IMAGE PROCESSING FOR AUTOMATED ROBOTIC WELDING

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The new developed by IMG and used by WADAN yards MTW image processing system for welding robots delivers a very fast automatically generated program. A laser line scanner with a scanning rate of 1 m/s and a fast working calculation unit gives a 3D picture in less than 3 min all over the 16 × 4 m panel. The accuracy of the robotic positioning is ±0.5 mm after the shake hand process between the image processing system and the robot programming system. This new developed 3D geometrically recognising and robot programming system allows a very fast and flexible production system for micropanels without any link to the central computer aided yard system. This «stand alone system» is independent, more flexible and shows beside of other advantages a high productivity.

Keywords: *robot welding, fillet welding, image processing, robot programming, micropanel welding, welding in shipbuilding*

The main parts in the prefabrication of ship hulls are flat and curved panels with dimensions up to 20 × × 40 m or more and so named micropanels. We meet especially the last one, the micropanels, in a large number of different forms an sizes beginning from 2 × × 2 up to 4 × 16 m. In a medium sized container freighter for 2000 containers there are about 2500 or more various micropanels. There are different production technologies for micropanels, consisting from plates and stiffeners. A modern micropanel production at a shipyard uses robots for mounting and welding as well. This is shown as an example in Figures 1 and 2. Due to the various construction types of micropanels and their large range from unique single construction up to minimum series there is a high demand on the programming of robot systems including the movement of the robots in the 3D coordinates and the various welding parameter. In shipbuilding each micropanel needs its own welding program. All of the known programming procedures require either additional information on the workpiece in the shape of CAD data or they need manual interaction. The classical programming of weld robots for micropanels takes places regardless of the really existing workpiece and production scenario by a partly automatic analysis of CAD data in combination with demanding manual interactions. The programming takes place temporally very much in advance of the production and needs a high quality and relevance of the available construction data. Unfortunately this is in contrast to the flexibility of the production flow and can not take in account some changes of construction. That means we have to take in account that normally the programming is done a long time before production and very often the NC construction data are changed in the meantime.

Refitting of an existing micropanel line by image processing. To meet the needs for a very high flexibility and for an automated programming on demand for the existing panel line (see Figures 1 and 2), the enterprise Ingenieurtechnik und Maschinenbau

Figure 1. Mounting gantry for stiffeners in micropanel line

Figure 2. Welding station in micropanel line using two robots before refitting

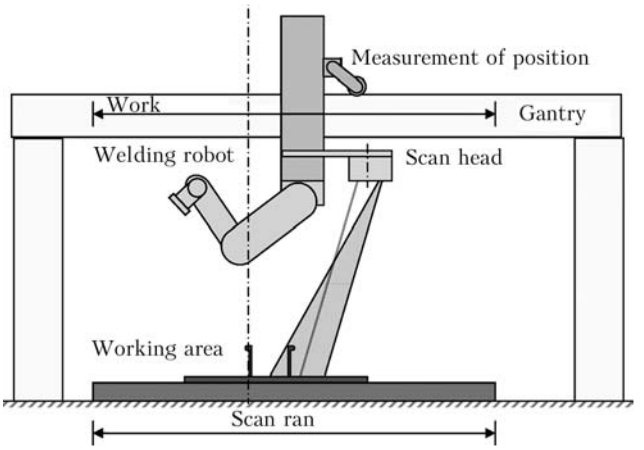

Figure 3. Principle of 3D image processing for robot programming

GmbH (IMG) designed, constructed and delivered recently a very fast working 3D image processing system in cooperation with the company's aviCOM and TSWE.

The principle of this 3D image processing system is shown in Figure 3, and Figure 4 gives an overview about the system controlling units.

The heart of the new industrial 3D scanner measuring system for micropanels is a camera head based on modern camera technology. The scan head measures 3D data according to the laser triangulation principle. Hence, to be able to measure 3D shape, an external line-generating laser source is used. The laser generator is mounted to the robot and projects its laser line on the working area from a distance of about 2 m in the height. The camera, that views the line from a different angle, sees a curve that follows the height profile of the object. By measuring the laser line deviations from a straight imaginary reference line, the height of the object can be computed.

The robot moves for scanning with the scan head and the laser line along the working area, contour slices of the object are generated. The collection of such slices, or 3D profiles, is a description of the complete object shape as seen from the upper side of the object. The unique camera technology is capable of finding the position of the laser line by itself and reducing to whole image information into compact laser coordinates. These laser coordinates are transmitted to the PC. That is what the mounted 3D imaging technology makes very fast and reliable.

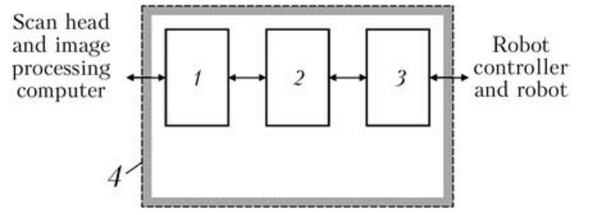

Figure 4. Controlling units of the image processing and robot programming system: *1* — image processing software; *2* — online programming system; *3* — server macroadministration; *4* — system controlling by industrial PC

Inside the scan head the camera offers several different methods for the generation of 3D profiles which differs in speed and height resolution. This flexibility of the camera was used to optimize results for the specific scanning task and material.

The measurement principle gives geometrical limitation concerning the measurement of hidden parts in relation to the camera view. There are two kinds of limitations, camera occlusion and laser occlusion. Camera occlusion occurs when the laser line is hidden from the camera by an object and laser occlusions occur when the laser cannot properly illuminate parts of an object because of its projection angle. Adjusting the angles of the scan head and the laser can reduce the effects of occlusion. Additionally we use two scan heads with two laser sources illuminating the micropanels and especially the profiles from opposite sides.

The measurement system 3D field-of-view (FOV) is a trapezoid-shaped region where the laser line intercepts the FOV of the camera. It is only in this region that the camera generates 3D measurements. The camera FOV is given by the selected lens and camera software parameters. The height resolution of the measurements is dependent on the angle between the laser and the camera — as the angle is increased, the resolution is also increased — and on the selected 3D method. Generally, if the precision of the profiling algorithm is high, the maximum profile rate is limited compared to a less precise but fast algorithm.

The maximum profile rate is dependent on a combination of the selected 3D method, the required meas-

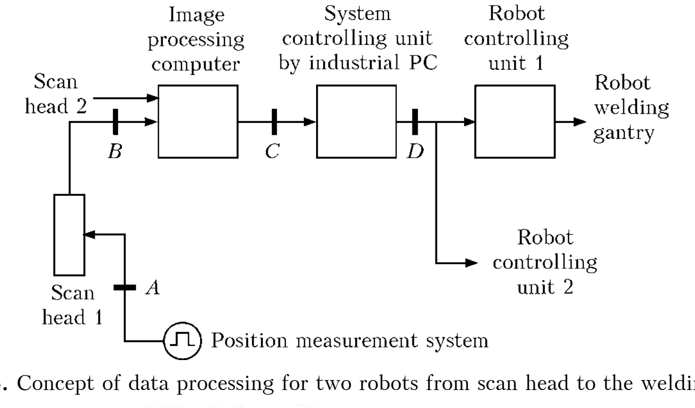

Figure 5. Concept of data processing for two robots from scan head to the welding robot

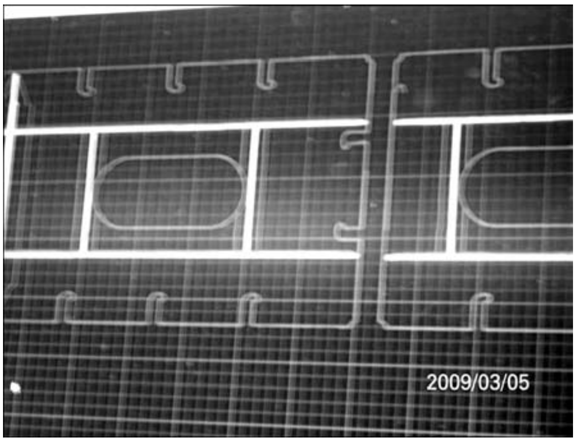

Figure 6. Visualization of micropanel on the user screen, ready for further high level processing

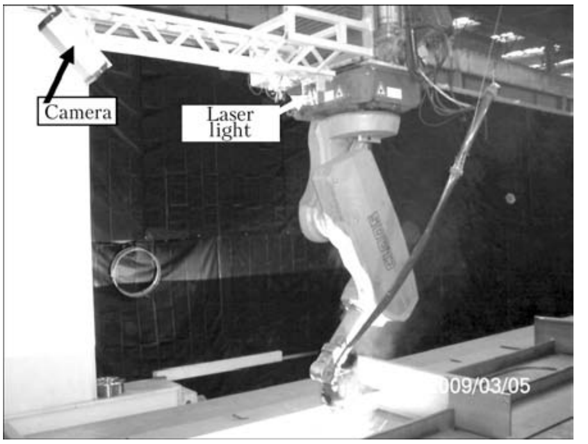

Figure 7. Refitted robot with automated programming system by image processing in operation at the yard

urement resolution, and the required height of the measurement region. By for instance decreasing the height region used for object inspection the profile rate can be increased. Note, however, that the maximal usable profile rate also depends on the amount of light reflected from the object.

The data stream of profiles was synchronized with the robot movement using an external encoder. This functionality will ensure that the length measurement and object scale in the movement direction is correct, even if the object speed varies (Figure 5).

All parameters were optimized for the application of scanning micropanels under production conditions. The result is a scanning speed of 0.5 m/s with a maximum of independence from surrounding light conditions. The resolution of the 3D points is about 1 mm in x- and y-direction and 2 mm in z- (height). It is to consider that the resolution differs over the field of view in the relation to the height of points. The measurement range in z-direction is actually 400 mm.

The design goal was to optimize the overall scanning time, the sum of time to scan and process data. Although the scanning speed could be higher (up to 1 m/s) it is shown that the shortest process time is reached by processing the data parallel to the scanning process.

The scanning is done in stripes of 1.2 m width and 16 m length in reversing order of forward and backward movement. Hence, the whole working area consists of a maximum of four stripes for each scanning head.

The measured 3D points in the laser plane of the scanner have to be processed with complex mathematical algorithms to calculate real world coordinates. This is done mostly during the scanning process parallel to the capture of 3D points. Additionally a first step of data reduction is done to extract object shape information as panel planes, profile planes and contours. The whole working area is scanned after about 3.5 min. At this time the extracted object shape information is available for high level processing in the final geometry extraction (Figure 6).

Figure 7 shows the scan jib together with the two laser sources and the camera fixed at the refitted robot.

The process of geometry extraction calculates the matching of all scanning stripes separately for each scan head. Additionally it calculates the matching of both scan heads to one description of the scene. This description consists of panels with 3D contour polygons, a plane approximation for profiles distinguishing different types such as HP, Flat, T- or L-profiles and an information which profile belongs to which panel.

Advantages of the new installed 3D image processing system. The main advantages of the recently installed new programming system by 3D image processing are the following:

• programming on demand guarantees a very high production flexibility;

• programming is a very fast process, there is no remarkable production time lost;

• the scan rate depending on the profile height is 0.5 up to 1 m/s;

• the process time for the whole process depending on the size of the panel and the number of stiffeners is 3.5 up to 12 min. This is very fast in comparison with some hours of welding time;

• the accuracy with 1 mm in x- and y-direction and 2 mm in z-direction is very high;

• it needs no operator for programming.

CONCLUSION

The micropanel is now successful in operation more than one year at one German shipyard. It needs only one operator for all processes including mounting and tacking of the stiffeners, changing the filler material for the two robots and so on. The automated micropanel line provides a high level of automation utilisation, production flexibility and an increase in efficiency. The experience at the yard shows that the play-back-time for the investment is in a range of one year.