Weld spot in the limelight

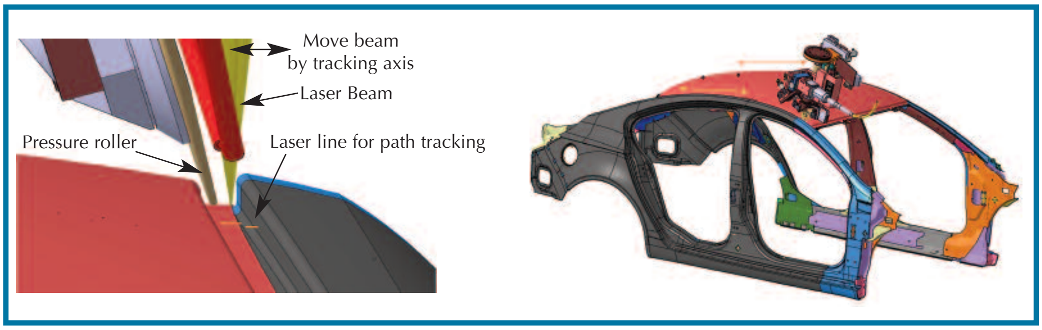

Fig. 1. When combined with the coaxial LPF seam tracking system, the welding head can compensate for positioning errors, roof flange cutting edge tolerances and any robot trajectory deviations. This guarantees a constant, precise and accurate weld seam. A pressure roller running collateral to the laser focal point presses the sheets together during welding.

The camera of Precitec's coaxial LPF seam tracking system directly observes car roof seams through the welding optics. In the example described here, two line generators positioned on top of one another create two light stripes that run perpendicular to the weld about 3 to 5 mm in front of and behind the weld spot. The feed line profile is continuously analysed, enabling the laser beam focus to be guided precisely along the lateral roof flange edge using a high-precision linear drive.

During manufacturing of the Opel Insignia's car body shell, the roof is welded upon the two side frames. Depending on the platform, the roof is made of uncoated or galvanised sheet steel, and the side panels are galvanised. In the robot welding cell, two arculated robots weld the right and left sided roof joints. The joining area is designed in such a way that the weld seams are located in narrow grooves or roof channels that run from the front screen opening to the rear window opening on both sides of the roof. In these roof channels, the lateral roof flanges are welded to the side panels by means of laser edge welding. The laser beam is directed towards the edge of the roof sheet metal at a specific angle, melting the edge evenly into the bottom sheet. The LPF seam tracking system by Precitec ensures that the laser beam is precisely focused on the edge over the whole length of the seam. The welding result is impressive: The seam does not simply possess the required strength, it is also uniform and almost free from pores, holes and spatters, conforming to the specification tolerances defined by Opel.

This is necessary as the weld will only be covered by a sealing bead and painted over. A roof cover strip is no longer required. This also eliminates the need for a 100% visual inspection in BIW manufacturing. If errors are detected by the monitoring system, the body concerned will be stopped in the next processing station. As the sheets are only joined from one side, there are no access holes available for weld guns in the side frame profiles, a circumstance which, as a result, makes them stiffer more lightweight constructions to be built. In addition to this saving potential, the joining method of laser edge welding offers the advantage of a much shorter cycle time compared to other methods of joining.

Continuous triangulation of the edge joint

The two multi-axis robots in the welding station work on both sides of the passenger compartment at the same time, but independently of one another. A lamp-pumped Nd:YAG laser is used as a laser source for each robot. The lasers' beams are conducted to the welding heads by means of fibre optic cables. The welding head consists of a 90° angled laser beam optics on a linear axis and a pressure roller. During welding, the roller presses the sheets together. Since the robot path cannot always be kept on an exact line parallel to the sheet edge, a system is required that can compensate for deviations extremely quickly and at the same time correct the laser focus which has a diameter of only 0.6 mm. It is also advantageous to have the system located, as far as possible, apart from the welding area so that the susceptibility to errors and maintenance costs are reduced. This is why the welding head is equipped with the coaxial LPF seam tracking system, the camera of which looks through the welding optics. It compensates for robot path errors, positioning errors and roof-flange trim edge tolerances, enabling a highly accurate and continuously homogeneous weld seam. The system works with two line generators mounted in front of the welding head. Each of these projects a light stripe 3 to 5 mm in front of and behind the laser focus and perpendicular to the welding edge. Thanks to its 10 ×10 mm observation window, the seam tracking system's coaxially-coupled camera situated in the laser welding head can monitor both light stripes.

Depending on the welding direction, the camera evaluates the light stripe located in front of the weld spot for seam tracking.

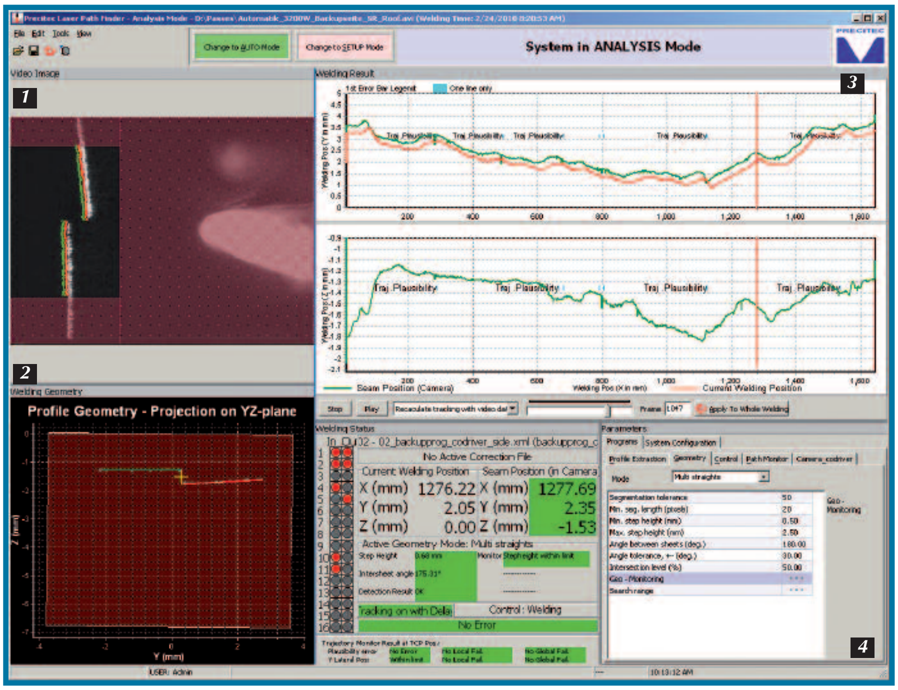

***Fig. 2**. User screen: Live video image with profile evaluation (1), geometry pane with roof edge profile extracted (2), tracking data pane with seam and axis position (3), results window (4).*

Since these stripes are projected forwards at a slant on to the overlapping sheet, they plot a stepped contour on the workpiece that matches the edge line on the workpiece. By means of optical triangulation the camera continuously targets the work piece and carries out positioning calculations. The results of these calculations are fed to the linear axis controller of the LPF linear drive which is mounted on the wrist of the robot.

The combination of the acquired joint position and the current position of the linear drive (upon which the laser optics is mounted) constitutes the foundation for the highly accurate lateral tracking of the laser spot along the edge to be welded. The correct vertical position of the laser welding head is ensured by the pressure roller of the robot system.

Since a light stripe is projected both in front of and behind the laser beam, the robot can weld in both directions. Welding in opposite directions can quickly become necessary if one of the two robots fails. If this happens, the robot on the other side of the car body can then take over the welding tasks of the failed robot. In this case, the welding head must be rotated 180°.

The welding direction can freely be chosen for this backup action. This concept guarantees a high level of equipment availability. The light stripes are created by a laser diode in the line generators and linearly widened by cylindrical lenses. "CrossJet" nozzles mounted at the line generators prevent that the geometry of the light stripes and the associated precision of the edge detection are impaired by a potential con-

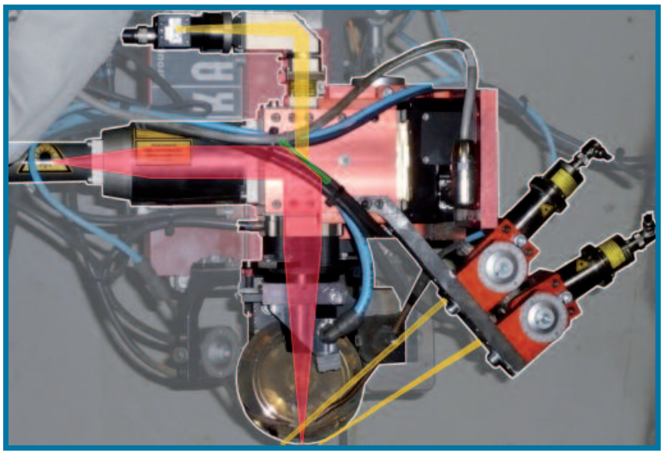

***Fig. 3.** The bi-directional LPF seam tracking system works with two line generators mounted in front of the welding head. Each of these projects a light stripe 3 to 5 mm in front of and behind the laser focus and perpendicular to the welding edge.*

tamination during the welding process. The optical components are thus protected from soiling by an ultrasonic curtain of air – and the components' process safety and service lifetimes are increased. The protective windows in front of the line generators are easy to replace. Targeted software precautions involving robust algorithms and validation checks compensate for any over-exposure of the video images caused by the extremely bright laser weld spot.

Suitable for the widest range of workpiece materials and seam geometries

Although not required in the example described here, the system is also eminently suitable for welding seams with small tracking radii. As described above, the line generator enables the light stripe to be projected onto the workpiece with a minimal leading gap (right through the welding laser beam itself) – and this in turn enables seam detection to be carried out, even in corners. The welding of a tight tracking radius naturally requires a certain amount of mobility on the part of the robotic welding head.

The LPF seam tracking system not only handles the steel applications described here perfectly – it can also tackle the laser beam welding of copper, titan, magnesium, zinc and aluminium with ease. Thanks to the system's modular software package, an extremely wide range of seam geometries can be detected, including T joints, corner joints, V/Y groove welds and edge joints. The adaptation of an additional lighting unit with grey tone image processing also makes the system suitable for welding zero-gap butt joints with the same sheet thicknesses. The system also displays its versatility with greater standoff distances. These are usually selected to lessen the influence of interfering contours. The LPF seam tracking system also gets top marks for its high degree of flexibility in welding product versions that deviate from one another – because the settings for seam tracking can be put together in configurations, saved in up to 256 selectable programs and called up whenever required by means of a primary controller. An offline analysis enables the simple parameterisation of profile detection, thanks to video analysis and simulation. The saved tracking data can also be used for process flow documentation. Communication with the PLC is also simple, because it takes place via standard industrial bus systems. The system operator has a clear and self-explanatory screen overview of the welding procedure at all times, plus a detailed insight into all current parameters. The LPF seam tracking system is not only suited for working with Nd:YAG lasers – it can be used with the solid-state lasers of many manufacturers, including disk, fibre and diode lasers. The system can also be easily adapted to work perfectly with robotic, gantry and orbital welding systems. The Precitec seam tracking system is available for various different focal lengths and can be flexibly modified to the welding process. In addition to the applications described here, the sensor system has proved itself time and time again in many other segments like, for example, power train, shipbuilding, seat track assemblies and CO_2 laser welding. The system is also being used successfully by other leaders in the automotive industry.

Flexible system with special strengths

As the Opel project management has reported, the LPF seam tracking system is one of the preferred system components for Kuka, the Stage 2 welding system supplier (i.e. the supplier of the laser welding station described here). The report indicates that the LPF system has other, much-appreciated capabilities to offer, like, for example, a special software limit switch for the linear drive, the possibility of resuming seam welding after signal loss or the setting of outputs when specific, parameterisable error events occur during the welding process. These events might be defined as e.g. "Correction path too long", "Gap dimensions too large" or "Limit switch reached" in the LPF software. The system can be used with up to eight different roof styling variations. It also offers user-friendly methods of controlling operation, e.g. in simulation mode or with the "Laser off" switch in the case of unsuitable edge detection. Users also appreciate yet another not-to-be-underestimated advantage – the assurance of global support thanks to Precitec's worldwide presence. GM, for example, carries out the vehicle roof welding described here in several countries all over the world. Opel in Rüsselsheim/Germany has two such laser robotic weld cells. In these plants, Precitec's LPF seam tracking systems make a major contribution to the financially successful manufacture of challenging and modern vehicles.

Volker Bayer, Adam Opel AG, Rüsselsheim/Germany and Thomas Nicolay, Precitec KG, Gaggenau/Germany