SOLUTIONS FOR THE AUTOMOTIVE GLASS INDUSTRY

Bending Iron Measurement System

STAR
Engineered Robotics Solutions

PREMISE

With "Bending Iron", is intended the metallic profile used for the bending of glasses into the bending furnaces by gravity. During the working cycle, such profiles can suffer deformations that can cause variations in the shape of the perimeter of the profile and displacements of the references used for centering the glasses during the loading process before the furnace.
The consequence of such modifications is a wrong shaping of glass that can cause breaks and/or shape defects.
Due to this reason, there is the exigency to check in line the profiles in order to test systematically the correspondence of the measures to the requisites. The STAR system is able to measure in line with a good accuracy the characteristic points of the profiles influencing the process of the glass bending.

TECHNICAL DESCRIPTION

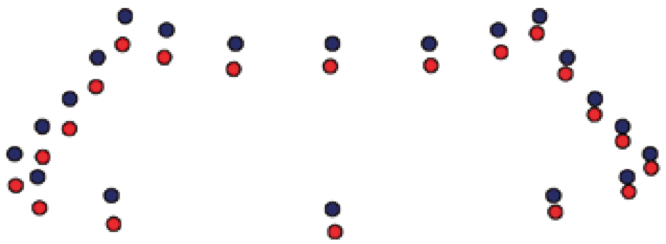
The support structure takes place on the section of the conveyor carrying the "bending irons" from the end of the furnace to the centring station situated at the beginning of the conveyor. Such a structure supports a robot able to move orthogonally to the direction of the bending iron feed, by means of a pneumatic actuator (see picture 1). Such movement lets the robot cover with its own working area the necessary area for the control of glasses responding to the following dimensions:

Width	*max 2000mm*	
Height	*max 1100mm*	
Camber	*min 0*	*max 200 mm*

The "carriage" stops under the portal and here is raised from the conveyor and pushed against a couple of front locators.
The robot has two sensors on the tool dedicated to the measure of the perimeter points of the profile. A vision system, also assembled on the support structure, locates the stationary position of the profile in the station, calculating the position of the three points of the loading centering and the corrective data of the robot trajectory.
At the end of the calculations, the vision software sends the trajectory corrections to the robot controller that brings the measure sensors in repetitive positions with regards to the centering references.

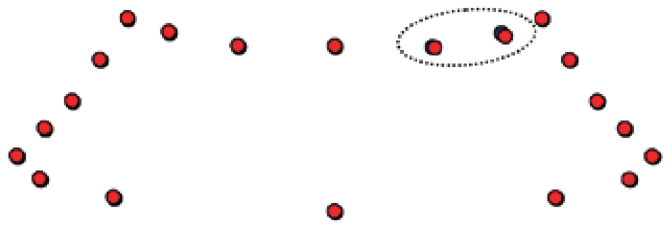
The location of the profile position by the vision system avoids the problems due to the fact that the piece is not squared mechanically under the station.
Even if the vision system guarantees an excellent accuracy in the location of the profile, avoiding the problem of measure the profile in different points of the shape during every cycle, it will be necessary to further purify the measurement data in order to avoid that others effects such as reference deformations, vertical position variations, rotations, translations, could affect the accuracy of the measurement.
This purifying operation is done by comparing in the right way the measures obtained with a set of reference measures and comparing them by a "best fitting" procedure illustrated below.
Using the mathematical description of the bending, it is possible to extract, by CAD measurements, the set of coordinates of the measure points of the profile in the basic reference system of the robot in a reference position of measurement. This is provided as

input to the control system for every model produced. An alternative to evaluate during the start-up, for the production of the reference data, could be the measurement of the actual sample reference with a numerical control measurement tool, that, assured the necessary precision, provides the coordinates of the measurement points quoted on the calibre.
In any case, knowing the coordinates of the reference measured points, some geometrically interesting quantities will be calculated, such as centre of gravity and main inertia axis of the set of points.
During the measurement cycle, the robot controller reconstructs the coordinates of the points measured on the profile in its basic reference system. Beginning from the actual coordinates of the TCP and from the position of the measurement systems referred to it, the same set of reference values is calculated.
For a better understanding, look at the following figure where are represented the set of nominal points (BLUE) and the set of the measured points (RED).



In this figure, the effect of possible rotations and translations over the position of the measurement points was exaggerated.
Evaluating the deviations in the condition above illustrated, the variations of the profile's shape, that "appears" deformed by the effect of translations and rotations, would be wrongly evaluated.
The software proceeds to the calculation of the center of gravity and the main inertia axis of the new measurement set.

The coordinates of the points are initially moved so as to overlap the center of gravity. Then, the main inertia axis and the coordinates will be rotated so as to align such axis.
The result of these mathematical operations is to put all the points interested in the measurement, in the same nominal positions, as showed in the following figure.



The example above shows a variation of the profile in the position highlighted by the dashed line. The measurements generated by the mathematical process are stored in an Access database that allows all the necessary analysis of the process. Profiles with deformations over the acceptance limits generates a rejected signal to the PLC of the line that will provide corrective actions to the production cycle.

THE MEASUREMENT SYSTEM

The verification of the conformity of the profiles with respect to the nominal values will be realized measuring in 22 relevant points of the profile perimeter in Z and Y direction, meaning by Z the direction orthogonal to the floor and by Y the direction orthogonal to the profile in the measurement point, in the entering sense.
The measure in direction Z is realized by a laser sensor, that generates a blame of light whose dimensions are 10 mm. Such sensor, brought by the robot to interfere with the upper profile of the bending iron, provides a measure proportional to the portion of the laser blame darkened. The measure in direction Y is realized by a laser sensor of distance, that for its own special characteris-

tics, presents a negligible degradation of the measurement precision changing the chromatic characteristics of the side surface of the bending iron.
All the measures are read by the robot controller and sent to a PC on which is installed a software dedicated to the control.

THE CENTERING SYSTEM

The measurement realized by the sensors mounted on the robot, will be obviously reported to an absolute reference system, since the position where the sensors make the measurement is defined in the base reference system of the robot.
In order to avoid that the position of the bending iron could cause wrong positioning of the measurement point (altering the result), the vision system mounted on the support structure will acquire the section of the bending iron where three centering references are situated.
This operation of optical centering, jointly with the mathematical operations of "best fitting" illustrated previously, allows to do measurements on the profile perimeter always referred to three centering points of the same.
The most important result of this measurement technique is that it will be possible to detect deformations of the perimeter as well deformations of the centering points, since both cases will cause changes of the perimeter position with respect to the references.

SOFTWARE OF THE CONTROL

The whole system is controlled by a supervision PC on which is installed a dedicated software that gives the following functions:
On-line display of the measures on the processed profile: the software shows on a picture of the bending iron the values of the measures corresponding to every point, and the differences between the position of centering and the reference points.
Managing of the vision system: a high level interface allows to the operator the configuration and the training of the vision system on the piece to be processed.
The last image acquired by the camera will be shown.
Interpolation of the measures: the software elaborates the necessary mathematical operations of interpolation for the exact evaluation of the deformations.
Managing of the operator interface: this section contains the commands and the parameters of the system configuration.
Interface with the PLC of the line: the software interfaces the PLC of the line with signals of synchronization of the operations and good/rejected signal.
Data storage: the data generated after every cycle are stored in a Access database allowing a historical analysis of the process.
For every measurement cycle, the software does an association between the values measured and the profile processed so as to refer the data always to the same profile.
Such association allows to create a database where, for every bending iron, is possible to reconstruct the history of the measures carried out with the possibility to do different kinds of statistical calculations.
The implementation of the Access database, allows to the operator to use forms for printing and analysis.

CYCLE TIME

The profiles are entirely measured after two consecutive passages in the control station. So, at every passage, the system controls 11 points on the perimeter + 3 points on the centring reference, with a measurement time of 15 sec.torefer the data always to the same profile.

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