Chapter 5

CONCEPT CHASSIS MANUFACTURING

The designed concept properties were deemed to be satisfactory with regards to the required performance factors and design criteria. The concept chassis had to be manufactured for experimental procedures. This chapter describe and explains the involved preparation, techniques and manufacturing processes of the chassis.

5.1 THE PROCESS OF MANUFACTURING

The construction of the chosen chassis frame was done at the North-West University's Mechanical Engineering workshop. Constructing a space frame is challenging due to unconventional geometries and non-standard reference points and planes. Using the correct equipment and processes is crucial. Processes involved include the correct welding technique together with the pipe cutting technique of each tube which forms an integral structural member of the chassis frame as a whole. The designed frame consists of numerous steel tubes, each with its own specification, length and properties. To ensure efficient construction and work rates, forehand preparation was required to ensure the necessary accuracy in the construction process. The drawings of the chassis frame parts for the manufacturing presented in Appendix E.

5.1.1 PREPARATION

The preparation and planning for the chassis frame construction process is very important as it helps to eliminate time consuming problems that may be encountered. It also helps to keep track of the progress made and clarifies which tubular member requires specific preparation and cutting technique.

The chosen concept consisted of more than 70 individual tubular pipes. As the chassis frame is longitudinally symmetric, a number of pipes were identical except for the mirroring differences between the symmetrical sides. Some pipes were unique in terms of their characteristics and length. Prior to the construction process, the frame was divided into three sections (Figure 5-1) which consisted of a front bay structure (FS), cockpit bay structure (CS) and a rear bay structure (RS).

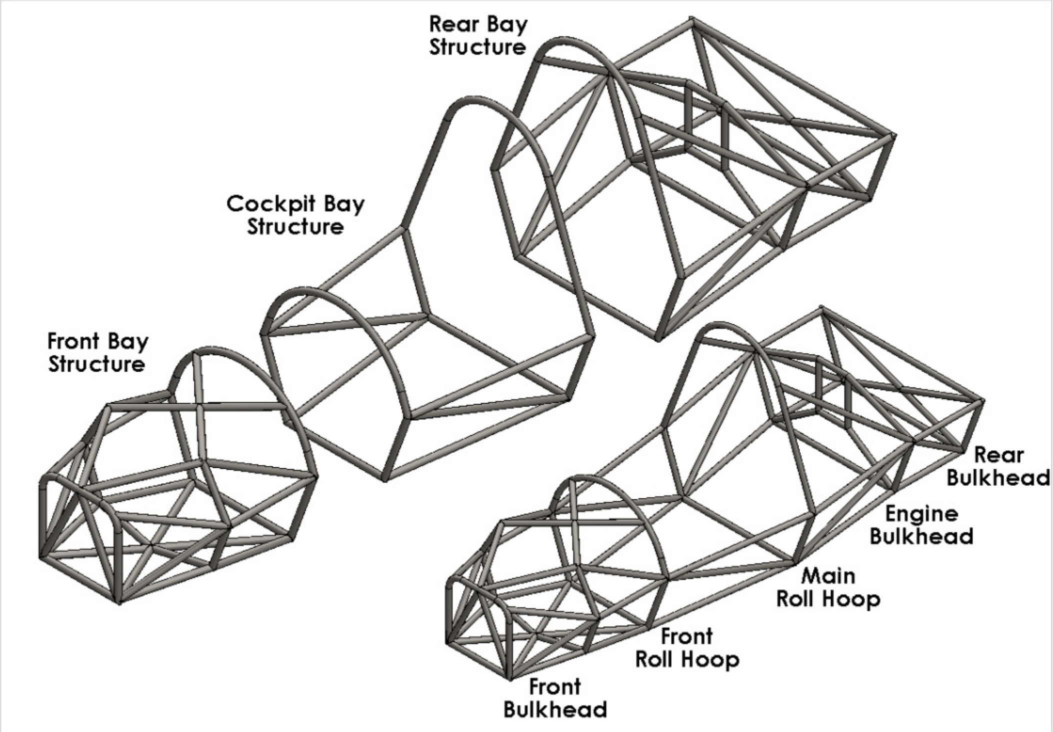

Figure 5-1: Illustration showing the three different chassis sections

Each and every tubular member of each section was individually identified with a numbering system, each listed with its accompanying length. Each member was cut to its specified length (Figure 5-2). With each frame tubular member identified and numbered, the members were individually analysed in order to identify the cutting technique needed to prepare the pipe for its position in the chassis frame.

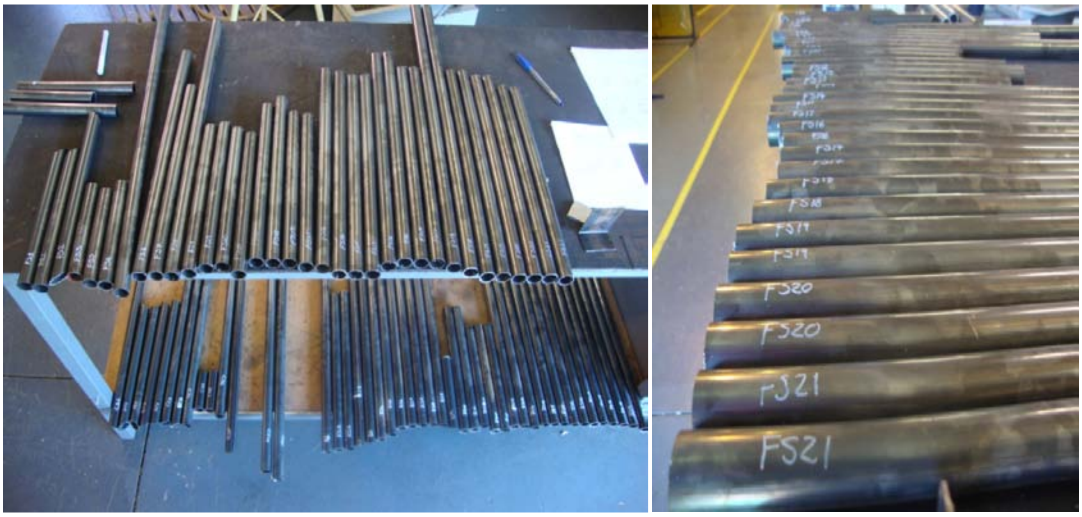

Figure 5-2: Photos of the individual pipes after being identified and cut

Due to the nature of the structure of the chassis frame with its tubular members and accompanying joints, each pipe was cut off plainly with a conventional band saw, or with a 4-axis Computer Numerical Control (CNC) machine (Figure 5-3). The numbering system and length of each pipe were prepared prior to cutting the individual parts.

5.1.2 MANUFACTURING AND PIPE CUTTING TECHNIQUES

All the pipe ends and corners were cut in either one of two styles (Figure 5-3). The first technique consisted of a pipe end being cut to a specific angle. This technique was done with a band saw with an adjustable angle clamp. The majority of the pipes that lie within the same transverse planes (like the bulkheads and the roll hoops) adopt these plain angles that can be cut straight. It is important to keep in mind that the cut corners should have equal angles as the pipe ends cannot be joined if the angles are not equal.

Figure 5-3: Example of simple cut off pipe ends (left) and profiled cut pipe ends (right)

The second technique is more complex but accommodates the fitment problem presented by pipe joints and geometries. The technique consisted of cutting a tubular member's end with a specific profile using a 4-axis CNC machine. The profile cut ensured an adequate fit for the tubular member into its designated structural position as well as improving the contact surface between the two members for welding purposes. A number of pipes of the chassis frame were cut using the pipe profiling technique, usually members that form part of triangulations and other intricate parts of the chassis frame. It was a time consuming process though as each and every member that needed to be prepared with this technique had to be individually identified, programmed and processed for manufacturing or cutting.

Pipe end profile cut process

The structural members requiring profiled cut ends are described by the following procedure.

<u>Identify the pipe member</u>

With the completed and correctly trimmed CAD model, each tubular member of the CAD model was identified in a user specified order. It is important to know beforehand which pipe will require a special profile. After identifying and isolating the member, it was considered as a new part.

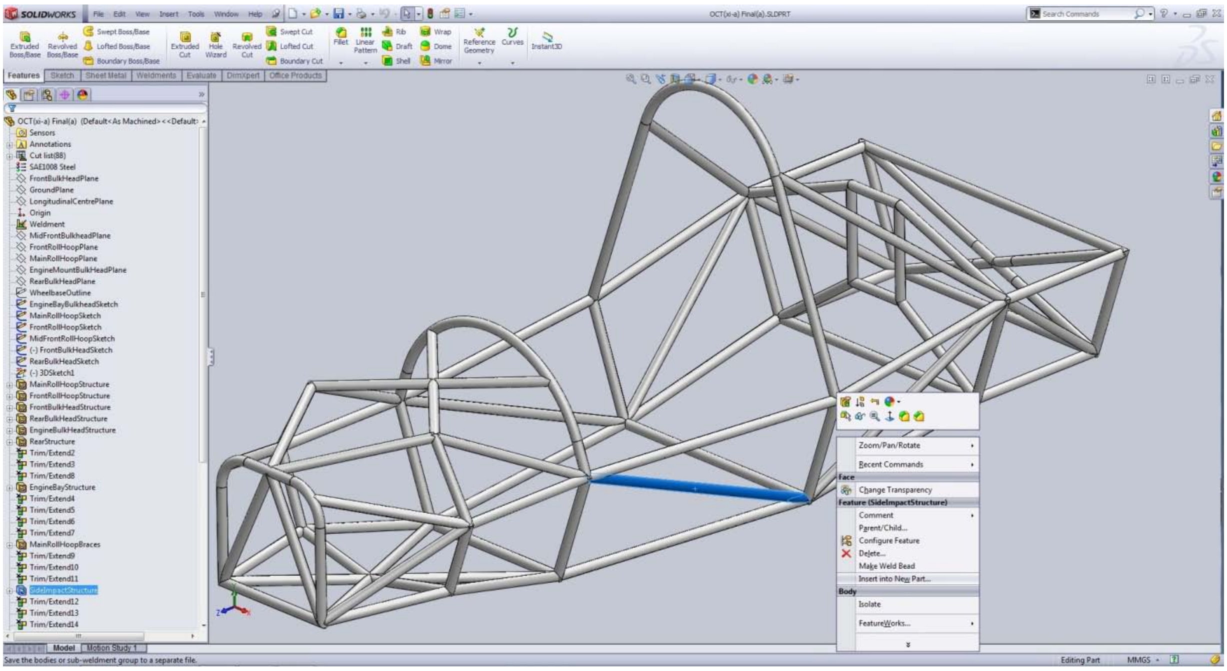

Figure 5-5-4 : Screenshot for selecting an individual pipe member

<u>Prepare the pipe profile as a DXF file</u>

After the specified tubular member had been singled out as a new part, it was modified in order to get the profile characteristics of its ends. With the pipe inserted as a new, separate part, a very small slot is longitudinally cut through the wall of the pipe in SolidWorks®.

The SolidWorks® Sheet Metal function was used to insert a bend reference point on one of the slot cut edges. The pipe can then be flattened out as if it is a piece of sheet metal. This allowed the end profiles to be linearly represented as a two-dimensional profile.

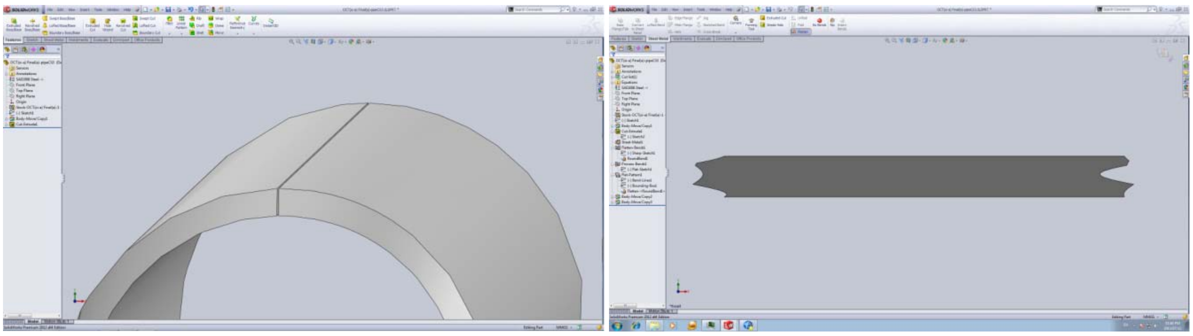

Figure 5-5-5: Screenshots illustrating a pipe prepared as a sheet metal profile

These pipe end profiles are saved within the CAD (Computer Aided Design) software as a DXF file. This is done within the CAD by selecting the various curvatures defining the pipe end profiles. This file was ready to be used by the CAM (Computer Aided Manufacturing) software.

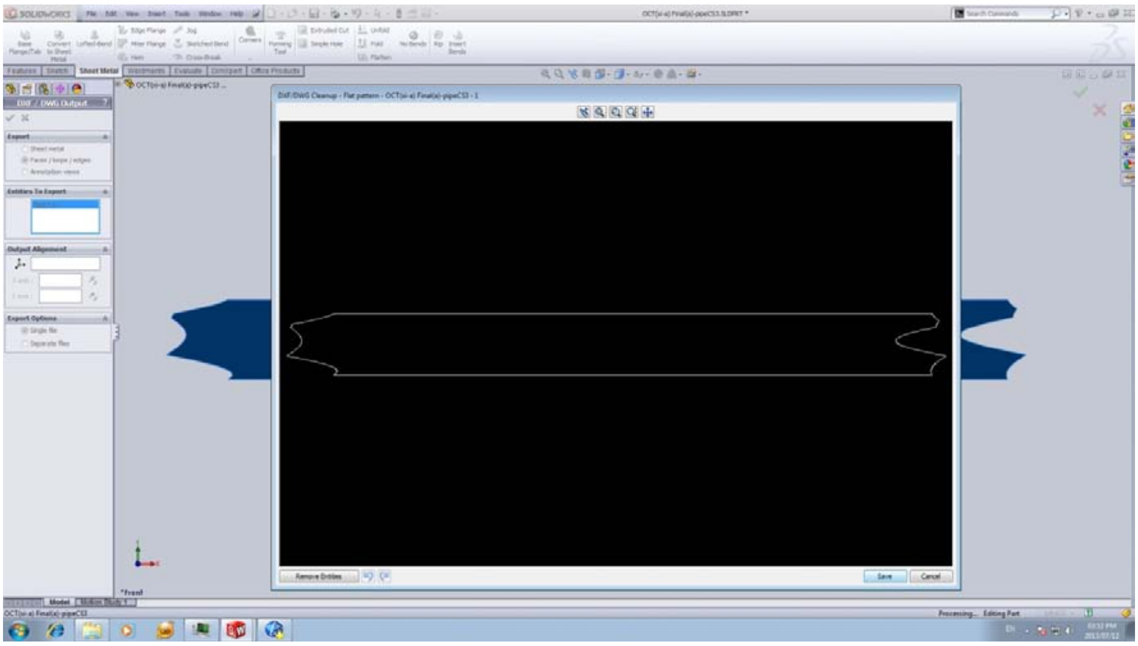

Figure 5-5-6: Screenshot illustrating the pipe end profile saved as a DXF file

Import the DXF profile into the CAM software

The part file of the specified tubular member is directly used in the CAM software package. Alternatively, the DXF file saved in the CAD package can directly be imported into the CAM software. The pipe end profiles are then prepared and defined according to the parameters and properties of the CNC (Computer Numerical Control) machine used for the operation. The orientation of the profile and the material layout is also defined within this process.

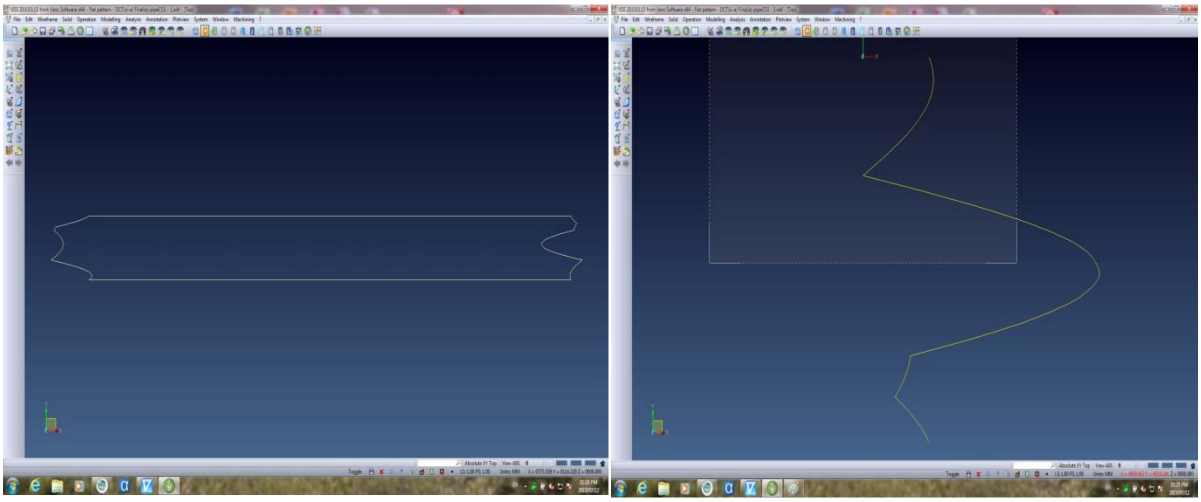

Figure 5-5-7: Screenshot illustrating the pipe profile in the CAM software

Use the CAM software to compile the machine code

With the pipe end profile properties and orientations defined, the CAM software compiles it with its post-processor as a procedure or a program. This program is known as machine code or G-code which is a compilation of instructions for the CNC machine used. This will vary between the different CNC manufacturers. The G-code is then loaded into the console or control panel of the CNC machine, after which the process is ready to start.

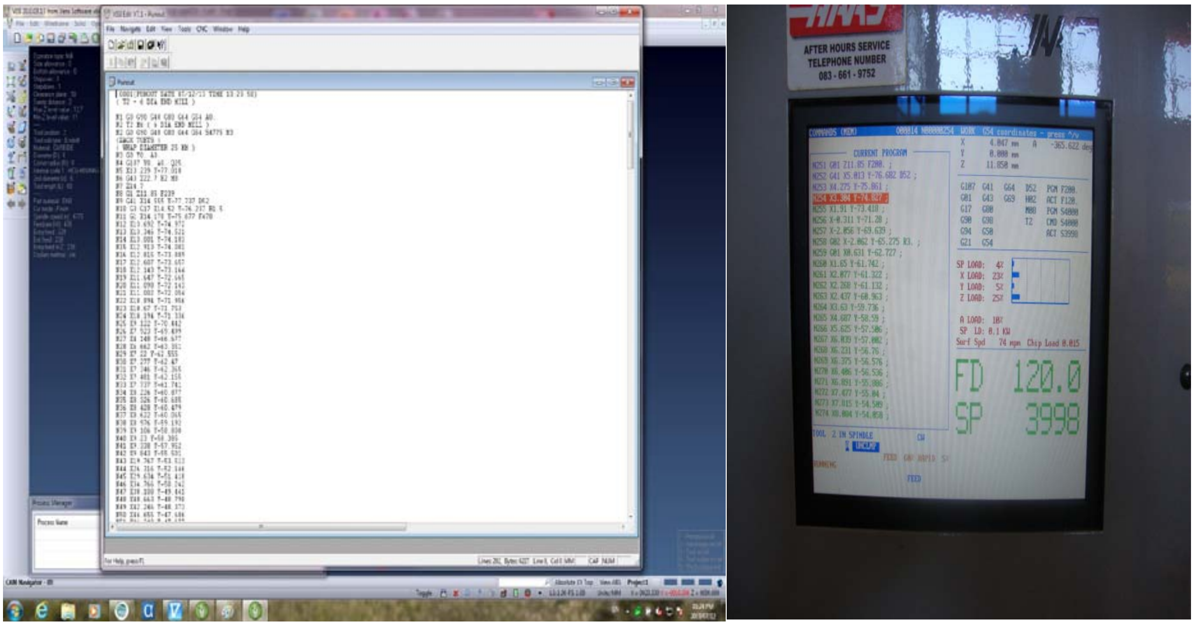

Figure 5-5-8: Screenshot illustrating the generated G-code (left) and the console of the CNC machine (right)

<u>The cutting procedure</u>

The cutting process of a tubular member involves tedious observation due to the importance of the correct orientation between the two pipe end profiles. If the two pipe end profiles don't line up correctly, the tubular member will not fit correctly within the chassis frame. This defect will decrease the welding contact surfaces and will reduce the structural integrity of the structural frame.

The procedure starts by mounting and inserting the individual pipe into the 4-axis CNC machine, noting that the pipe is already cut to its specified maximum length. The CNC machine is then prepared for cutting by identifying the material position and the cutting starting point. The orientation of the pipe is not relevant at this stage.

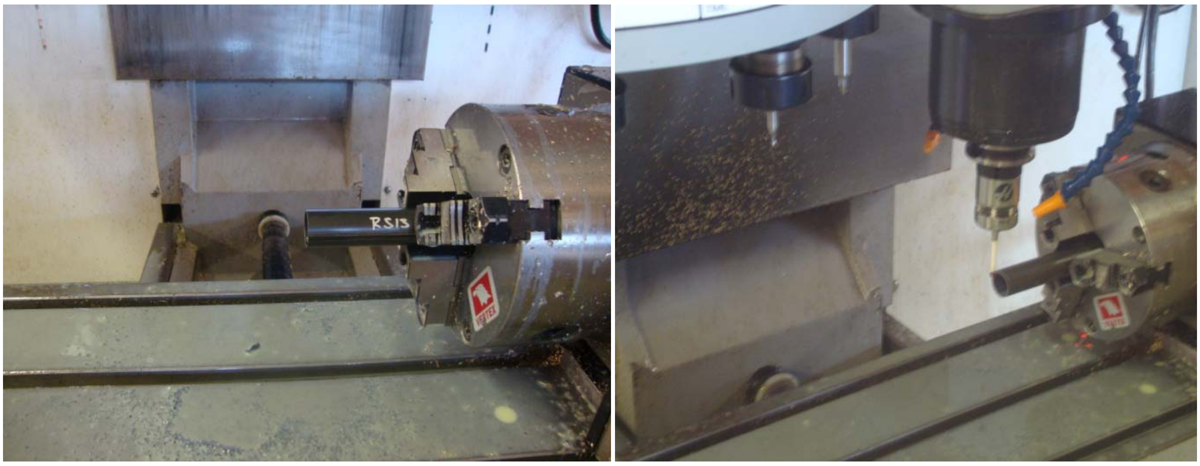

Figure 5-5-9: Photos of a mounted pipe being prepared for profile cutting

With the pipe secured in the chuck, the profile cutting process is started, where the pipe's own specific profile is cut out according to its location in the chassis frame.

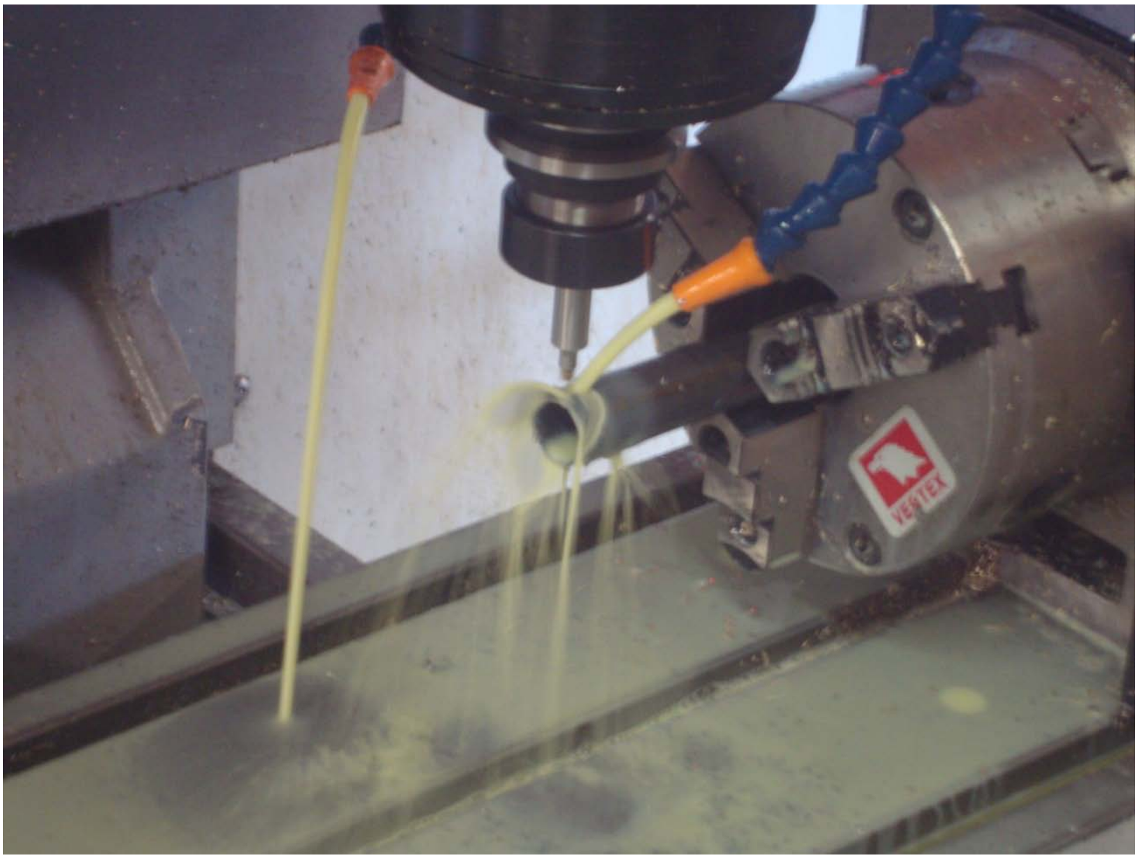

Figure 5-5-10: Photo of the profile cutting process

After the cutting process has been completed, the orientation of the tube becomes very important. The starting point of the opposite end should line up exactly with the starting point of the pipe end that was cut first. To establish this, a jig is made that can be securely mounted on the cut pipe. The jig is mounted horizontally precisely, with the help of a spirit level. With the jig secured, the pipe is removed from the chuck of the CNC machine.

Figure 5-5-11: Photos of the orientation jigs being installed

Another, identical jig is then also horizontally mounted to the other end of the pipe member. The two jigs should be lined up exactly horizontally. The first jig can be removed and the tubular member can then be inserted back into the chuck of the CNC machine, with the second, uncut pipe end facing the milling side of the machine. The pipe is again horizontally mounted with the aid of the jig and a spirit level. The jig can be removed if the pipe is securely mounted within the chuck, ready to be cut.

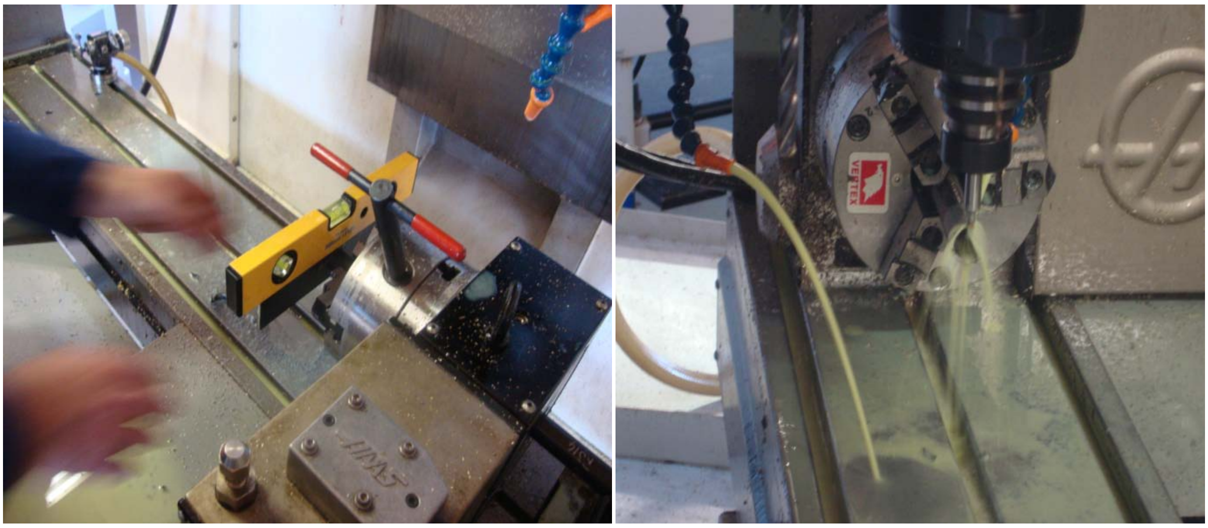

Figure 5-5-12: Photos of a pipe being mounted with the correct orientation (left) and the cutting process of the opposite ends

5.1.3 CONSTRUCTION PROCESS

After all the pipes were successfully cut to their desired sizes, shapes and profiles, they were orientated and positioned for assembly and welding. The MIG welding technique was used due to its advantageous properties with regards to thin materials and tubular members as well as its operational ease, availability and speed. All the components in the same transverse planes were assembled and welded first. The components included the roll hoops and bulkheads. The components were then connected with the various structural members that make the complete structure. The cockpit structure was constructed first as the primary structure. From then, the rest of the structure was built upon it. The rear end structure was built after the cockpit structure. The complex front end structure was constructed last. The construction process is schematically presented in Figure 5-13.

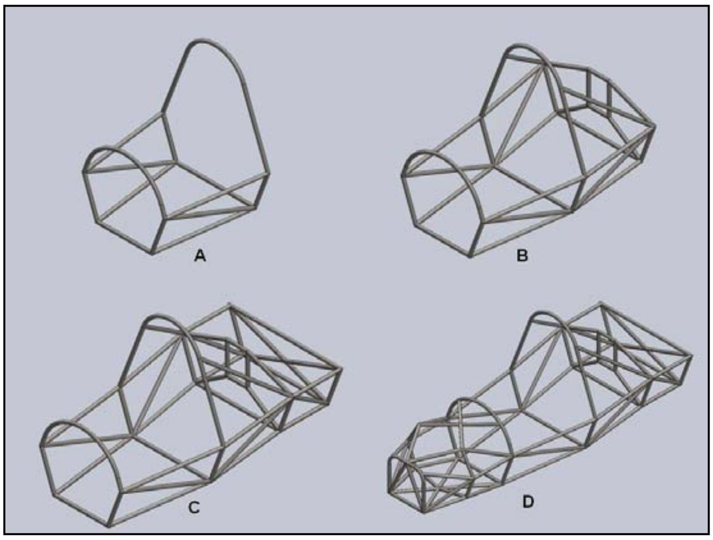

Figure 5-13: Illustration showing the chronological construction order of the chosen concept. A shows the cockpit structure. B shows the engine bay attached to the cockpit structure. C shows the structure with the rear bay attached and D show the complete chassis.

The main and front roll hoops were the first parts to be welded together. All the tubular members that made up these structures had simple pipe end profiles that were directly cut off with a band saw. The two hoop sections on both structures were bent using a conventional hydraulic pipe bending device. The hoops were compared to a 1:1 scale drawing in order to find the correct bent radius (Figure 5-14). Though the two roll hoops were good starting points due to their simplicity, their symmetric orientation relative to each other was crucially important. The orientation would have influenced the symmetry of the complete structural frame. The front and main roll hoops are shown in Figure 5-15.

Figure 5-14: Bending of the main and front roll hoops

Figure 5-15: Photos of the roll hoops and cockpit structure construction

All the tubular members were only tack welded at first in order for the structure to stand on its own. Figure 5-16 shows an example of tack welded pipes joined together. The structure was then examined and its symmetry, lengths and square angles were checked and corrected. When satisfactory, the structure was finally welded together. The procedure was followed for all the sub-structures that made up the entire chassis frame to ensure continuity and symmetry.

Figure 5-16: Photos of a tack welded joint (left) and a structure undergoing tack welding

The primary cockpit structure was followed by the engine bulkhead together with structural braces connecting it to the main roll hoop. This was repeated for the rear bulkhead. The completion of the rear end was followed by the preparation for the complex front end.

The front bulkhead was the first sub-structure to be made for the front bay structure. The bottom structure of the front bay structure was used to initially connect the front bulkhead to the front roll hoop of the primary structure (Figure 5-17). This provided a reliable and stable platform and reference point for all the tubular members forming the rest of the structural members and bulkhead braces.

Figure 5-17: Photos of the front structure under construction

5.2 THE MANUFACTURED CHASSIS

From the first pipe being cut to the final product, over sixty meters of pipe were prepared, cut and welded. Constructing the concept was a tedious process, but although the chosen concept had the most advantageous structural properties, it posed challenging manufacturing techniques. The entire manufacturing process took between three and four weeks. Overall dimensions of the (Computer Aided Design) CAD model and the constructed chassis were successfully matched. The final product can be seen in Figure 5-18.

Figure 5-18: The manufactured chassis

5.3 CONCLUSION

This chapter described the manufacturing process of the designed chassis. The initial preparation helped to improve the work rate of the construction process. Advanced cutting techniques were used on specified pipe members to increase the structure's integrity. The chassis was manufactured and conformed to the designed specifications.

The following chapter will discuss the test setup and procedures. The chapter will also discuss the weight, torsional stiffness and stress setup rigs, as well as the equipment involved in the experimental procedures to validate the chassis frame's designed characteristics.