Welding in the material world

The implications of using newer materials in hydroforming, tailor welded blanks and welding are considered **by John Osborne.** He also weighs the case for greater use of lasers in welding

Aluminum and higher strength steels are increasingly being used in vehicles but they will only become adopted widely when their performance in key processes is better understood.

Aluminum could well be the steel makers' savior. It could also be a synonym for innovation. After two years of research and development, Corus, which these days promotes itself as "the international metals company", has developed an electric resistance-welded aluminum tube which is suitable for hydroforming.

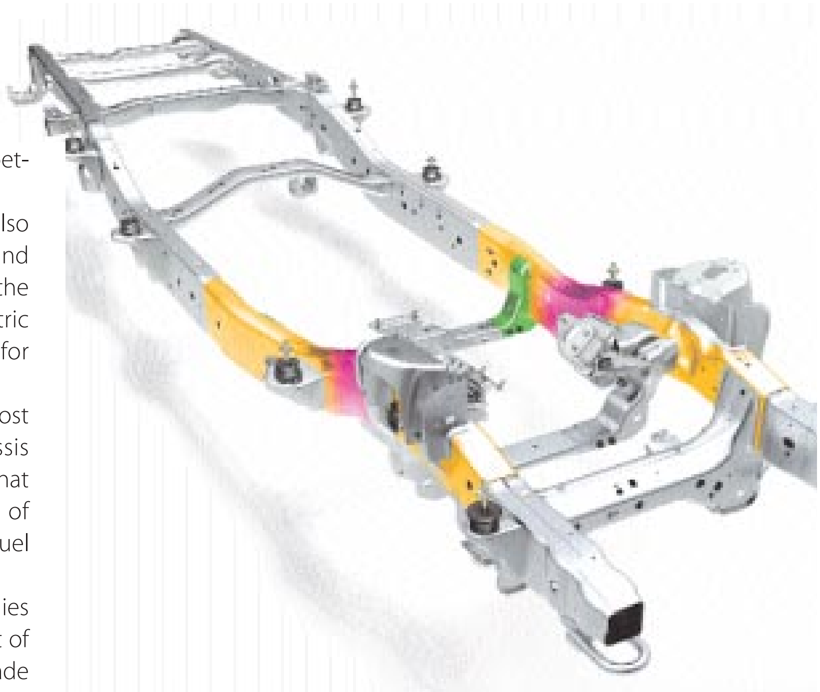
Corus said recently that steel continues to be the most widely used material for automotive body and chassis structures for mass production models. However, it believes that there is a growing demand for specific applications of aluminum in order to achieve weight savings. These reduce fuel consumption and emissions.

The metals supplier said that independent market studies anticipate that in certain vehicle segments, up to 25 percent of body structure and 20 percent of chassis parts could be made from aluminum by the end of the decade. Typical body and chassis applications for aluminum tubes will include rear subframes, engine cradles and suspension parts. Bolt-on body components, such as the radiator support for sports utility and light truck applications could also be made from aluminum tubes.

Rise of aluminum

Corus' aluminum tube products will be made primarily from 5000 series alloys. It claims that these offer strong forming capabilities making them suitable for vehicle body and chassis applications. This not only includes the established 5000 series, but also special grades developed by Corus Aluminium Rolled Products (CARP) Duffel.

For structural body and chassis applications, Corus recently developed a new aluminum grade called Templite. It is a high magnesium (Mg) (>4 percent) alloy with good resistance against intergranular corrosion (IGC) at elevated temperatures. Corus said that the material is well suited for hydroformed applications, which are subjected to higher temperatures. This alloy will also be available as a sheet product as well as a welded tube.



Dana's use of hydroforming on the Ford F-150 box frame has helped reduce weight

While new products are likely to be welcomed by designers, manufacturing and process experts have to tread carefully. Andrew Sherman is senior technical specialist, Ford Manufacturing, Research, and Engineering. Cedric Xia is a technical specialist and works with Sherman. They are based in Dearborn, Michigan, US and are involved in hydroforming research programs. "We are working on two things," says Sherman. "Firstly, working out how to make the process more cost effective. Secondly, the materials side. Although high strength steel and aluminum are being used, more mild steel is still the predominant material. Ford isn't currently manufacturing any aluminum frames but we have got some research programs to develop some techniques to support that application in the future."

Changing materials

Also, there are many factors which have to be considered when changing materials. "Hydroforming dies are expensive, so the process cannot be used to make every component. In addition to the high cost of production dies there is the cost of dies needed to make prototypes," points out Sherman.

Although aluminum components reduce weight they also introduce another element into the manufacturing process. "Most hydroforming presses have been developed for use with steel," says Sherman. Changing over a press to take an unfamiliar metal takes time and there are numerous other issues to consider such as the selection of a suitable release agent and staff training. Using aluminum may not necessarily make the process more expensive or more complicated but they are factors which must be considered.

Another important issue is what to do when a hydroforming press has to be adapted for a foreign market. Dana Corporation, which is still pushing the boundaries of hydroforming found out what that meant on some recent projects. Rich Marando is director of Technology Innovation, Dana Corporation and is based in Reading, Pennslyvannia, US.

Dana has used hydroforming to reduce weight on the new Ford F-series of pickup trucks. The welded overlap flanges and the filler material were eliminated. Marando added that the company has made some very long rails (160in per rail) for the new Land Rover Discovery. "Two hydroformed parts were made for each vehicle", explains Marando. "Each part consists of two sections. They were laser cut apart so we got two parts with each press stroke."

The components were made under the auspices of Chassis Systems Limited, a company which is based in Telford, Shropshire, UK. It is a joint venture between GKN and Dana Corporation. The hydroformed rails were made using the fourth generation of Dana's Roboclamp hydroforming press. Marando says that it was a challenge to make the rails because the press had to be adapted to meet European standards. "Just about everything changed, from British Standards units to metric sizing. Also, in Europe Allen Bradley is not the control system you want to be running. You want to be running Siemens because there are more technicians in Europe that can repair Siemens systems."

Adapting presses

Adapting presses to suit different markets may not be quite that simple. "The longer the hydroformed part the more you have to accept design limitations," comments Sherman. "If you make one long part you are forced to use a common thickness and the same alloy. There is a trade-off between manufacturing capability which may enable you to make more cost-effective parts but that may be at the expense of lightweight parts. Where there are differences in terms of the economics and the efficiency of the design you are making a trade-off," says Sherman.

Corus has addressed this need through its advanced Hyfo Tubes facility, which as an industry first introduced tailored welded tubular blanks allowing for thickness and strength of steel, either circumferentially or along the length of the tube according to the designer's wishes (see *AMS* issue Aug/Sept 2002).

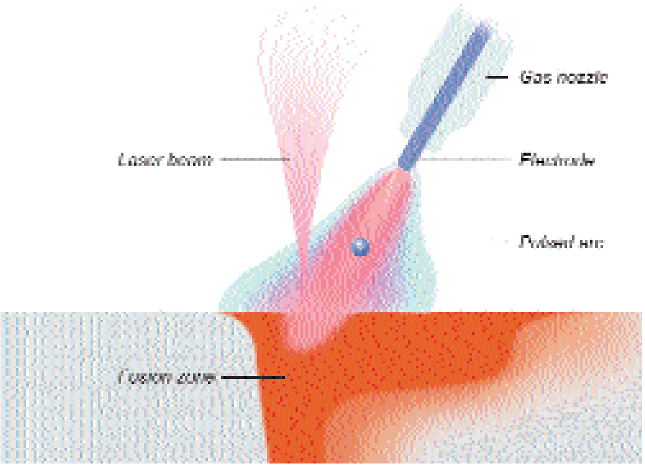
For aluminum components, friction stir welding (pictured) and NdYAG laser hybrid welding are the main processes for future applications – Kari Erik Lahti, ESAB

"If you look at a cross-member," says Xia, "in particular the rear, you don't want the rear to be the same thickness." He said that the whole cross-member could be hydroformed but there is a safety consideration because certain parts of a car must be more resistant to impacts than other parts. "If you have a rail, different segments have different purposes," explains Xia. He said that the challenge is to design one hydroformed component that meets the needs of all those parts. The alternative is the traditional approach which means different alloys and different thicknesses. "However, there is the expense of having multiple parts that have to be assembled.

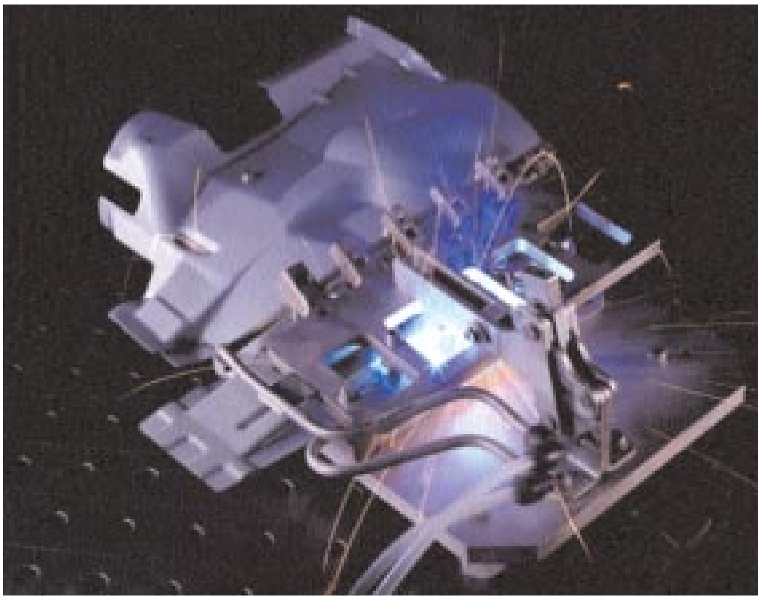
"Aluminum is a lot less formable than steel. We are involved in a collaborative program. Domestic companies such GM and DaimlerChrysler are validating computer models," adds Sherman. One of the ways that concerns about the newer grades of steel and aluminum have been resolved and presented is in discussions about industry-wide programs such as ULSAB-AVC (Ultra Light Steel Auto Body-Advanced Vehicle Concepts). ULSAB-AVC has also been a forum for the presentation of advances in tailored blanking. Aluminum is certainly the hot topic but the implications of using the newer grades of steel have been talked about for several years.

High-strength, low-alloy steel

Stanley L Ream is now Automotive Market Leader, Edison Welding Institute, Columbus, Ohio, US. He describes himself as. "a veteran of the tailored blank welding wars in the early 1990s". In an article titled *Targeted tailored blank welding* published in the August 1999 issue of *Industrial Laser Solutions*, he pointed out that the Ultra Light Steel Auto Body derived "half of its structure from laser-welded high strength low alloy (HSLA) blanks".



Schematic representation of laser hybrid welding process



Trumpf claims that laser scanner welding does not subject parts to wear and tear and exhibits high consistency

Since then the greater use of HSLA steels has increased. In 2002 these steels accounted for nearly 40 percent of the ULSAB-AVC body structures. While this is more than three times that found in vehicles currently – around 13 to 14 percent of the new body structures are tailored welded blanks – there is a continued strong uptake of this process by leading automakers and sheet steel component manufacturers.

"The shift toward HSLA steels is requiring a higher level of understanding of welded-blank formability and increasing attention to weld quality monitoring." In mid-2003 he stressed that the effect on formability of using those higher strength steels that have high carbon content is now a major focus for concern. Another major area of current discussion is the quality of the joints which are made when aluminum and these newer grades of steel are welded.

"Customers have shown interest in joining aluminum to steel," says Tony Van Der Veldt, Knowledge Group Leader, Automotive Joining Technology, Corus, Ijmuiden, The Netherlands. He says that one area of current concern is heat expansion, due to joining metals with different expansion coefficients.

Joining tailored blanks

"When a coating is applied to an aluminum blank and joined to a steel one the metals will be heated to 180°C. Therefore, one always has to consider the material and joining solution in relation to the application," Van Der Veldt comments.

He explains that aluminum-steel tailored blanks would be attractive from a designer's point of view because large pressed components such as roofs could be lighter. However, "Currently not enough is known about the long-term performance of welds between aluminum and steel."

USING ALUMINUM TAILORED BLANKS

Henk Zandbergen is sales manager, AWL-Techniek BV in The Netherlands. He summarizes his experiences.

Laser welding machine type:	HAAS-laser HL4006D 4kW CW Nd: YAG lamp-pumped
Wavelength:	1064 nm
Beam quality:	24 mm·mrad
Beam delivery system:	HAAS LLK-B 06, 0.6 mm fiber core
Beam focusing system:	HAAS 70032090, collimator, objective lens f=100 mm. En Bifocaal optiek
Plasma suppression gas system:	HAAS extraction cone 12-04-38-00

NOTE

More specified details are not available due to lack of rights on the investigation.

- Weldability of aluminum tailored blank depends strongly on the aluminum kind when there is no additional material used (equal to conventional welding without additional material).
- Differences in thickness are no problem.
- With the thicker AL-kinds, the possibility of Keyhole closing becomes larger which causes gas chambers to arise.
- Use of duo spot technology can have a positive effect on the quality of the weld.
- Pre-treatment of the welding wire (cutting edges) is extremely important. This also goes for the clamping and the attaching cycle.
- Laser is very appropriate for thin aluminum sheets because of its low HAZ in the weld and the low degree of transformation.
- Hybrid is often necessary because a wire has to be fed in order to obtain the proper weld quality. Cold or warm wire (hybrid MIG) makes the sensibility for tolerances smaller and makes the welding speeds higher.
- According to my experience welding aluminum the oxide skin on aluminum has little or no effect of the desired quality.

More needs to be learned about joining dissimilar materials. As Van Der Veldt points out aluminum and even magnesium are being used in combination with steel in car bodies. In the immediate future there is likely to be more interest in what happens when the newer grades of steel are subjected to further forming. These include TRIP, dual-phase and HSLA steels.

Some of the welding problems encountered when using ultra-high strength steels have not been solved yet. "In spot welding, the most frequently used technique in current manufacturing, this might be solved by post-weld heat. In the welding process, you change the microstructure of the steel. For ultra high strength steels the result is a harder weld. Sometimes softening of the heat affected zone will occur," he says.

Laser welding debate

In addition to the metallurgical aspects there is currently a considerable amount of debate about the merits of using lasers in welding in body construction and to join tailored blanks. Laser hybrid welding (see last boxed section) is a relatively new process. Kari Erik Lahti, marketing manager, Advanced Engineering Products, ESAB AB Welding Automation, Göteborg, Sweden, said that the reliability and quality of laser welds can be further improved by adding an arc welding process, for example MIG/MAG, TIG or plasma welding.

"Reliability of laser hybrid welding is at least as good as laser welding or MIG/MAG welding alone," says Lahti. Laser welding with CO_2 has a relatively high welding speed (8 to 10 m/min typically). "However the accuracy needed for edge preparation is very time consuming and hence expensive. With laser hybrid welding, either with cold wire feeding or MIG/MAG, TIG or plasma processes, wider tolerances are allowed without decreasing the welding speed. Additionally, the weld metal composition can be controlled in order to reduce the cracking tendency in high-strength steels. For aluminum components, friction stir welding and NdYAG laser hybrid welding are the main processes for future applications."

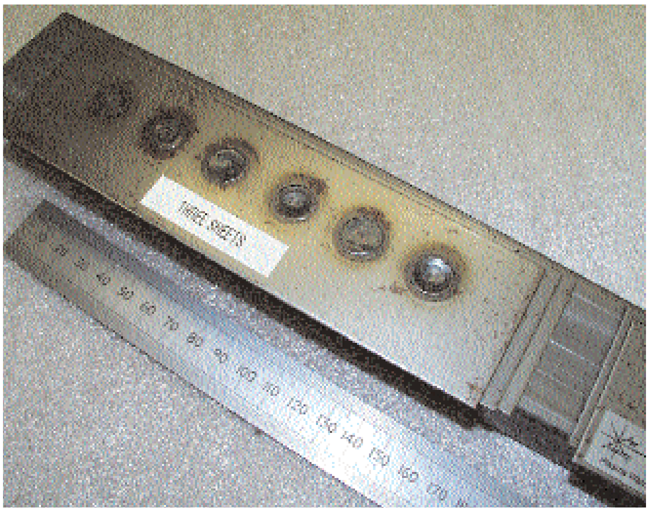
Although there are many parameters which need to be controlled when using lasers in welding, suppliers of laser equipment say that lasers are still attractive.

Scanner welding

Trumpf, which has offices in the UK and Germany, says that the BMW Group recently qualified and approved scanner welding with the TLW 60 S for use in serial production. The decisive advantage of the scanner technology is its very high positioning speed at more than 700m/minute.

The supplier claimed that as opposed to traditional joining methods like resistance spot welding, laser scanner welding does not subject parts to wear and tear. "Moreover, the typical advantages of laser welding are higher consistency over the entire production cycle, improved qualities of the weld seam surface, smaller welding flanges and one-sided accessibility of the component."

Linde, a supplier of gases used in laser welding, which has offices in Germany and the US, also pointed out the merits of this type of welding. It said that compared to conventional welding methods like GMA welding or TIG welding, laser welding enables more targeted heat input, less distortion and very high welding speeds.



Automakers in the US are re-examining some of the old technologies and considering updating the welding methods

Plasma welding

The gases supplier added that when using this method the plasma produced by the laser beam can be influenced by the welding gas in order to produce a stable and reliable welding process. With its LASERLINE program the Linde Gas division of Linde AG claims that it offers the right welding gases for obtaining optimum results in laser welding.

However, laser welding also has disadvantages according to Russ Hughes. He is vice president of Arc Kinetics and is based in Redford, Michigan, US. "Lasers are incredibly expensive," says Hughes "and access is an issue. How do you get the laser inside the vehicle to weld it? "His main criticism of laser welding is that as it is one of the newer forms of welding there are fewer operatives who are familiar with it. "Resistance spot welding has been used for 100 years. You don't need highly skilled people. If you have a problem with laser welding do you need a laser optics guy or a laser physics guy?

"If you were to place an advertisement for a laser welding expert with 10 years' experience in automotive plants you wouldn't get a reply," adds Hughes. He said that because of the skills shortage automakers in the US are re-examining some of the old technologies and considering updating the welding methods.

Disagreement about skills shortage

Users of laser welding equipment disagree about the skills issue. Gerry Jones is general manager, Laser Systems, Trumpf, and is based in Luton, Bedfordshire, UK. Corus is one of its customers. He said that Trumpf is able to respond quickly when the company's customers have problems operating laser equipment that it has supplied.

"I wasn't aware of such shortage", says Lahti. "ESAB has trained personnel able to serve its laser equipment customers 24 hours a day. Maybe one of the reasons why car manufacturers feel that there is a severe shortage of skilled personnel could be that they usually buy lines from line integrators." He says that the latter, "Just purchase equipment according to specifications that they have received from the buyer. The process know-how may not be properly transferred."

It has been difficult to obtain prices for laser welding

UNDERSTANDING THE IMPORTANCE OF FIT UP WHEN USING LASERS

Bill Gulliver is the business development manager for Europe and North America, Corus AutoLaser Technologies, a division of Corus UK Ltd, Wolverhampton, UK. He talked to *Automotive Manufacturing Solutions* about the fit up issues which need to be understood when using lasers in welding.

Gulliver points out that laser welding is currently used in two fundamentally different ways in auto making. Upstream it is used in the manufacture of tailored blanks and downstream in a further process – laser welding of vehicle body construction assembly, when the blanks and other components are joined together to form sub-assemblies and ultimately the main vehicle structure, (otherwise known as the body-in-white).

He believes that the blank fit up requirements concerns regarding laser welded joints used in the manufacture of tailor welded blanks (TWBs) from the familiar grades (and dissimilar gauges) of steel are fundamental to successful welding. He says that the high level of precision required during fit up can be achieved when the blanks are cut using blanking dies designed for TWB technology.

According to Gulliver there are some process parameters which have to be carefully controlled and monitored when welding TWBs. These are: control of the metal when it is moved into position for welding; variations in flatness, oiling levels and the mechanical properties of the metal; and movement due to heat generated when two blanks are welded.

"All these can affect the fit up processes. However, they can be controlled using specialized clamping fixturing equipment and the use of special blanking dies designed for TWB production," says Gulliver.

equipment because there are so many variables. However, ESAB responded to another of Hughes' concerns about laser welding which was cycle time. He says that a resistance spot weld could be made in 3 seconds. "If you define cycle time as, in-transport of part – welding – out-transport of part, it will be tough to beat 3 seconds. I think the transport time for a complete car body may be typically around 10 seconds or a minimum 5 seconds."

Lasers may only be adopted more widely in welding if welds can be produced extremely quickly. Recently, TMS, a company based in Linz, Austria, reported an unusual cycle time on a project involving welding. TMS supplied body-in-white production equipment for the new smart roadster coupé, to Magna. "Because of the small batch numbers to be produced," explains Peter Oyrer, the TMS project manager, "the smart roadster coupé, has an unusual cycle time of 396 seconds and as many operations as possible have to be completed in one station with a very high use of robot capacity."

Whereas 5 to 15 weld points are carried out by one welding gun in the manufacture of the smart-city-coupé, it is 50 to 60 weld points with the smart-roadster-coupé. Plant flexibility is thus an indispensable requirement and is fulfilled by the 38 robots with their 61 welding guns.

Cost and efficiency

Ultimately though, as Hughes stresses, it comes down to costs. Automakers may only buy laser welding equipment if welds can be made very quickly. Prices fluctuate and governments may intervene. One of the forces still driving automakers to make more hydroforming components is the need to use materials more efficiently. Hydroforming is an attractive process because, as Marando points out, there is less scrap than with many other processes. While President Bush's steel tariffs have not directly affected the use of hydroforming they have made OEMs think more carefully about the cost of the steel.

The debate about the merits of using aluminum and higher strength steels will continue. Perhaps the experts are sailing into uncharted waters, but it is clear that they will need to work closely together to find the most appropriate solutions. ■

HYBRID IS MORE THAN JUST LASER PLUS MIG

TPS-Fronius is a leading supplier of laser hybrid welding equipment. The company explained the principles of the technique to *Automotive Manufacturing Solutions*. It also gives an overview of its system.

Just as the whole is often more than the sum of its parts, laser hybrid is more than just a laser process plus a MIG welding process. TPS-Fronius offers what it claims is the first-ever complete, industry-standard laser hybrid system. Before its première at Schweissen & Schneiden, this integrated solution was tested for more than eighteen months in the German automobile industry.

TPS-Fronius says that the user gets an industrially proven system which comes with an extensive consultancy package. Starting with the user's work piece, this also addresses the overall operating conditions and even extends as far as process monitoring. It says this thereby conveniently integrates such aspects as process dependability, system availability, productivity and profitability.

In laser hybrid welding, the energy of the laser beam is directed at the speed of light to meet the plasma of the arc. The two act simultaneously on the same welding zone, influencing and assisting one another as they do so. In comparison with the results where each process is used separately, the outcome is: greater bridge ability, at the same time as very much higher joining rates; deeper penetration and narrow seams, yet less thermal input; and high weld ductility, joint strength and scope for influencing the structure by means of the filler metal.

The system as a whole consists of a welding power source, the welding head and the process software (all supplied by Fronius), together with commercially available robots and a laser source. Being the 'heart' of the whole system, the welding head meets such requirements as robot-compatible design, great flexibility in terms of its maneuverability, compact construction, good positional ability of laser beam and arc with respect to one another. TPS Fronius said that the system also offers a high degree of process reliability.