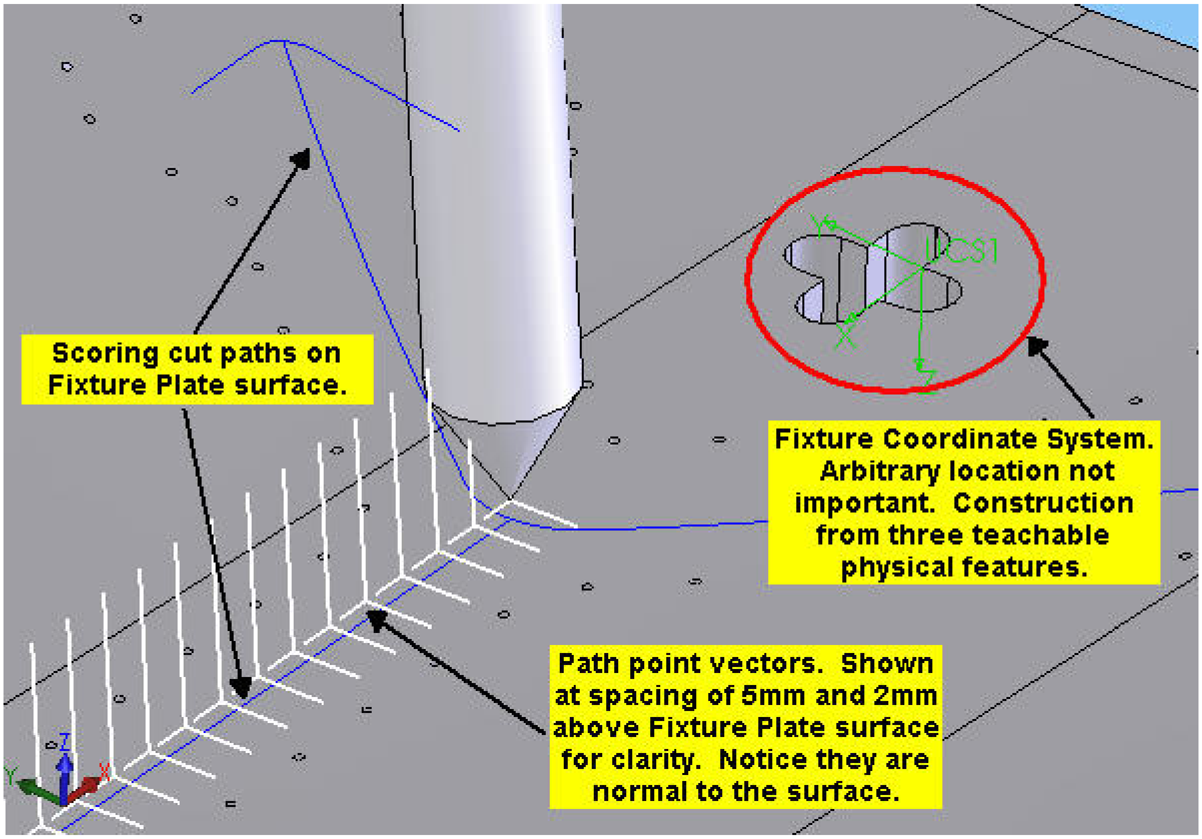


Figure 6: Scoring Fixture detail.

RESULTS

- ***Excellent results were attained on the first attempt of this proposed method.***
- Initial fixture location as installed by shop personnel produced locations out of reach of the RX130B arm. This was seen in the RobotWorks simulation and verified in the shop. The fixture was moved and easily re-calibrated by teaching three new coordinate system location points.
- Robot Path Points were developed in RobotWorks software. Points were imported to the CS8 controller and a simple motion program was written in VAL3 language. Correct arm configuration and motion was verified. Final adjustments to the correct EOAT position to produce acceptable RWT was done by changing the value of the robot Tool definition. Minor adjustments to correct arm configuration problems were easily accomplished and downloaded to the CS8 controller.
- Initial motion parameters were point spacing 0.3mm and elevation 0.4mm above fixture surface. The CS8 architecture caused a Motion Stack problem with the quantity of points and their spacing. This was quickly and easily changed to 1mm spacing.
- Total time: 8 hours including learning VAL3 language requirements and fixture relocation.
- Now that the procedures are well documented for importing and using robot locations in a Staubli CS8 robot controller, this task would only take an estimated 1.5 hours.
- The Program Manager for the project was so pleased that he demanded that his second project be modified to use RobotWorks-generated paths (the "SECOND" job).

A second existing Skin Scoring job was retrofitted to use this method. This job has had many problems and schedule delays over the previous few weeks. ***Results were again excellent:***

- The fixture designer was requested to design three arbitrary features on the existing Fixture Plate Insert. After discussion, it was decided to place three "X" scribe marks on the Fixture Plate Insert. These "X" marks would be used to define a coordinate system on the fixture.
- Fixture was removed from the Scoring Machine. Scribe marks were milled on the Fixture Plate Insert for an arbitrary Fixture Coordinate System. The Fixture Plate Insert was left assembled into the overall fixture due to the difficulty of dis-assembly.
- RobotWorks was used to develop the robot path. Use of actual CAD data for the showed that the manually-taught path previously used had an inaccurate form.
- Due to the fact that the Fixture Insert Plate was not removed from the overall fixture, there was an induced error in the calculated path. This error was minor and was easily corrected by programming Robot Tool Offset adjustments along different regions of the path.
- After verifying the RWT for this job, 108 sequential parts were run successfully. The previous robot code had only allowed ~35 parts before re-calibration was required.

CONCLUSIONS

This proposed method has the potential of ***dramatically reducing*** the amount of engineering effort required for:

- setup
- maintenance
- installation
- on-site support
- re-programming and adjustment of paths
- engineering resource utilization

This proposed method presents an easier, faster, more direct, and more accurate method for teaching the initial scoring path locations. It uses the philosophy of teaching points through calculation of ***a defined coordinate sytem on the fixture plate***, then re-teaching the coordinate system to accomodate changes. Further, use of multiple coordinate transformations (e.g., CarCoordSys => FixtureCoordSys => InsertCoordSys = RobotCoordSys) is not required. This eliminates the possibility of calculation error accumulation.

The existing code philosophy uses sensors to try to adapt constantly to system changes. This existing method has inherent problems with error accumulation and setup difficulties.

A tolerance analysis showed that the error between the theoretical score path and the straight-line motion between robot points at 1mm spacing is neglible.

A requirement to make this alternative method "production ready" would be to develop an elegant method of teaching the three Fixture Coordinate System points at some convenient interval. It would be necessary to automatically acquire and re-teach the FCS points.

- A possible solution is perhaps a system of tooling balls that are recessed into pockets in the fixture plate. A suitable sensor to determine point locations could be permanently attached to the EOAT. For example:

  - Balluff through-beam
  - CMM probe
- Another possible solution is simple slots milled into the Scoring Fixture Plate insert as shown in Figure 4 (or similar). A laser triangulation sensor could be mounted to the robot EOAT and a search algorithm could be developed to search and determine the corner points of intersecting slots.
- The disadvantage to this method would be minor reduction in overall system throughput.

This method, if proven, can easily retrofit existing installations in the field.

APPENDIX 1

CAD Part Import & RobotWorks Path Development Process Description

GIVEN:

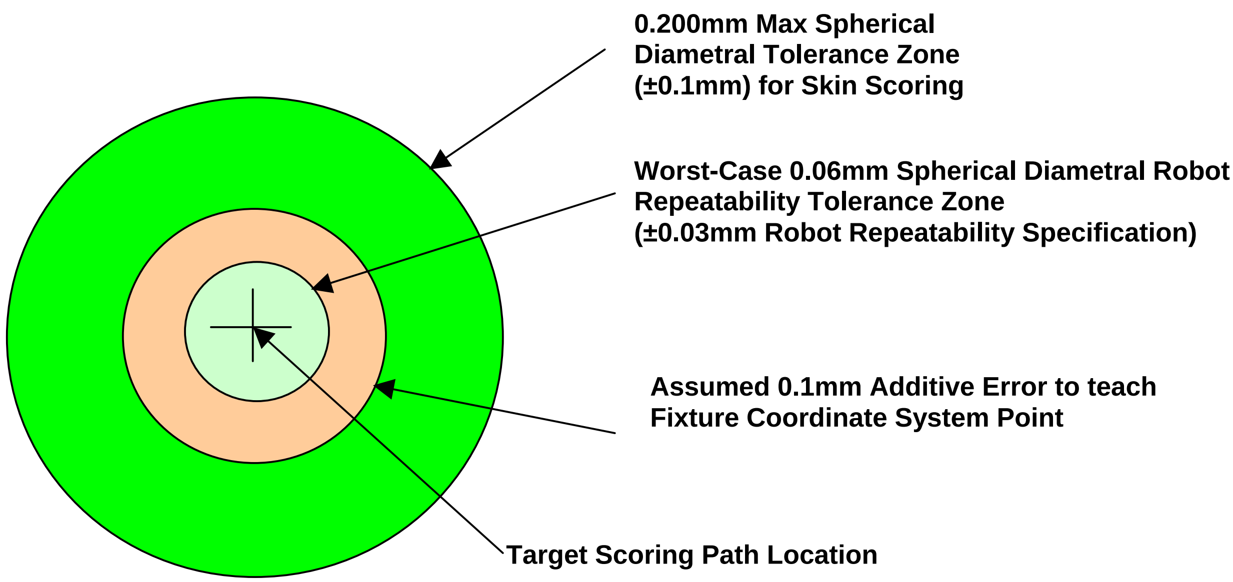
- Fixture Plate Insert part provided in Parasolid format
- Scoring Path part provided in IGES format

1. Import Fixture Plate and Score Path parts into SolidWorks format.
2. Create a SolidWorks Assembly file with these two parts. Part Origins are mated to the Assembly Origin.
3. Transfer the Score Paths to the Fixture Plate.
    a. While in the Assembly, Edit the Fixture part.
    b. Verify that the "No External References" icon is clicked ON.
    c. Select the curve segment.
    d. Select 3DSketch icon.
    e. Select Convert Entities icon.
    f. Repeat for all curve segments.
    g. Save As Part.
    h. Close Assembly.
    i. Open newly created Part
    j. Select the 3DSketch Entity.
    k. Select Compound Curve icon to convert 3DSketch entity to Compound Curve entity.
    l. Save Part.
4. Attach a simple pointer of accurate known dimension to the robot. Invoke a tool transform for the pointer. Select three corner points and teach these locations in the Real World workcell. Record the X-Y-Z values of these three corner points.
5. Create a new SolidWorks Assembly. Insert the Fixture Plate part. Position the Fixture Plate in the Assembly using Distance Mates and the three sets of X-Y-Z data. This will calibrate the Fixture Plate's Real World position to the CAD Space location.
    a. Mate one corner point with X-Y-Z distance values mated to the three appropriate Assembly planes.
    b. Mate a second corner point with X-Y distance values to the two appropriate Assembly planes.
    c. Mate the third corner point with the Z distance to the appropriate Assembly plane.
6. Create and insert a suitable End Of Arm Tooling (EOAT) model. This EOAT must be properly constructed to RobotWorks-required specifications. In this case, the simple Pointer Tool model was used.
7. Use RobotWorks to create robot paths for Scoring. Motion parameters were set to provide Score Path points at 1mm spacing and 0.4mm from the fixture plate surface. ***NOTE: it is only necessary to use a convenient robot tool in CAD to create the path point locations of the TCP***.
8. Insert the RX130B robot model and verify arm reach, collision detections, and arm configuration requirements.
9. Export the path data to robot locations Staubli location file format. The converted robot points are made relative to the taught Fixture Coordinate System for higher accuracy. ***NOTE: this allows the fixture to change location in the field. This allows the possibility of re-calibrating the fixture in production***.

10. Import the Staubli path location data to the Staubli controller.
11. Develop a suitable robot motion program in the Staubli VAL3 robot language to move the EOAT along the path.

APPENDIX 2

Preliminary Tolerance Analysis for Proposed Method



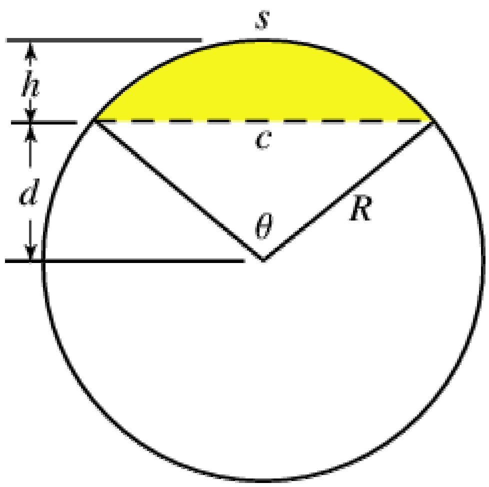
Path Point Spacing Error:

The existing robot code method produces points approximately every 0.12mm along the path. This corresponds to the 4mS (250Hz) update cycle time of the CS8 trajectory generator at a 30mm/S speed.

The proposed method used Scoring Path Point spacing = 1mm.

The error between the theoretical path (arc ***s***) and the transcribed linear path (chord ***c***) is given by the distance ***h***. See Figure below.

h = R-d = R - 0.5 * (SQRT (4R^2 - c^2))



Sample errors for various values of radius R at constant chord "c" values = 1mm :

Values of Skin Scoring Path Curvaturve "R", mm	***Values of path error "h", mm***
20	0.006251
50	0.002500
100	0.001250
150	0.000833
200	0.006250
300	0.000417
400	0.000313
500	0.000250

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