BODY WELDING - CAN IT BE FLEXIBLE?

BODY WELDING - CAN IT BE FLEXIBLE?

Some 250~300 pressed panels from in-house and vendor facilities are brought to different subassembly stations of Body Weld Shop. Subassemblies of pressed components are carried out mainly by resistance welding and other joining methods in a planned sequence at number of stations. Some subassemblies are done in off-line manufacturing cells and fed in at appropriate locations into the main assembly line. Fig. 6.1 shows a layout of a typical Body Weld Shop. Front end, rear floor, and front floor, are transported to underbody body line, where all these are welded together in sequence to form the floor structure. Underbody is then transferred to main body welding station. Right hand and left hand body side panels are brought from two sides to main body weld station, after completion of all subassembly operations in separate lines. Preframing of body structure is carried out on special fixture. At same or next station, roof is added to form the body shell, Fig. 6.2. Thereafter, rear doors, front fenders, hood and decklid/ tailgate fitments are carried out to complete the body-in-White. If necessary, a metal finish line may be added for minor repair of Body-in-White before it moves for painting. Fig. 6.3 illustrates the sequences of subassemblies and the main body weld.

Typically, Body weld shop activities cover fixturing, welding, and transportation between the work stations, and the related support services..

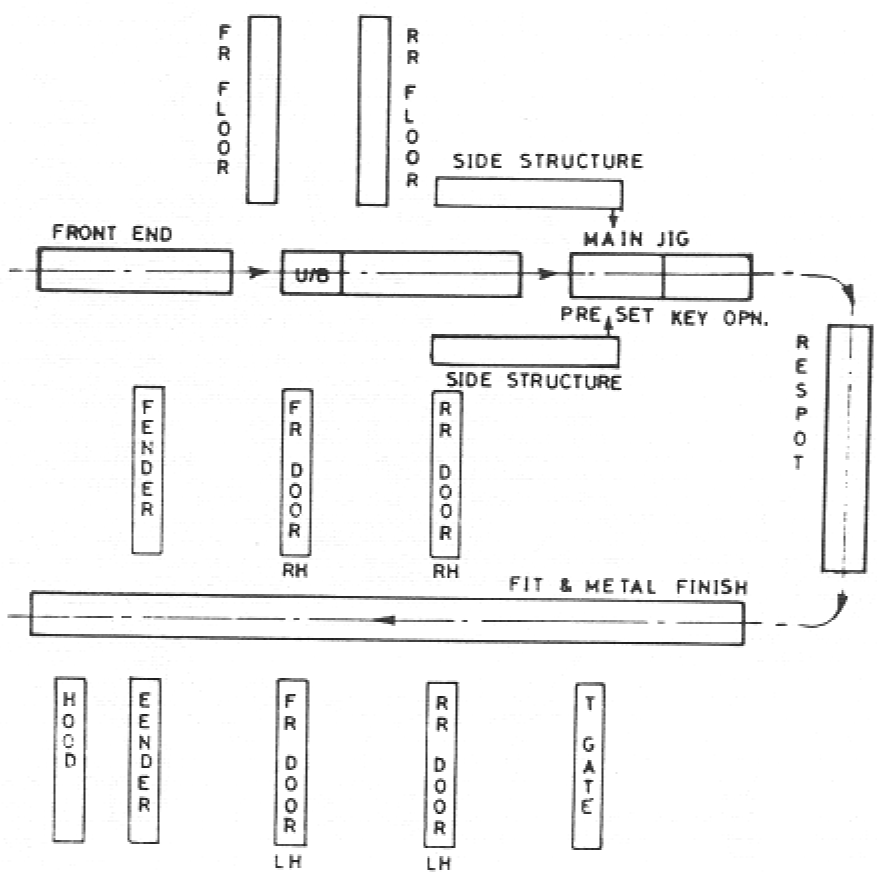


Fig. **6.1 A Typical Body Welding Shop Layout**

Over the years, the concept of building the fixturing for body shop has undergone changes. In earlier concept small unit parts used to grow to large ones by sequential welding in jigs/fixtures. For better rigidity and to avoid distortion causing dimensional inaccuracy of structures, the parts were clamped on dedicated and complicated fixtures with manual toggle

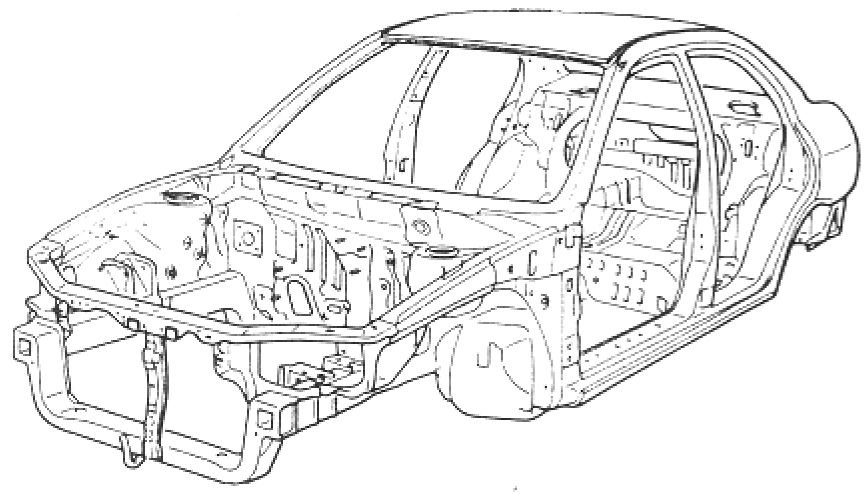


Fig. **6.2 A Typical Body Shell Construction**

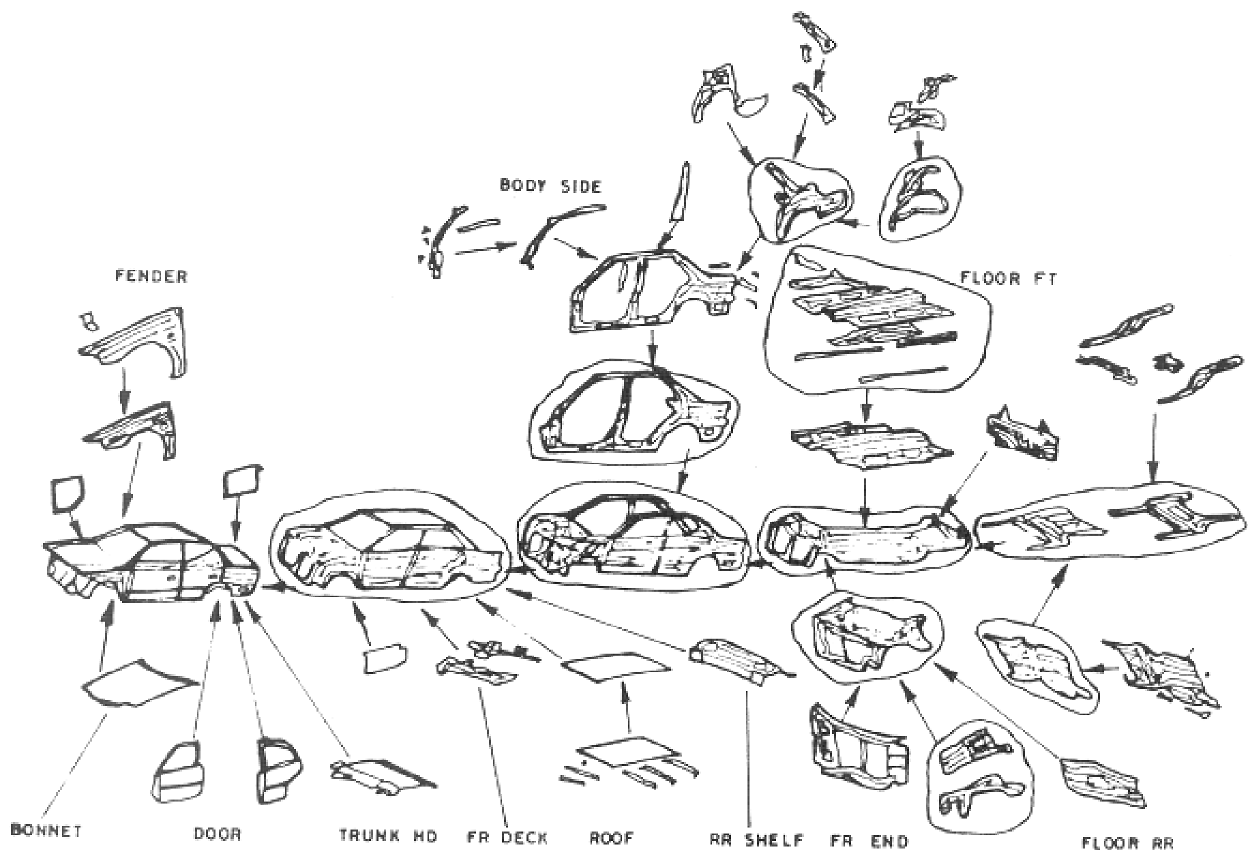


Fig. **6.3 Sequences of Sub-Assemblies and Main Body Welding**

clamps or through an integrated pneumatic clamping system. All possible welding was carried out at each station before moving to the next station. The accuracy of each of these preprocesses was deciding the accuracy of the final assembly of body-in-white in line. At final line, the accuracy could not be affected. The new concept now limits welding points to minimum at dedicated fixtures for subassemblies. It leaves finish welding as much as possible for the final welding line to ensure quality. However, the finish welding is done, necessarily, after making necessary adjustment for the position errors.

Trends for body welding have changed from individual spot welding guns, to special purpose multi-welding machines, and then to application of robots for welding and other joining processes in cells and lines.

SPOT WELDING LINES USING INDIVIDUAL GUNS

Individual product specific fixtures are used for subassemblies of different pressed components with help of manually operated overhead spot welding guns. The numbers of guns depend on production requirement and space availability for additional operators and/or additional guns. Assembly requirements of individual components going in the subassembly and accessibility of weld spots decide the numbers of stages required and weld gun style. Welding guns are generally available in standard configurations dependent on size and style. Special guns may be essential to meet specific requirement of body design. Numbers of fixtures and welding guns, man power engaged and their efficiency along with efficiency of the overall system such as maintenance, decide the production capacity of the line. In an automobile body, typically something like 3000~5000 spot welds are required. Fig. 6.4 shows a typical view of spot welding machines in a low volume weld shop.

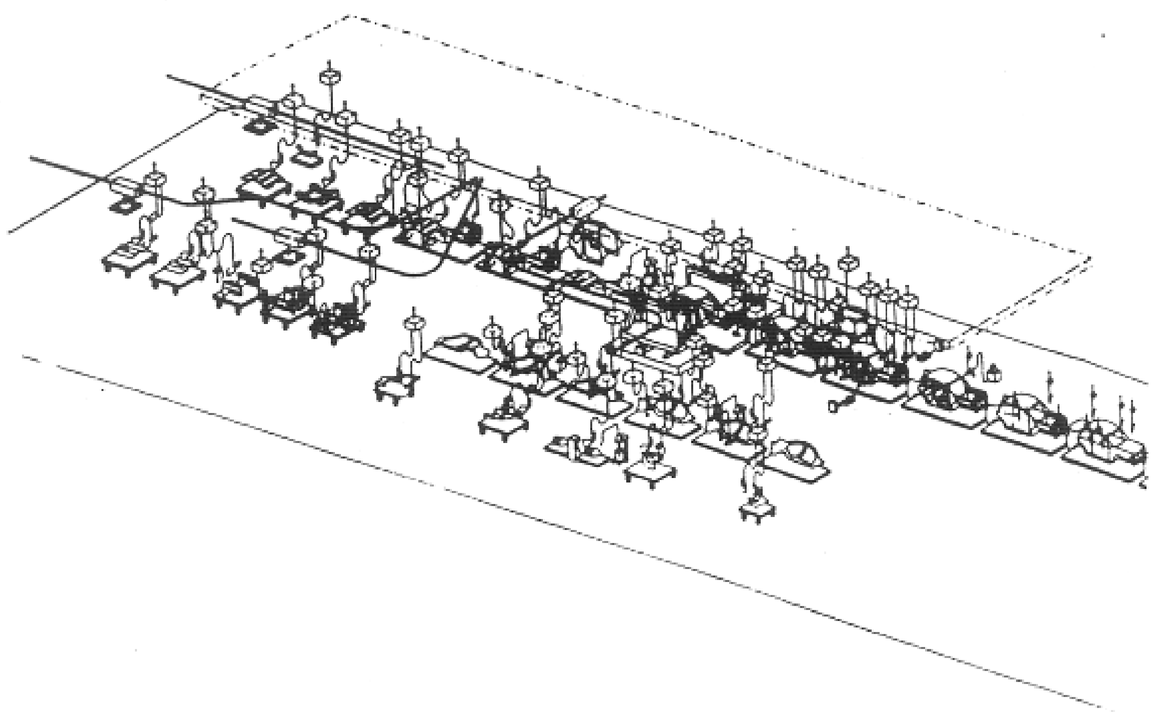


Fig. **6.4 A Typical View of a Low Volume Body Weld Shop**

MULTI-WELD MACHINES

Special purpose welding stationsand/or machines have basically multiple spot welding guns built-up in fixtures at different locations as per process requirement with automatic control for clamping/unclamping, and welding sequences. These machines are integrated in automatic lines. Besides their cost, these machines are product-specific, highly inflexible and require total replacement for new model change.

Equipment manufacturers are trying hard to find an economical solution for combining high output with flexibility. In one such system, a hexaphase DC power-pack is integrated with a multi-axis component positioning system. Component holding frames are manipulated using AC drives. Lower head is programmable through a Z-axis drive. Options include multiple electrodes, additional heads, head rotation about vertical axis, angled head, etc.

ROBOTS IN WELD LINES

Portable spot welding is one of the most tedious and tiring operations in automobile manufacturing. The odd shaped weld guns are to be moved and maneuvered from one location to another at sufficiently high speed to meet the production requirement. The process is time-consuming and dependent totally on operator-efficiency. Manual MIG arc welding is skillwise more demanding and hazardous. A large work-force is essential for welding shops dependent on volume of production. Multi-weld stations reduce the problems to certain extent but require very high capital investment and that also in totally dedicated setup that is to be discarded with every model change. Robot for welding system provides the ideal solution for high production plant. Flexibility improves with application of robot (in comparison to multi-weld facility). The quality of weld spots is consistent. Design of welding fixtures gets simpler. The robot eliminates inhuman workload of operators that is caused in handling of heavy welding guns. A robot does not become tired. A robot does not forget to make a spot weld that has been programmed. The robot will always weld at the right place, in every cycle, and for all the hours of the day. Basic superiority in the quality of work carried out by a robot over that performed by an operator are:

- High positioning precision
- High repeatability
- No deviation in results due to fatigue
- Highly accurate inspections and measurements using sensors.

Use of robot for spot welding generally brings down the number of spot welds. Robots may be either floor-, wall-, or ceiling- mounted. For covering larger areas and to overcome space constraints, gantry mounted robots are used. Robots may again be single purpose or multi-purpose type. For cost effective utilisation of a robot, quick change tool adapters are used to allow a variety of end effectors to be quickly and automatically changed on the robot wrist. An industrial robot may apply a structural adhesive along the hem of a door. It will then automatically change its dispensing head for a spot welding gun with an integrated transformer in order to carry out some welding operations. It subsequently picks up a gripper in place of the spotting gun and loads the door in the next position. Maximum numbers of robots in any automotive plant are today used in body welding facility.

GATE LINES

As the production requirement increased, different systems evolved for production of body shell. In gate line system, a number of ‘gates’ with manual clamping fixtures are used for underbody and body side panels RH/LH. The numbers of gates depend on production requirements. At the end of gate line, the gates are clamped together and spot welded. Positional accuracy of all the gates with respect to reference surfaces must be same, otherwise the body quality will be inconsistent. Thereafter, the body shell moves on a conveyor where rest of the welding operations are carried out at different stations.

ROBOGATE - CONCEPT FOR MASS PRODUCTION:

Robogate uses only one 'gate', the holding device that locates the sheet metal panels for welding. Having only one gate ensures weld consistency and allows any problems to be easily pin-pointed. There are two types of Robogate. The first uses self-propelled trailers for the floor handling of parts to be welded, whereas in the second type they pass through the welding stations in sequence along a line.

In a typical robogate line, a lift unit feeds body floor pans into the start end of a robogate. Another feeder injects roof parts into the line, after adjusting the height to suit the model (coupes are generally lower than sedans). Side frames are produced on two sides of the main robogate in lines similar to robogate and fed to the robogate. Basically, in these subassembly lines, robots pick up parts for the assembly from conveyors and place them in sequence into assembly for tack welding. Spot Welding is carried out at respotting stages. Robogate is fully mechanised for assembling floor pans, built-up sides, roof, shelf, and other details, producing a body shell to required dimensions.

Presently most of the body welding facilities are being planned with model-specific tacking stages for major subassemblies followed by flexible spot welding on lines with industrial robots, Fig. 6.5.

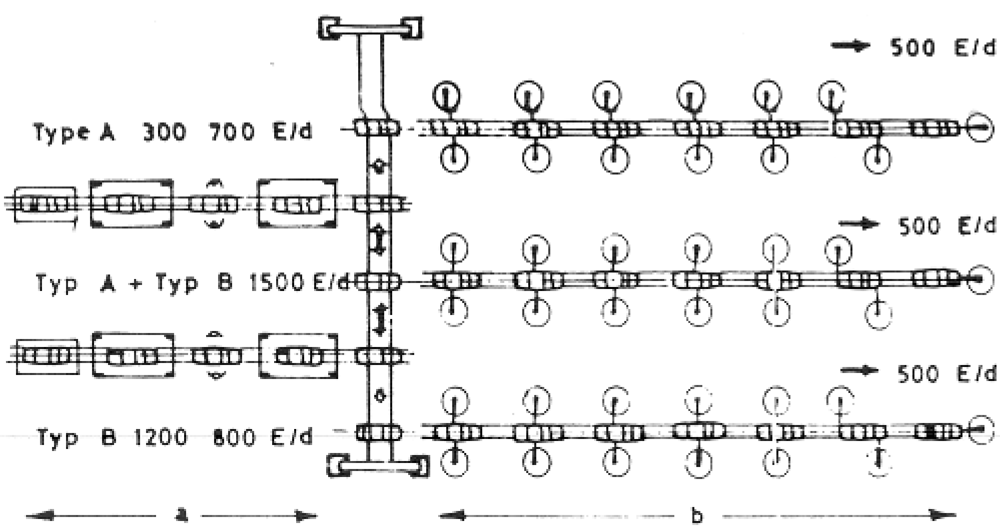


Fig. **6.5 Model Specific Tacking and Flexible Spot Welding Lines**

MAIN BODY JIG OR FRAMING STATION

Main body jig or framing station has been dedicated and complex for a model of body. Over the years, different concepts of framing jigs have been developed with objective of high productivity and assured quality. However, with changing manufacturing strategy to attain lean inventory and more variety, flexibility of framing jig has become more demanding requirement.

For a change-over or addition of a new model, the manufacturing management has three alternatives:

1. Change the old line with new one by stopping production for a considerable period.

2. Allocate the new line in different location.

3. Change manufacturing line for production of forthcoming models while production of the current model/s go on.

Naturally, the best option for the manufacturers is number 3 and flexibility is a necessity for reasons as follows:

1. To improve mixed production
2. Enormous investment for change over when the model is changed
3. Stoppage of manufacturing lines prior to change over
4. Surplus tied up production capacity during phasing out of model
5. Huge manpower to change the layout and installation of new equipment

Main functions of the framing system that are to be considered for incorporating flexibility are:

1. Geometry function which includes all necessary means to ensure accurate positioning of parts in relations to each other.

2. Handling function that includes all equipment necessary to move parts, tooling, etc. Accuracy level is lower than that required for geometry function

3. Tool function which includes all equipment adding a value to the product being manufactured (welding guns).

Product-specific framing stations for single model as shown in Fig. 6.6 are changing. Normally on a single platform of underbody structure, all auto manufacturers try to build different models such as 2/3/4/ door sedan, van, using different body-side panels RH/LH. So, a concept of a 2~4 face rotary construction - each side for one model of body side panels RH/LH has been developed as shown in Fig. 6.7. The total line, i.e. main frame, locators, and robots can be changed to different models through computer controls. However, this method could only make a maximum of 4 models with one framing station. Additional station/s are to be added for more models, if required to be taken for production in the same line. In one such system, a set of 3 framing stations in the line is producing 10 models with skipping to the desired framing station for the specific model in production as per program.

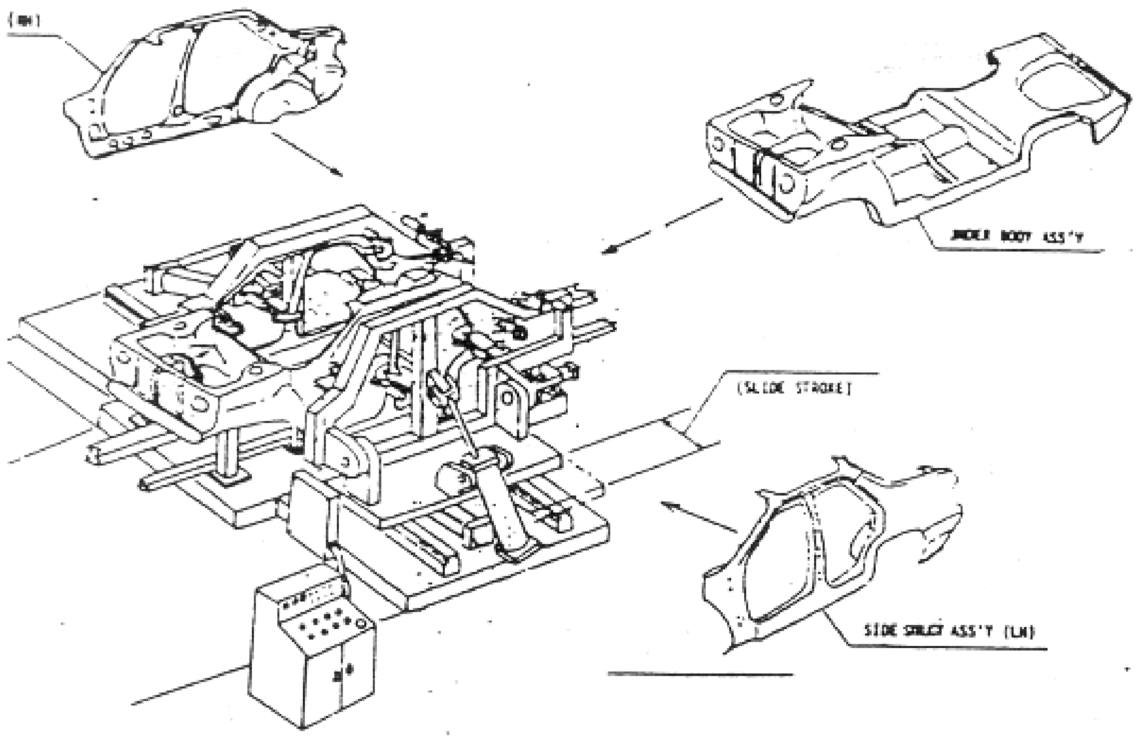


Fig. **6.6. Model Specific Framing Station**

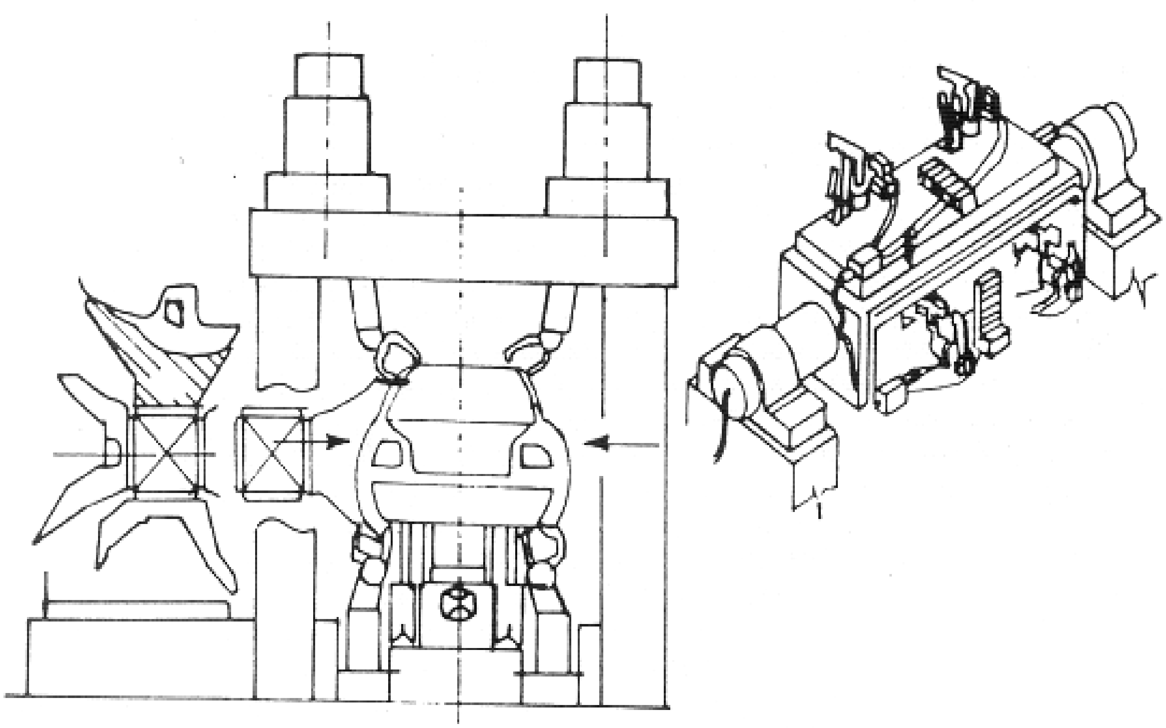


Fig. **6.7 An Improved Version of Body Framing Station**

Some more flexible systems have been developed by top ranking automobile manufacturers in different part of the world for the main framing station:

1. *Renault's Preciflex*
2. *Toyota's Flexible Body Line*
3. *Nissan's Intelligent Body Assembly System (IBAS)*

1. RENAULT'S PRECIFLEX

Preciflex has a triangular structure, Fig. 6.8, that comprises of three different frames on which the geometrical references, clamps, and welding guns (if necessary) are installed;

1. Lower Frame integrates all the geometrical references of the underbody. The tooling is unique for all models having the same platform (underbody).

2. Upper front frame integrates all the geometrical references of front part of the body. The frame remains same for all the models having the same front part of the body.

3. Upper rear frame integrates all geometrical references of the rear part of the body (sedan, hatch-back, station wagon, and so on).

The modular concept of the system allows the addition of standard frame change equipment and thus phased investment. Addition may be for:

1. Front or rear magazine (turret) for upper frame change
2. Linear shuttle for lower tooling change

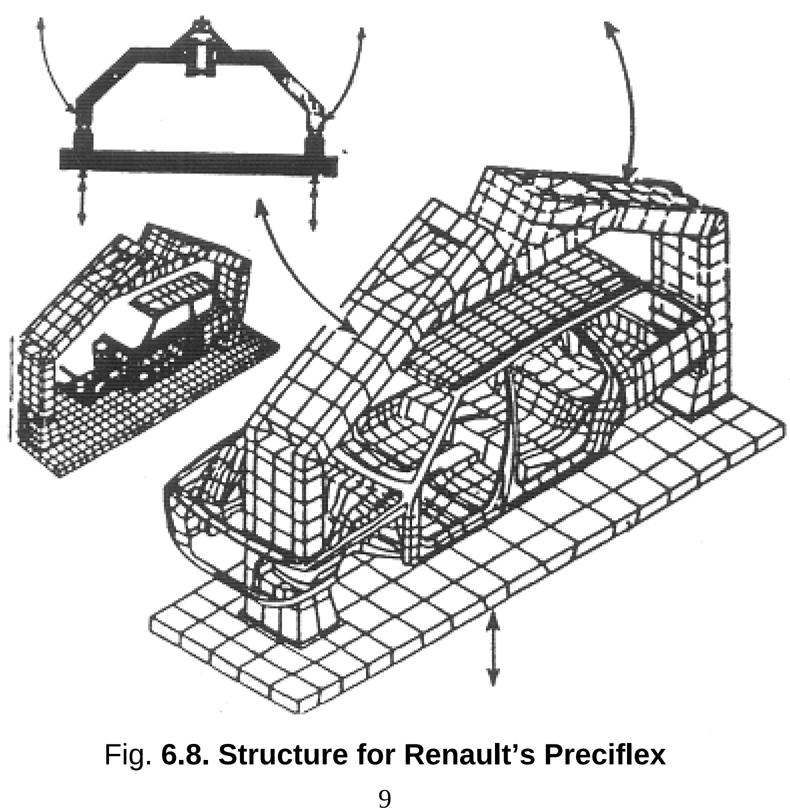


Fig. **6.8. Structure for Renault's Preciflex**

The change operation for the lower and upper frame can be carried out in 8-9 seconds. Even a new frame for new car generation can be incorporated in the system in 2-3 hours through setup change that is done off-line. So even pilot bodies can be produced with the normal production equipment. Production rate of the Preciflex can reach about 80 vehicles per hour. With lateral accessibility, both manual guns as well as robots (upto six) can be used.

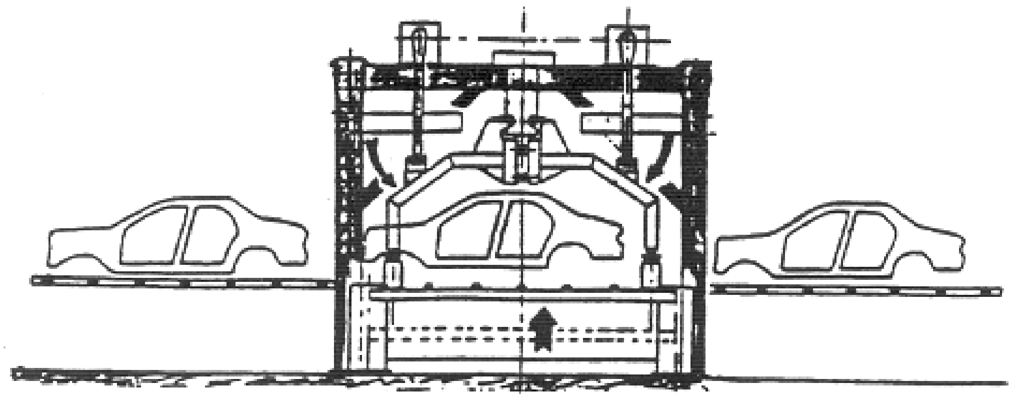


Fig. **6.9. Preciflex for One Unique Model**

The system may be created for one unique model with minimum initial investment, Fig. 6.9. The system provides the possibility of creating several different models for the same car family, where the front and lower frames remain the same, Fig. 6.10. It may also be possible

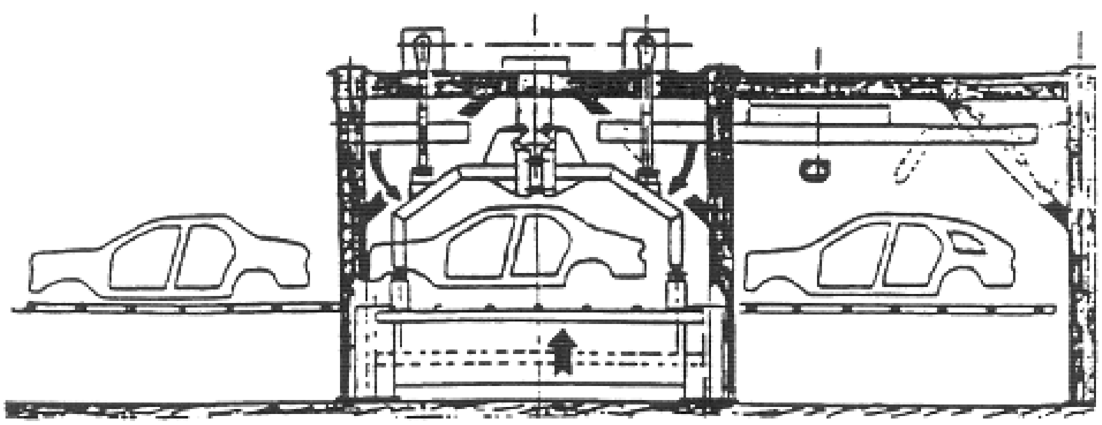


Fig. **6.10. Preciflex for several models for same car family**

to create the facility to cater for several families of different car series by adding two upper magazines and a lower shuttle to distribute different frames, Fig. 6.11. All controls are through PLC without requiring any software or hardware modifications with the introduction of a new model.

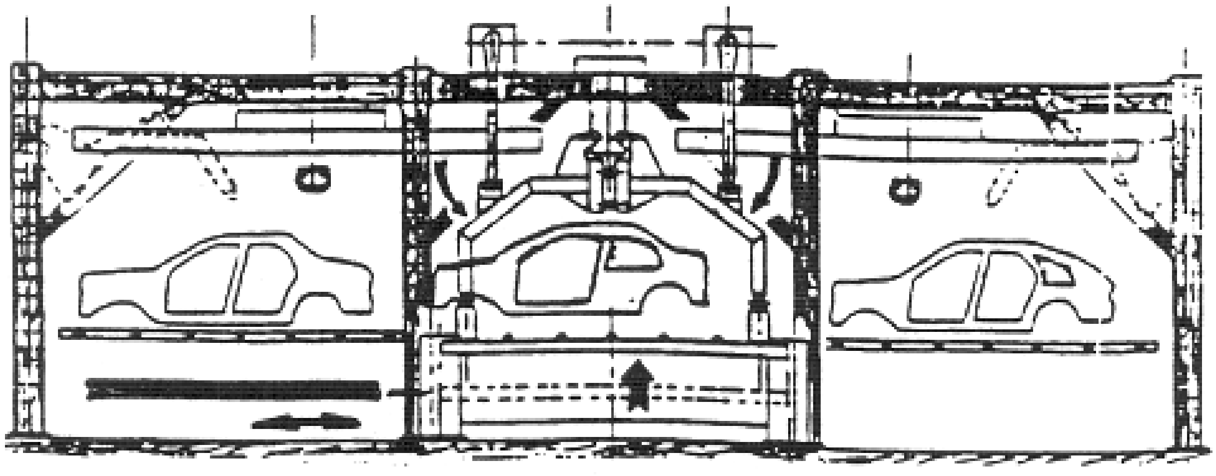


Fig. **6.11. Preciflex for Several Families for Different Car Families**

Preciflex system enables:

1. A high level of adaptability of the equipment, minimising the initial investment

2. An important reduction of the time required to change the tooling when starting the production of a new model.

3. A fast production setup with a pre-certified (off-line) quality level

4. An off-line tooling certification

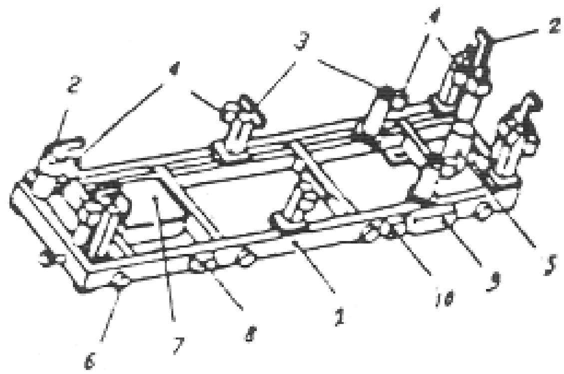
5. The possibility of producing pilot body or preproduction body directly with the final production setup. The modular concept allows the addition of standard tooling change equipment (front or rear magazine, lower magazine change) as phased investment.

6. Possibility of evolution from a manual welding operation to an automatic line with robots.
7. Loading of different parts as body sides, roof crossmembers or reinforcements directly in the geometry station.

2. TOYOTA'S FLEXIBLE BODY LINE (FBL)

FBL includes 'jig pallet circulation method', 'off-line programming of robots', and 'highly reliable robots'. The system uses a high speed transferring machine to carry on jig pallets that function to fix and transfer pressed components. The transferring machine circulates the jig pallets within the manufacturing process. Jig Circulation Method does not remove workpieces between manufacturing processes and so it is suitable for small lot production of many varieties. In a line, intelligent jig pallets (Fig. 6.12) are used for main subassemblies such as

1. Underbody 2. Body side member RH/LH 3. Roof, Cowl, Upper back, and Lower back (RCUL)



❶ Main body frame ❷ Workpiece positioning standard and clamp ❸ Workpiece positioning standard ❹ Sensor ❺ Jig pallet transfer pin ❻ Wheel ❼ PCL ❽ Communication coupling ❾ Power supply coupling ❿ Air Supply unit.

Fig. **6.12 An Intelligent Jig Pallet**

The jig pallets are provided with a **PLC** *(Programmable Logic Controller)* data recognition and transferring functions in order to control industrial robots and other machines as per the model. The system gives more stable quality to body accuracy compared to Fixed Jig Method, that fixes jigs to each process to assemble pressed components per manufacturing process. It can make as many different body vehicle models on a single line as many sets of pallets are made available. Fig. 6.13 shows jig pallets for different subassemblies going in vehicle body main framing station. Toyota has reduced the lead time by 50%, as CAD/CAE system assists an off-line programming of the robots. The system provides individually computerised calculation for positioning of industrial robots, selection of spot welding guns for industrial robots, and welding conditions. The system also has improved accuracy of bodies. New jig pallets for new models can be fabricated and introduced in the system for production without stopping the line.

To increase manufacturing quantity per production process, Toyota concentrates on robots' allocation per manufacturing process. Work in process inventory is reduced. Number of running jig pallets is minimised by increasing circulation speed. Facility investment remains controlled, and complicated production management system is eliminated.

Most robots incorporate position error compensation function of the off-line and on-line operations by teaching 4 standard points on a manufacturing spot. Machine errors, distortion by load, etc., are compensated through the use of a computing function at each robot. Body accuracy is measured on line with industrial robots, and accuracy of jig pallets is controlled by statistical processing of measurement data. FBL is further supported by in-house developed software for new flexible production control system - comprising of the manufacturing control software, the line control, the quality control, and the software for supporting production preparation. The controller of manufacturing processes manages even the supply of power and air to a jig pallet independently per manufacturing process as well as effectively processes data among jig pallets, robots and transfer controller units.

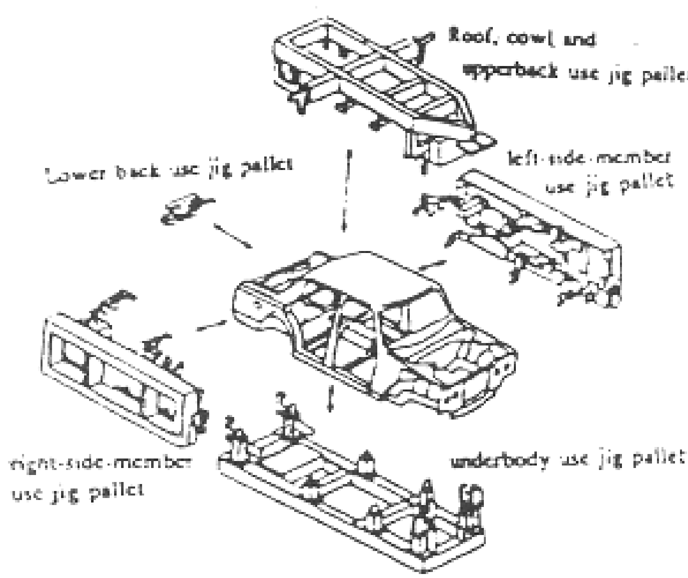


Fig. **6.13 Different Jig Pallets for Major Subassemblies**

3. NISSAN'S INTELLIGENT BODY ASSEMBLY SYSTEM (IBAS)

IBAS comprises of three stages:

At *stage 1*, provisional assembly of a total of seven parts (floor, body side, roof, air box, rear parcel self, and rear panel) is carried out, but without welding. The body side is supported by transfer equipment; and such parts as the roof and air box self-locate (but no 'toy tabs' are used).

At *stage 2*, the seven panels are brought by shuttle into its steel structure (known as NC locator), are positioned by 35 positioning robots with accuracy of +/- 0.1 mm. Thereafter, the panels are spot-welded by additional 16 robots at 62 locations for holding the panels together.

At stage 3, a body accuracy measuring unit uses sensors to check all critical dimensions. If any part of the finished body is out of specification, the NC locator can be readjusted through its feed back system ensuring an accuracy of +/- 0.5 millimeter. Points measured include standard holes for body assembly, holes for installing various parts, and positioning points

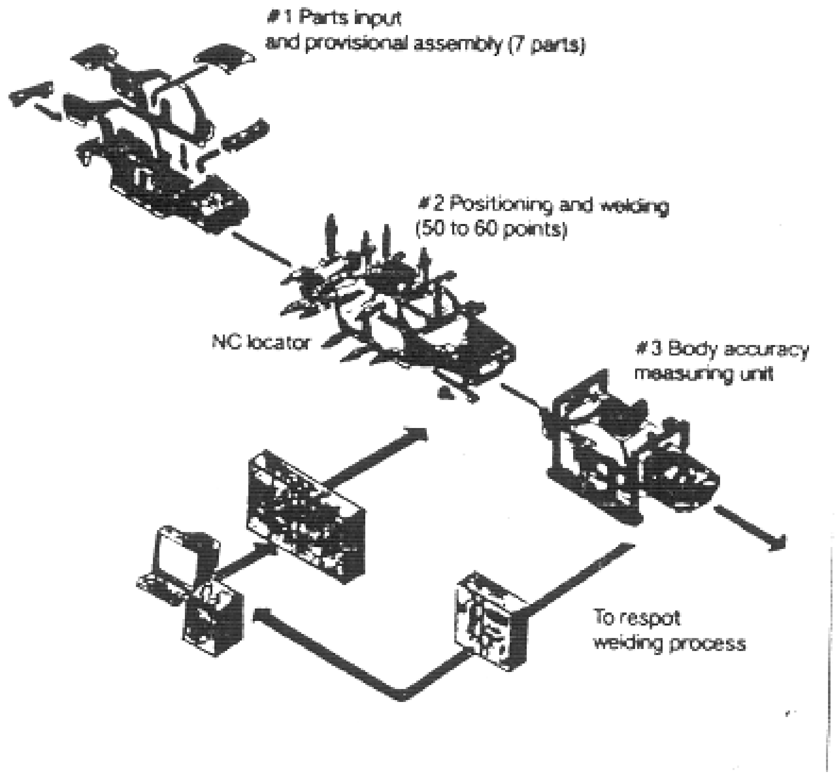


Fig. **6.14 Stages of Nissan's Intelligent Body Assembly System**

for window panes, doors, hoods, and trunk openings. Usually, measurements for holes are accomplished using a two-dimension sensor. The cross-section measurements of positions for openings involve measurements of curved surfaces, which requires seeking out virtual points, for which Nissan uses proprietary 'flying spot sensors'. The principle of the flying-spot sensor is to hit the object to be measured with a laser beam, receive the reflected beam by optical camera, and measure the objects position. The angle of the reflecting beam changes, if the position of the object undergoes any change. To record the cross-sectional shape of parts, a movable mirror is set up between the light source and the light receptors. When the light Os turned on, cross-sectional measurements can be accomplished. Cross-section data is calculated from the position-coordinates' value, mirror rotating angle of the measuring robot, and the data acquired by a sensor in the camera. Sixty positions are measured, and measurement results are recorded and displayed. If the actual data and the body CAD data indicate a trend in differences exceeding the specified tolerance, data is transmitted to the NC locator to enable positioning corrections. Fig. 6.14 shows schematically the IBAS

Various support tools are used with IBAS:

- The failure diagnosis system monitors the status of the entire IBAS. If a problem occurs in the NC locator, it pinpoints the location, identifies the cause and indicates the corrective action.

- The CAD teaching system supports the off-line programming of the NC locator, based on the CAD data of the models to be produced.

- The CAD simulation system is used to calculate cycle times and conduct computer simulations to check for interference between the robots and body panels. The system is expected to support trial production by computer for simultaneous engineering, through the use of a quality assurance Artificial Intelligence database and the CAD data.

Advantages are:

1. Reduced lead time for retooling for a body of new model (from 12 months to 2-3 months), as design work and production launch preparations are carried out concurrently.
2. Reduced cost of change over.
3. Allows body production to be simulated on a computer allowing potential assembly problems to be worked out before the body design is even finalised.
4. Facilitates small lot production of a variety of models.
5. Achieves significant quality improvements.

NC locator has the capability to recognise different body models and automatically adjust its robot jigs and welding robots to assure a perfect fit every time. No further adjustment is necessary. The system for Nissan handles all 27 models and 54 body types. The line can produce one car in 45 seconds.

However, the most appropriate technology for welding shop may require the best combination of conventional and flexible technology.

JOINING TECHNIQUES USED IN BODY STRUCTURE

Some of the major joining techniques used in body-in-white lines are:

- ✓ Resistance spot welding
- ✓ Weld bonding
- ✓ MIG arc welding
- ✓ Seam welding
- ✓ Laser welding
- ✓ Mechanical joining

Resistance spot welding

Resistance spot welding uses the surface resistance of the materials to be joined to generate an intense localised heat under pressure with a short passage of a high current. Use of coated sheet in vehicles for corrosion resistance have presented problems related to the electrode life. The electrode life may get reduced to 50~500 welds before maintenance (tip dressing) as against 3000~6000 welds in case of uncoated plain steels. With introduction of

HSLA steels, the need for reliability of weld quality has become much more demanding. Suitable shop floor quality tests are vitally important.

Spot weld quality is ensured through control of four principal parameters:

- ✓ Current
- ✓ Weld Force
- ✓ Weld time
- ✓ Electrode configuration

Japanese automotive manufacturing system emphasised first on constant current in resistant welding for its practical advantages:

- Automatic compensation for power variation of mains.
- Correction for welding gun impedance change when welding across large sections of body panel.
- Less program changes
- Compensation allows different number of thickness to be welded on one setting in many applications.

Weld timers provide the ability to monitor each spot weld so that its peak current level is within predetermined limits. Dynamic resistance principle measuring the variation of resistance over time during the weld is also used to ensure a higher level of guaranteed quality. A sophisticated dynamic resistance system may incorporate an adaptive control feature that varies the weld settings within certain limits to achieve correct weld quality. The system also includes a weld current stepper function linked to the counting of welds executed. The parameter limits are established for the specific application and programmed for control. With capability of microprocessor based controls, the constant current system could easily be attained for ensuring weld quality.

The weld time variation is unlikely with electronic controls. Welding force is applied pneumatically through line supply and hardly require a more rigid control attained for ensuring weld quality. Tips of electrodes are to be maintained for consistent current density. Either an individual weld count or an interface with the robot (if used) is applied to make electrode dressing compulsory after an established number of cycles. Pneumatic or electrically driven tip dressers shape both electrodes simultaneously to ensure established geometry and decontaminated condition of the tip surfaces.

For quality of spot welding of automotive body, in addition to accurate panels and jigs, tightly controlled position, sequence and direction of spot welding as well as attitude of welding gun are necessary. Spot welding was basically manual operation. Dedicated multi weld machines are used for high volume production in totally automatic mode. The application of robots provided the appropriate human solution with much higher precision in positioning and repeatability as shown Table 1.

With increased acceleration and deceleration of robots, spots can be applied at high rate: a 50 mm step takes less than 0.3 seconds and a 300 mm one can be traversed in under 0.7 second. Welding robots are generally supplied as a complete system including gun,

TABLE. 1 DIMENSIONAL ACCURACY IN BODY ASSEMBLY

FEATURES	DEVIATION OF HUMAN WORKER	DEVIATION OF ROBOT
Welding position	+/- 20~30 mm	+/- 0.5~1.0 mm
Number of welding points	Stipulated points +/- 0~2%	Stipulated points +/- 0%
Attitude of welding guns	Perpendicular to surface within +/- 10~20 degrees	Perpendicular to surface within +/- 1 degree

transformer, air, water and electrical power supply, and all controls. The controller contains the elements to control all the robot functions, acceleration, speed, position and so on, as well as the means of controlling the welding process. Using a simple PC, welding robot system may include a function that uniformly distributes the current utilisation between several welding transformers, so that only one robot welds at any instance of time. With larger welding lines employing a large number of robots, this can result in a significant reduction in peak demand and thus in electricity cost.

Earlier, resistance spot welding robots were fitted with an overhanging transformer. However, the robots have been made more efficient with integrated transformer and gun fixed in wrist of the robot. Weight of transformer has gone down and energy saving has been significant. Besides, the reliability of robots has significantly improved extending the length of the Mean Time Between Failure (MTBF) to over 30,000 hours. Moreover, number of parts and types of parts from previous generation of robots has led to a significant price reduction, while the performance has improved by 40%. For spot welding robot, the trailing electric cables that supply the welding power may restrict the access into the car body. Newer robots have come with integrated welding media supplies that pass through the arm and wrist, with virtually no exposed cabling. Fig. 6.15 shows an improved version of resistance spot welding robot. Flexible 5-6 axis spot welding robots with articulated arm or revolute coordinate are generally used. Modular 1-3 axis inexpensive robot may be judiciously integrated in the line providing the rigidity of minimum overhang and corresponding minimal deflection. In some of the modular robot system, the module is build around a base system. By means of a few simple changes, the robot system can be changed to give a completely different set of characteristics desired for a new body model. Modular robot system provides the automotive industry with a wide range of robot versions with an extremely favourable price-performance ratio, and offers outstanding flexibility in automation solutions.

For some locations in car body, stationary spot welding, stud welding, punching stations, or some other special equipment are used. Stud welding is another process based on resistance welding that is carried out to fix fastening/aligning parts with manual, semi- or fully automatic equipment

Weld bonding

Weld bonding, which is the combination of resistance spot welding and adhesive bonding, is

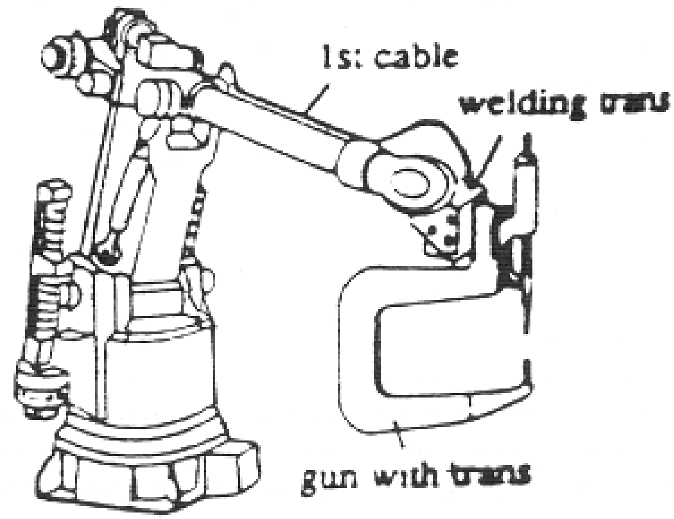


Fig. **6.15. An Improved Version of Spot Welding Robot**

another process that is receiving increasing application in body shop. It ensures the high productivity advantages of resistance spot welding and the high static strength and fatigue resistance of adhesive bonds. Generally the panels are joined through resistance welding through a preplaced paste adhesive. Curing of the adhesives is accomplished during the paint bake operation.

Adhesive application system requires metering unit for uniform application, a dispensing unit, a cleaning unit for dispensing nozzle to ensure reproducible application conditions. As like other processes, the adhesive application can also be robotised.

Inert gas arc welding

In some areas of body structure welding, arc welding is still required for the reason of structural stability. In stead of general arc welding, MIG arc welding systems are used. The system comprises of a current source, push-push wire feeder, a hose bundle, torch head and torch cleaning unit. The system is supplemented with various sensors to achieve consistent quality. Different shielding gases are used for specific materials being joined. Recent advances in MIG welding are concerned with power source design for better accuracy and ease of tuning the welding equipment, and process techniques for improving the operating characteristics and reducing cost. Trend is towards electronic power sources based on thyristor, transistor, and AC line rectifier. Specific advantages of electronic power sources in MIG welding are:

- ✓ more precisely controlled welding parameters through a feed back system

- ✓ accurate tuning of the welding parameters through continually variable voltage setting
- ✓ Control system can be readily interfaced with mechanical or automatic equipment
- ✓ Micro computer for storage of welding parameters for different program

Advantages of MIG welding are:

- High welding speed
- High deposition efficiency
- Uniform penetration
- Excellent mechanical- technological properties
- Reduction in operating cost

The skilled welders are usually employed to make compensation for matching of parts. Arc welding is more demanding because of its continuous path as against point-to- point application of spot welding. Robots have proved to be extremely useful in realising the full potential of arc welding in assembly in assembly line situations. Specifications of robotic arc welding include constant weld conditions, reproducible process parameters and high weld

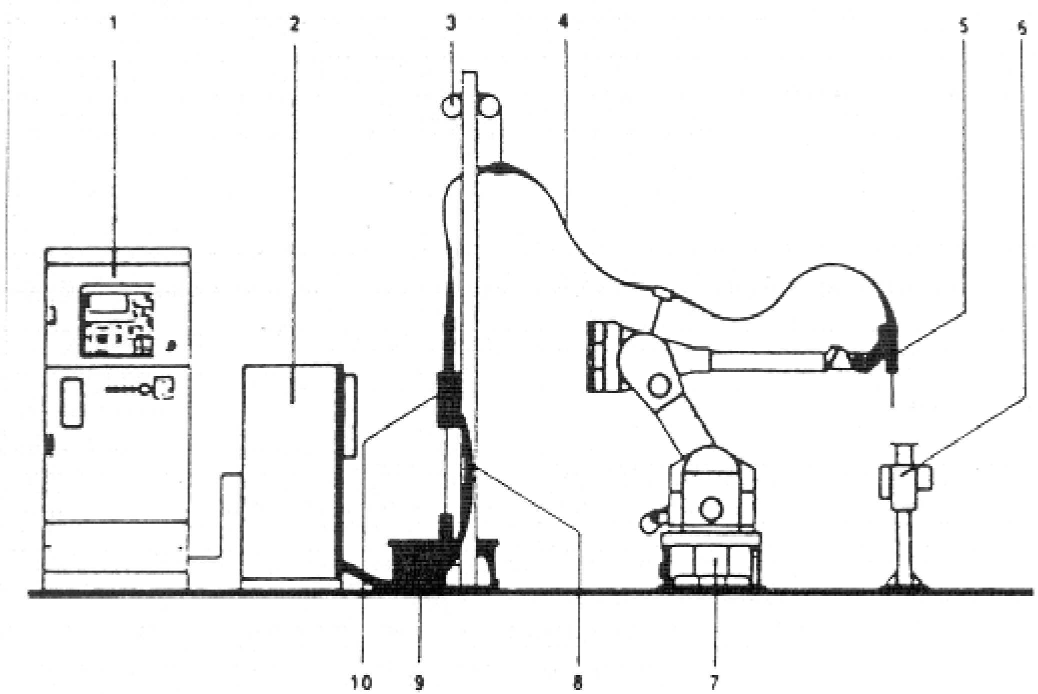


Fig. 6.16 An Arc Welding Robot

quality. Basic configurations of the MIG arc welding systems have been customised for mounting on an articulated arm robot, Fig. 6.16. Robotic arc welding is used both for on-line and off-line applications. Earlier effort of utilising robots required more accurate parts and fixturing, as the robot could follow only the programmed path. However, various methods of sensing of seam variations developed over years have made the robotised arc welding a practical proposition, with a growth rate higher than even spot welding robots.

Two of the methods used for sensing of seam variations during arc welding using robots generally in body weld application, are:

1. *Through-the arc- sensing*
2. *Optical sensing (non-contact)*

Through-the-arc sensing is usually combined with a seam finding system, tactile or visual, to establish the starting point of weld joint. Thereafter, the current is sensed during weaving. The robot controller responds to current variations by adjusting the robot's position so that the dynamic currents at the opposite weave amplitudes are maintained equal. The controller indicates that the arc lengths at these positions are the same and therefore the mid-position coincides with the joint line. Monitoring only has to be done during the first weld pass when the seam line is being learned, and can be switched off for subsequent run.

For welding of sheet materials such as car bodies, *one-pass optical system* is used. The beam is focused ahead of the torch to avoid sensor being blinded by the weld arc. Sensing unit is usually mounted on a rotary axis so that it can be continually aligned with the seam.

In automotive body welding shop, arc welding may be carried out manually or with robot both on-line or off-line. One such demanding application is the sensor guided arc welding of car roof seams. The cosmetic need of the weld is to be invisible on the finished body. With a bronze wire, gas arc welding is performed in a cycle time of 70 seconds.

Seam welding

Seam welding is still used for a number of parts and/or subassemblies such as gas tank. Seam welding of coated sheets- such as galvanised/Terne, is drastically different from that of unclad steels. During weld cycles, the metal coating tends to build up on electrode wheels. The build-up produces a high resistance path creating an undesirable heating effect in the welding zone that results in inconsistent weld quality (voids, leakage points). A new system uses copper wire as an intermediate electrode running over the welding wheels at normal welding speeds, Fig. 6.17. The copper wire picks up and carries off all melted coating materials as the workpiece passes through the electrode welding wheels. The process ensures consistent high weld quality.

MIG welding may demand very positive earthing. Special spring loaded copper earthing bars are fitted along the line that get engaged with the body skid as it passes through and earths the body through the supporting fixtures.

Laser welding- the new technology

A typical vehicle body has approximately 40 metres of pinch weld flanges, requiring 800 or

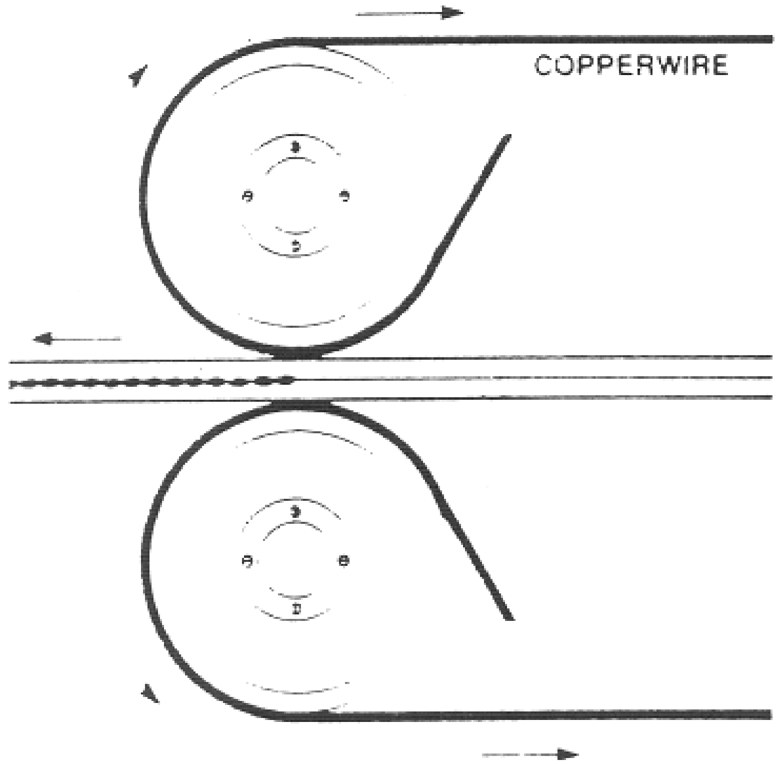


Fig. **6.17. An Improved Seam Welding for Coated Steel**

more spot welds. The pinch weld flange widths may be significantly reduced with laser welding that may result in a weight reduction of 40 kgs for a typical body.

Fig. 6.18 shows areas of car body structure where the fabrications by laser welding are

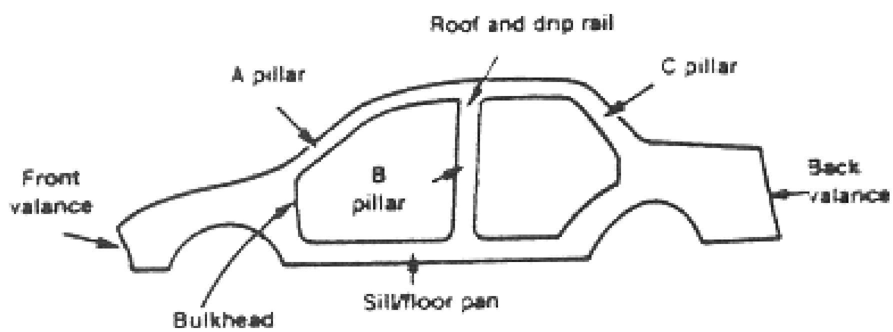


Fig. **6.18 Possible Laser Welding Areas of Autobody** being considered. With possibility of reduced flange widths, many alternative types of joint configurations (such as lap, butt, edge, edge fillet, T and flared T joint) may use laser welding. The process change may bring many improvements in body design and reduce cost.

SPOT WELDING VS LASER WELDING

1. *Conventional spot welding* requires two-sided access, whereas *laser welding* requires only single-sided access.
2. *Spot welding* causes heat distortion zone (equivalent to the size of weld nugget), and additionally mechanical distortion and wavy flange. *Laser welding* produces a very narrow heat distortion zone. As it is non- contact process, no mechanical distortion is caused.
3. *Laser welding* is better in both tensile and shear strength.
4. *Spot welding* requires 3 to 4 seconds for each spot weld depending on spot spacing and maneuvering requirements. *Laser welding* is carried out at speed of over 2 metres per minute.
5. *Laser welding* eliminates the consumable required for *spot welding* such as jumper cables, air and water hoses, transformers and weld controls, reduces cost.
6. With specified fit up conditions, *laser welding* produces consistent weld integrity.
7. *Laser welding* provides many new opportunities for design flexibility.

Good metal fit up will be critical requirement for laser welding, without which it can not become a viable alternative for spot welding. However, seam tracking devices are now integrated in laser welding system to take care of the positional error of mating parts. Besides, robotisation of laser welding will be a necessity to get the process integrated in body-in-line manufacturing lines. Constraints are many:

Requirements for robotic laser welding system:

- A minimum of 90% uptime including robot and beam delivery system.
- Less in beam delivery system to be less than 5%.
- Minimum of 10 years useful life for equipment.
- Beam delivery system should have a minimum number of mirrors.
- Beam delivery system should require no mirror adjustment once initially established.
- Robot and beam delivery system should be modular in nature and should provide a target mean time for repair not to exceed one hour.
- Target cost for the complete system including generator, welding robot, beam delivery system, chillers and control not to exceed $200,000.

In one case, the laser welding is used to join the top of the rear quarter panel behind the rear side window to the roof. It used to be a difficult joint for conventional pressure spot welding gun to reach. In an off-line laser welding cell, body position is checked with special fingers, using machine vision to find the *ditch* and align the motion of the laser carriage. The head can weld at feed rate of 2 metres per minute. At one of the facility of another renowned automobile manufacturer-BMW, drip moldings are laser welded to roof panels in an off-line

subassembly cell. Weld lengths of 1900 mm on each side are welded at rate of 4.2 metres per minute.

Mechanical Joining: A re-emerging joining technology

Panels of coated steels and HSLA steels, as well as panels out of tailored blanks with material combinations are being increasingly used to meet product functionality requirements such as reduced weight, service life and recyclability. The commonly used spot welding can no longer be process selection by default. Some self-piercing riveting technologies are emerging fast as a key mechanical joining method for automotive bodies. Rivet material and its geometry along with die geometry will be critical to this joining process. Compared with spot welding, the improved version of self-piercing riveting is claimed to have advantages as follows:

- Virtually noiseless
- Does not create sparks
- Does not create fumes
- Can join dissimilar materials
- Is not sensitive to material coating properties or thickness.
- Does not destroy corrosion protection
- Creates insignificant heat
- Requires less power
- Is visually checkable
- Does not require capital investment for cooling or fume extraction facilities
- Fully compatible with adhesive bonding

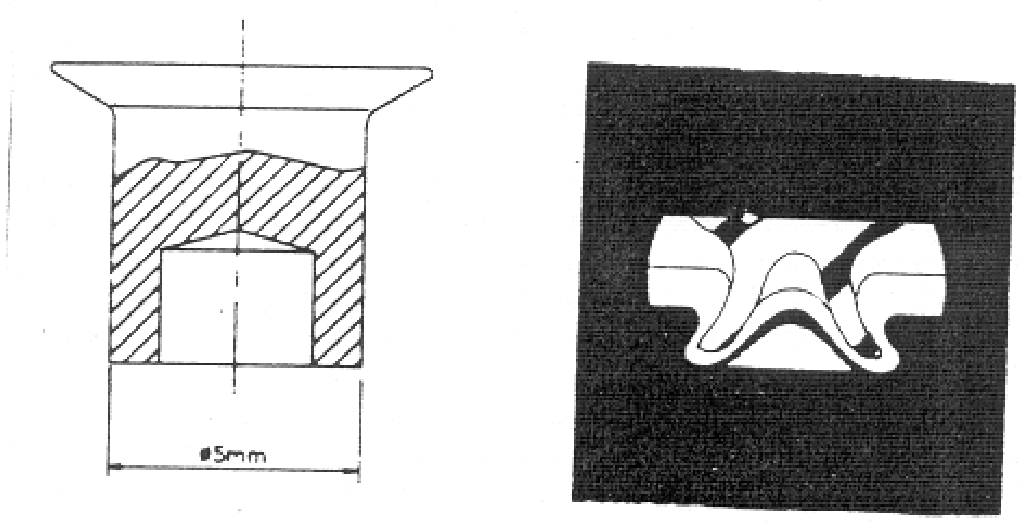


Fig. **6.19 A Self Piercing Rivet**

The self-piercing riveting tool can be mounted on robots in line or off line. Many automotive manufacturers do use these riveting processes. Peugeot SA has been using the technology since 1991.

FDS screw of EJOT, Germany is another prospective candidate for application of mechanical joining. The process uses a combination of flow drilling and thread forming. Mode of operation of the FDS screw is shown in Fig. 6.19. The process is useful for 0.3~1.2 mm of steel sheet.

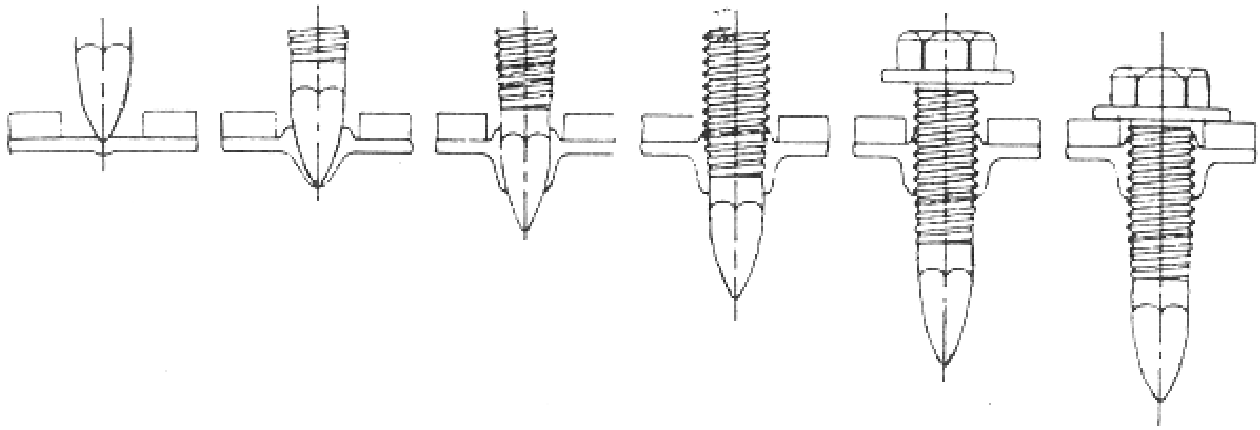


Fig. **6.20 FDS Screw**

SEALANT APPLICATION

All hems, gaps, apertures, overlaps and double panels are sealed in body (and paint) shop with paste type and plastic sealant that can basically be categorised in two:

1. Functional sealing against the ingress of water into the passenger and luggage compartments.
2. Aesthetic sealing of hems, flanges and overlaps for the prevention of corrosion in the directly visible area of the body.

The equipment may be operated manually or may be integrated in robots.

TRANSPORTATION IN BODY WELD SHOP

Part handling devices in body welding system are expected to lift, transfer and locate parts prior to their being welded. The sheet metal panels require special care in transportation because of its flimsy character. Damages caused by any mishandling affects overall aesthetic quality of the vehicle. Repair is difficult as well as undesirable. So, the motion employed for transfer must employ soft touch part lifting. The system decelerates to near zero speed as it contacts the part, and accelerates as it transfers the part. The system decelerates again as it reaches final position. All these motions must be carried with maximum possible speed and positioning accuracy for desired productivity and quality.

Transportation system will comprise of different types of material handling equipment depending on applications, parts and subassemblies, shape and process, and production capacity of the facility:

- Transfer lines- floor/overhead, electro-mechanical drive or CNC drive
- Electric overhead conveyor
- Shuttles, Lift and carry conveyor
- Inverted power and free conveyor
- Robots and AGVs
- Slat conveyor
- Other accessories such as lift, turn table, storage magazine, etc.

Automation achieved in body weld shop of a world class automotive plant is maximum in comparison with all other shops. Individual panels may be fed to the shop from press shop and/or vendors through overhead or belt conveyors, picked up and placed by robots in fixtures. Either through a floor-type chain conveyor or Lift and Carry conveyors, the subassemblies may be moved from station to station, as the spot weldings are carried out at different stations. Inverted power and free conveyor are also used for the purpose. The system is designed to automatically stop at the robotic welding stations or if required to move slowly and continuously through the manual lines. An overhead conveyor- either chain or powered trolley system is used to lower the parts automatically to a position where they can be off-loaded on to the floor conveyor jig. Overhead delivery conveyors can also serve as storage. For underbody line, and the main line, the subassemblies are fed through overhead system. In metal finish line, slat conveyors are used. AGVs (Automatic Guided Vehicles) are another means of transportation of body-in-white between work stations. Cross transfer conveyors are used to transfer bodies sideways from one line to the other. However, the transportation system entirely depends on the production capacity to be created and the company's priority. For low volume production, manual and low cost material handling system, say, a two-rollers and body skids in metal finish, may be good enough.

Automation level in body-weld shop of a typical advanced automobile manufacturing facility has reached 95% or more. However, the present trend is to reduce the level of automation to 70~80%.

INSPECTION OF BODY-IN-WHITE

A measuring system for body-in-white quality assurance, the basic requirements are as follows:

- Capability of getting integrated in the production line using the same part loading devices and interfaced with the monitoring computer of the manufacturing line.
- Matching of inspection speed for quicker feed back to production system
- Flexibility to allow bodies of different models
- Accuracy to generate reliable and useful data
- Ruggedness to operate in shop environments

For a body weld shop, basically two types of inspection systems are essential- one to inspect the sub-assemblies, and the other for fully assembled car bodies. At one time, checking fixtures (dog house gauges) were extensively used for all subassemblies for quality assurance. In some world class plants, some sophisticated laser based inspection system checks for absolute position of selected body openings and physical features. The systems are located at the end of the lines of major subassemblies and/or after framing stations. Today, CNC Coordinate Measuring Machine (CMM) is extensively used for measuring subassemblies and body-in-white on sample basis. 5-axis horizontal arm measuring centre is used in single or double column version with axis movements to match with the body shell dimensions Multi-sensor technology provides tactile and non-contact optical probing. An articulating probe holder moves the sensors to the appropriate spatial positions to measure hard-to-reach structures and to position the sensors at right angles to the surfaces to be measured. Double Column machines are ideal for checking the symmetry.

One essential feature for all car body measuring tasks is mathematical alignment despite the use of workpiece fixturing. Other features of an automatic body-in-white measuring cell are:

- Software capable to analyse the results to get these maximum benefits out of the inspection.
- Ability to change reference systems to perform measurement according to our reference system.
- Possibility of easily modification.

Depending on the inspection results, the numbers of parts to be measured are increased or decreased. It depends on the technology used for welding the body and indicates the robustness of the manufacturing process.

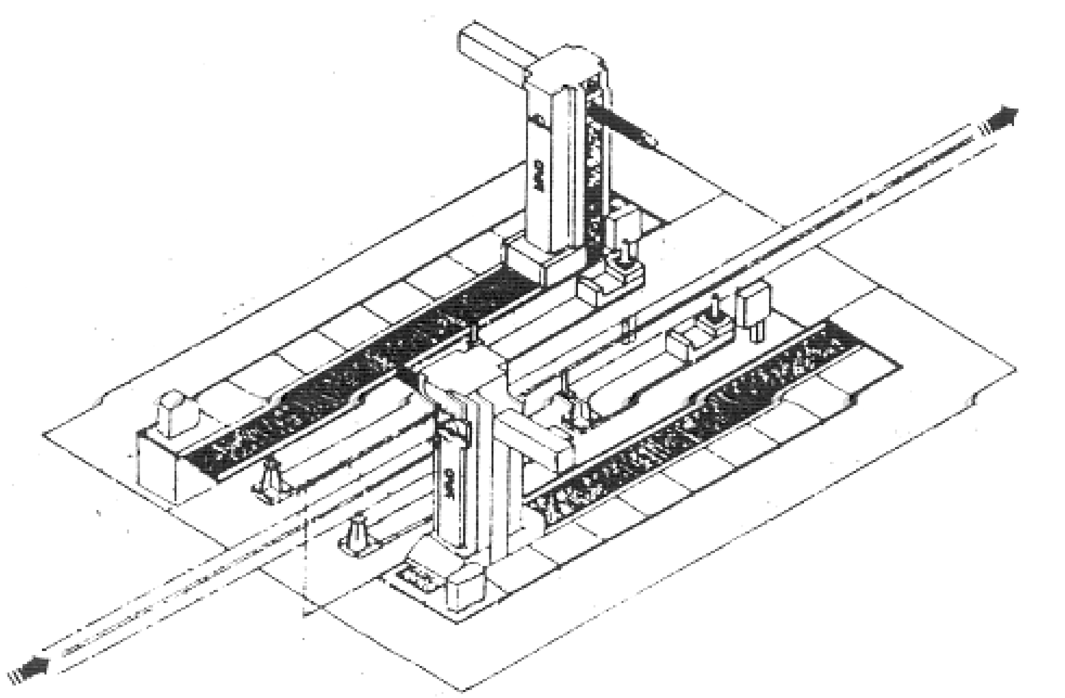


Fig. **6.21 A Robotised Cell for Body Inspection**

However, pretty expensive dedicated fixtures are used to support and reference the part to be measured. Flexing objects such as sheet metal subassemblies need not only to be supported but also to be forced to assume its theoretical geometry and dimensions, if capable of assuming it.

Presently, flexible fixturing system allows the quick configuration of very accurate fixtures that may be carried out by the measuring robot prior to the beginning of inspection cycles.

Integrated robotised cells, Fig. 6.21 may provide an optimum solution for flexible dimensional inspection in body weld shop. The consists of the measuring robot for body-in-white applications must be highly rugged that can maintain high repeatability with long extensions at the high speeds and accelerate of the measuring robot. To give an idea of the speed of measurement, in one case 350 dimensions on each car is measured in 20 minutes. Data can be obtained in many forms:

1) Printouts showing a drawing of individual elements of the car body in the value of each measurement.
2) Result in form of 'index of geometric quality' derived from the deviations from the ideal dimensions of the measurements taken.

Measuring robots with a dedicated software can collect and collate a complete set of dimensional data on the welded car body. With the feed back of the accuracy data to the previous manufacturing step, the accuracy deviation of 1 mm of body-in-white can be reduced to 0.5 mm. The process of CAD and CAM gets completed with CAI (Computer-Aided-Inspection).

Over the years, the Body Weld Shops have undergone a sea change. Major automation through extensive application of robots in almost all activities have brought the number of workers to minimum. Sophisticated synchronised transportation system controlling and monitoring all the movements of parts and subassemblies as well as the body-in-white has eliminated the possibility of in-process damage. Flexible fixturing system such as Nissan's IBAS or Toyota's FBL can produce even new model without stopping the line. On-line measuring stations monitor and ensure the desired value for quality characteristics through close loop parameter control. Surprisingly, the machinery and equipment manufacturers have been able to meet the demands of low and medium volume automobile manufacturers also with same amount of success. Body welding plants have provided unique example of integration of simultaneous improvements in different areas of related technologies.