

# ULSAS MANUFACTURING APPROACH



- **Manufacturing Feasibility**
- **Material Requirement Analysis**
  - NB: All material strength requirements quoted are for minimum yield level
- **Assembly Analysis**
- **Assembly Time Estimates for input into the Costing Analysis**
- **Consortium Member Input**

Throughout the ULSAS Programme the manufacturing implications of the designs were reviewed. Close liaison between the Lotus design team, manufacturing department and Consortium Members ensured the ULSAS systems are lightweight, safe, affordable and manufacturable.

Reviewing the manufacturing feasibility of the designs is an integral part of the iterative design process. This has resulted in a high level of confidence in the manufacturing feasibility of the ULSAS concept designs.

The material requirements of the components were reviewed on an individual basis throughout the design process. Where applicable, i.e. beneficial to mass or cost, high strength and near reach materials have been incorporated. Combinations of high and extra high strength steel sheet and forging grades were considered to satisfy performance requirements.

The assembly processes and orders for each of the solutions has been considered throughout. This has resulted in estimation of the time taken to assemble the sub-assemblies, assemblies and the fixation to the vehicle. This data has been input into the costing analysis exercise.

Consortium members contributed by attending periodic design reviews and providing details of appropriate near reach materials and technologies. Additional support was available in the form of the latest manufacturing forming simulation techniques, a process utilised on several of the components.

## ULSAS MANUFACTURING PROCEDURE:

- **Manufacturing Component Feasibility**
- **Material Requirements**
- **Assembly**
- **Timing Study**
- **Welding**

Feasibility studies of pressed sheet, forged and fabricated components commenced at the earliest possible stage in the design loop and continued on a simultaneous basis throughout the design process. Detailed formability evaluation was carried out in conjunction with forming simulation analysis on selected parts to further enhance manufacturing input into component design. Simplification of component design was considered at all stages to aid manufacturing feasibility and reduce the associated tooling costs. This was done whilst avoiding, where possible, compromises to the components performance for example with non-handed parts. Consideration was also given to commercial availability of grades and target volume requirements.

Detailed finite element analysis (FEA) techniques were used to validate part stiffness properties and structural integrity performance, which provided data to support material requirements, in terms of material properties for the components. Prior to FEA, an estimation of the applicable material properties was made to enable feasibility studies to commence. In addition to structural demands, each unique component was reviewed on an individual basis in order to consider manufacturing requirements based on the component design.

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- **Assembly**
- **Timing Study**
- **Welding**

Detailed drawings of the designs were studied both in hardcopy and on the CAD workstations. This formed the basis of the assembly analysis. The complex multi link system was subjected to a detailed assembly analysis using a industry recognised software package. This has the advantage of linking with the Catia generated design files to ensure assembly feasibility.

The timing study was carried out using the industry recognised manual assembly data system PMTS (Pre Determined Motion Time System). A manual system was used to ensure equality for comparison purposes.

Welding feasibility studies were carried out in conjunction with The Welding Institute Cambridge, UK.

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## ULSAS TIMING STUDY ASSUMPTIONS:

- During assembly, the largest possible unit is fitted.
- Torque sensing power tools utilised wherever possible.
- No confirmation actions such as paint marking are carried out.
- Bolts would be supplied complete with any washers required.
- For the fitting operation the unit or units are already lifted in place.
- The systems have been assembled on a single site.
- All parts and tools are ergonomically situated for optimum performance.
- Estimates are for total system including fitment of brakes and calipers.

In order to make a labour cost analysis of the systems investigated and to compare this with the benchmarked systems, it was necessary to establish the time taken for fitting and sub assembly.

For the purposes of this investigation Lotus has chosen to use the Integrated Business Controls, Motor Industry Assembly Data system. This system was developed for quick estimating, particularly in pre-production or design office situations. IBC uses data blocks of work that can be described in simple terms, be easily recognised and counted with a known statistical variation. The IBC data blocks look at each individual operation as a whole. Therefore the times quoted include elements such as picking up parts and tools, aligning, fitting together and putting down any tools required.

In order to carry out this study the above assumptions, in common with those used on the benchmark vehicles, have been made.

## ULSAS MATERIAL SELECTION ASSUMPTIONS: Pressings

### Material Selection - Sheet Grades

Sheet steel grades would be specified to meet the strength requirements as determined by CAE analysis. The nearest available grade with a strength level equal to or higher than the minimum requirement would need to be selected. Commercially available high strength grades would meet many of the requirements for high strength combined with good formability. There are a number of considerations when specifying appropriate sheet grades:

Allowance should be made on parts where springback/shape problems could be an issue following forming. Material influences such as gauge reduction and high yield requirements, in addition to geometrical influences such as open ended panel designs, can promote the susceptibility to panel shape loss through springback. Consideration of these influences should be included in material selection. For example, grades with a lower yield to UTS ratio for a given strength reduce the potential for springback.

Stretched flanges or holes require good edge ductility, an influence not only of the quality of cut edge, but also the edge forming characteristics of the material. Certain grades delivering equal strength can offer superior edge ductility.

Weight reduction requirements dictate grades of thinner gauge offering high strength characteristics. A consequence of these extremes of grade is the current limited commercial availability. Opportunities exist for availability of such grades to be made more widespread, in line with promoting opportunities for near reach high and ultra-high strength grades.

Specific requirements and commercial availability should be discussed in detail with the appropriate Consortium Member Companies.

**NB: All material strength requirements quoted are for minimum yield levels**

# ULSAS MANUFACTURING APPROACH



## ULSAS MATERIAL SELECTION ASSUMPTIONS: Tubes

### Material Selection - Tube Grades

Tube steel grades would be specified to meet the strength requirements as determined by CAE analysis. The nearest available grade with a strength level equal to or higher than the minimum yield requirement would need to be selected. Commercially available high strength grades would meet many of the requirements for high strength and good weldability. Specification of appropriate tube grades would be as follows:

- Tube requirements would primarily be met with conventional welded tube.
- Extreme requirements for combinations of high gauge/small diameters may need to be specified as cold drawn tube.

Specific requirements and commercial availability should be discussed in detail with the appropriate steel supplier(s).

**NB: All material strength requirements quoted are for minimum yield level**



## ULSAS MATERIAL SELECTION ASSUMPTIONS: Forgings

### Material Selection - Forging Grades

Forging grades would be specified to meet the strength requirements as determined by CAE analysis. The nearest available grade with a strength level equal to or higher than the minimum yield requirement would need to be selected. There are a number of considerations when specifying appropriate forging grades:

- Air cooled forging grades are preferable through elimination of secondary heat treatment operations for lower strength requirements.
- The associated increase in carbon content for the higher strength grades could cause weldability issues. Preheat and possibly post weld heat treatment of the components following welding could be carried out in order to achieve higher strength levels, but would be unacceptable on the basis of the volume requirements for these parts.
- Strength levels can vary with the section size of the individual forged components.

There is ongoing research on air cooled forging steels in the steel industry to offer grades to meet higher strength requirements, while maintaining a lower carbon content to avoid the need for pre/post weld heat treatment.

There is a specific requirement for a high strength forging grade with a minimum yield >750MPa, for the Multi Link configuration. Heat treatment following forging would be required to obtain this strength level. However, for production purposes, it is favourable to avoid post operations such as heat treating. Unfortunately, air cooled grades are not currently commercially available to meet these high strength requirements, signalling a real opportunity for grades of this type to be developed to meet customer needs in the longer term.

These issues would need to be investigated further at the detailed design stage with trials being carried out where necessary to validate fully. All requirements should be discussed in detail with the appropriate steel supplier(s).

# ULSAS MANUFACTURING APPROACH



## ULSAS MATERIAL COATING ASSUMPTIONS:

### Coating/Corrosion Considerations

Opportunities exist for extensive use of pre-zinc coated steels. Coated steels will help to meet warranty requirements and place less reliance on protection offered by secondary coatings. Further weight/cost savings may be achieved through avoidance of wax injecting and/or the use of thinner additional coatings.

Organic coating methods such as Electrocoating, are commonly applied to provide a barrier against corrosion. Internal coating of the assembly would require access holes for the in-flow and out-flow of the fluid. The addition of tooling holes (added at the detailed design stage) could also benefit the coating process.

Clearly the type and level of corrosion protection required would be dictated by the manufacturers own corrosion requirements. Allowance for the type and method of corrosion protection to be employed would need to be considered at the detailed design stage.



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## ULSAS WELDING ASSUMPTIONS:

### Laser Welding/Trimming

#### Edge Welding Panels/Blanks

Edge or butt laser welding requires very close control of gap and offset tolerances. As a guide, the requirement for welding panels is as follows (assuming 2mm gauge material):

Offset tolerance 1mm max

Gap tolerance 0.2mm max.

Control to these tolerances when welding together finished panels in volume production is difficult, particularly with application of thinner high strength grades where shape/springback issues increase dimensional inconsistency of parts. It is recommended that MIG welding be used as an alternative for joining butt edges in these instances where appropriate.

Laser welding of sheet/blanks is a well-developed technology, where significantly tighter offset tolerances can be achieved providing accurate edge treatment is carried out prior to welding.

### Flange/Lap Welding

Through wall lap welding from one side can be achieved on flanges. Welding can occur just off the radius of the flange where two flat surfaces can be guaranteed. A weld width of 1.0 to 1.5mm should be deposited onto the flange. A gap tolerance between the laps of 0.2mm maximum can be tolerated and is ordinarily achieved by clamping the flange during welding. It is possible to increase this tolerance through the use of feed wire, but this would be at the expense of welding speed and mass. Gauge limitations for laser lap welding are well in excess of normal automotive gauge requirements.

The size of flange is primarily a clamping requirement as opposed to a welding limitation. The force/area required to maintain a flat area within the aforementioned 0.2mm max. tolerance would need to be determined. The required flange width may fall inside that conventionally required for spot welding to the advantage of weight reduction, although trial work would be required to validate this (laser trimming the flange back to the weld would reduce the flange size further - see following passage). This method is further limited by the geometrical design of the component and allowing access for clamp tooling.