IMPORTANCE OF THE CONNECTING PLATES IN A WELD CONNECTED SYSTEM AND THEIR DESIGN BY CATIA

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Abstract

This study is related with the design of connecting plates in a weld connected construction and the impact of such added connecting plates onto the resistance of the construction. Design has been accomplished through observing and ensuring that the weld joining lines and plates are integrated with the construction. Utilization of the plates as the auxiliary installation element has been also targeted.

Design of the connecting plates has been realized under a true and perfect engineering application. Compiling of a task list, its preference on the construction of standard profiles, welding process, choice of welding method, weld-end opening and unopened condition on the welding process, design in conformity with the production facility, computerized stress analyses are the basic phases of the present application.

The engineering application by which the study has been realized; It is an operation that an industrial type electrical chamber cooling unit is included in the existing process by means of a carrier construction. The construction which carries the cooler/refrigerator has been designed in strict compliance with the layout plan. The present construction has been designed, modeled and manufactured by CATIA; and it has been already used.

Keywords: CATIA, welding, stress analysis, welding connections, construction design

INTRODUCTION

The two methods most commonly used in forming the constructions are the assembly with bolts and the welding connection. Welding connections are first remembered one when "insoluble" connections are mentioned. General definition of welded joints is as follows.

Welding is a process whereby usually metals are bonded together locally and completely in an insoluble manner by an appropriate combination of temperature, pressure and metallurgical conditions. As the combination of pressure and temperature involves very wide and different conditions such as high temperature without pressure or high pressure + constant temperature, conditions of the welding is also very variable.

Today, the most widely used welding methods are electric arc welding and gas-metal arc welding (inert-gas welding). Gas-metal arc welding provides advantages in terms of labor and continuous welding especially for series production. It is possible to achieve smooth, high penetration welds [1].

There exist several electrodes and gas-metal arc wires with different chemical compositions in the large-content catalogs of the manufacturers of welding consumables. The choice for wires to be used for gas-metal arc welding can be made among three types as SG1, SG2, SG3 for general use. Use of SG1 type wire is suitable for ST37 and up to St 44, and SG2 type wire for up to St52. The SG3 type wire is for high strength steels with alloys.

Standard "U" profiles has a material content of SFe37.2 and SFe44.2. St37-44 is a general structural steel that can be welded smoothly. Use of SG2 wire is suitable for use in standard profiles [2]. Welding of the same property can be obtained by using SG3 wire for standard profiles. The only drawback is that to use this wire increases the cost of welding for the welding connection of the same property.

There are also special gas-metal arc wires. For example, SG 80 S-D2 heat-resistant gas-metal arc wire is resistant to 550^{o}C to -45^{o}C. Minimum yield strength is 470 MPa.

ER 110 SG High-strength gas-metal arc wire has a yield strength od 880 - 920 MPa (it is for high-strength structural steels) [3].

The choice of wire must absolutely be made according to the construction.

Joining the metals with the welding depends on several conditions. These are such factors as the material of the part to be welded, its shape given in the construction, method of the welding, and the stress it will receive while in operation, as shown in Figure 1.

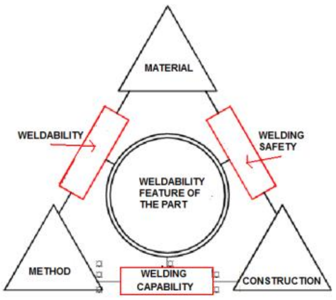

Figure 1. Weldability feature of the part

The weldability feature of the material is the ability of the said material to make a insoluble metallic connection by any welding process together with a solid, molten or slurry material of the same or similar type [4].

In this study, it is particularly aimed to obtain a rigid structure through improvement of the constructive details.

Construction Suitable to Welding

Tables are available which provide suggestions about the seams and dimensions of the welded constructions. The goal of welded constructions is to perform their functions by meeting the stresses with the adequate safety and to be as cheap as possible, depending on the usage manner of the weld in the operation. These requirements have been standardized in DIN 8525 standard.

The saying related with welding that “The most excellent welding construction is the one with the least weld seams." was taken into account when carrying out the design with CATIA.

Strengthening the constructions with metal plates is one of the indispensable construction methods. Weld seams are not sufficient enough for joining the two parts in particular in locations with sudden section changes. The use of additional joint plates distributes the load directly on the welding onto the metal plate. In addition, when connecting the weld and the carrier profile plate, they form a half-shaped connected system.

Using the plates as a patch in a new design causes both the construction to give a sense of insecurity to the environment and the plate not to perform its task fully. Plate design is achieved by taking into account weld lines and geometry [5].

The design of welded constructions can be made with CATIA. There is also a special module in CATIA dedicated to the welding design. Located under the “Parts Design” module, this module makes it possible to prepare all welding fill types that are available in the practical applications. Another way to accomplish the welding process in CATIA is achieved by defining the bonds in the analysis of the assembled parts as the welding joint.

With CATIA, it is also possible to perform stress analyses of the weld-containing models. There are two methods for this procedure. The first method is to define the mounting system in the analysis module and make a stress analysis. Defining linear welding joint requires a bond for each line and it is lengthy process. The second method is to model the mounting system as a one-piece unit.

Figure 2 depicts a welding bond defined as a line in a mounting system. For the stress analysis of this joint, a total of 12 definitions (for each line) was needed [6].

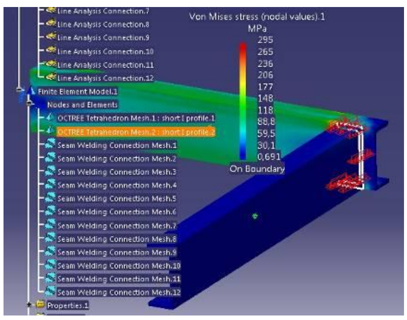

Figure 2. Linear Joint

If the stress analysis is implemented as the analysis of a single part and not as a mounting analysis, definition of only 1 (one) bond will suffice for the process (Figure 3).

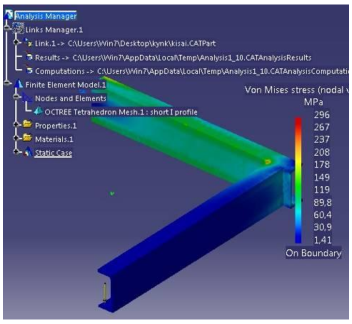

Figure 3. Analysis of the assembly as a part

Performing the analysis for the same mesh size over the system model created in one piece using the definition of welding with mounting gives the same results for the same boundary conditions and for the same loading conditions. Therefore, this method is generally preferred for the weld joints.

When the system is desired to be analyzed, defining welding joints with a fastened tie will provide the same process as the one-piece analysis.

If different section and different property is to be defined for the welding, then the analysis should be made by joining the parts with welding. This process requires several definitions and computer processor capacity. In this study, the system was analyzed as a single piece.

Materials and Methods

Below are provided the design goals and limits defined for producing, in accordance with the methodical construction principles, a load-bearing structure that is required to include an industrial cooling unit into a process:

1- A level of resistance that will not be damaged even in earthquakes and disasters.

2- Capability of carrying a load of 1200 kg with links at 6 points.

3- Use of the limited area within the layout plan.

4- The maximum height allowed for the carrier is 180 mm.

5- Having a structure suitable for operating under vibration.

6- It should be a system that can be produced by a single worker alone.

7- System should be produced using standard profiles.

8- The carrier element should be appropriate to use additional sheets and thin plates.

9- Only welding joint should be present in the production of the system.

Preparing the Design in Accordance with Methodical Construction Principles

1-Determination of the Carrier Dimensions:

The area where the carrier of industrial refrigerator device is in contact with the I-section profile of 300 size is shown in Figure 4. The system is in contact with only 76 mm part the profile. In the process where the carrier is to be mounted, it is important for the design to increase the contact area with the I-section profile of 300 size. A proposal was made to the process managers, and the approval was obtained to increase the 76 mm area to 250 mm. A grid spacing of 50 mm is allocated.

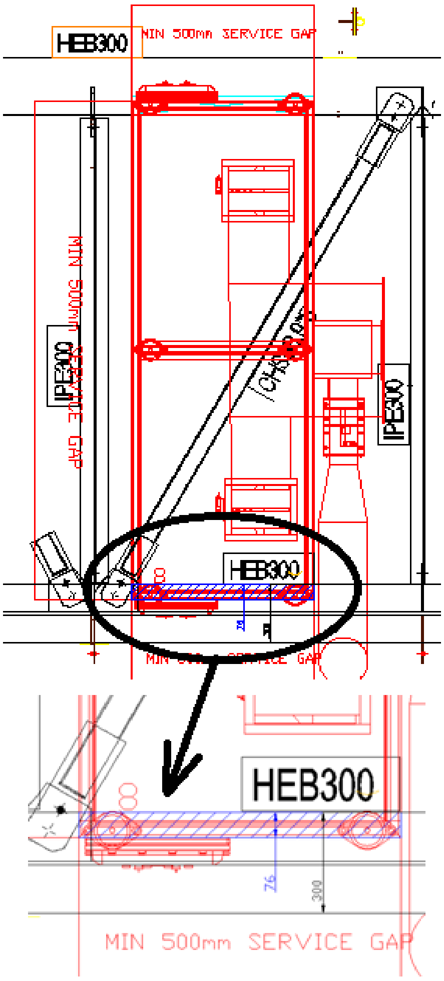

Figure 4. Positioning of the Industrial Refrigerator in the process

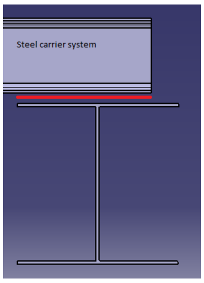

Figure 5. The contact of the carrier with the I-section profile

Although the desired and proposed length for the carrier system is 2620 mm, the length of the carrier system is redefined as 2950mm.The width is 830 mm.

2- Selection of the Standard Profile:

Although the use of I-section profiles for bending is more appropriate, the corner joints of I-section profiles are not suitable geometrically. In addition, holes will be opened in the carrier profile for bolt connections. Therefore, standard U-section profile was selected as the basic carrier profile of the construction.

3- Selection of the Welding Method

In order to ensure that the welding of the plates is smooth, made within a short period and contains medium filling, gas-metal (mixed gas) arc welding is is preferred. Gas-metal arc welding provides advantage in terms of labor.

For standard U-section profile (St37); according to DIN 18800, safe welding seam stress under static strain for steel structures is 160 MPa. [7]

4- Plate selection: The thickness of the plates should be somewhat thicker than or equal to the wall thickness of the selected profile. The design of St37 plates suitable to welding joint will be made at the later stages [6].

Design of the Carrier System with CATIA

In this study, 3 (three) different designs has been made using a standard profile of the same size.

DESIGN I

The carrier system made of U-section profile and recommended for the Refrigerator according to the first layout plan is shown in Figure 6.

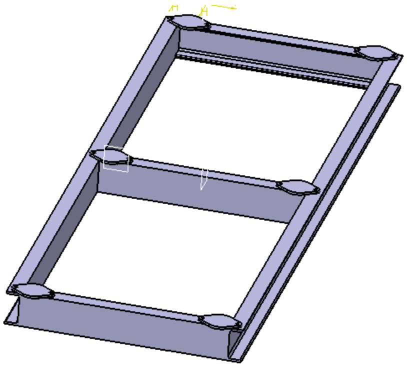

Figure 6. Design I - Construction of the Refrigerator carrier

The stress analysis of this system is shown in Figure 7. With the repeated stress analyses, U-section profile of 140 size which does not exceed the maximum height limit has been decided. Maximum stress value for this analysis is 23.2 MPa. Safety factor is 6.7.

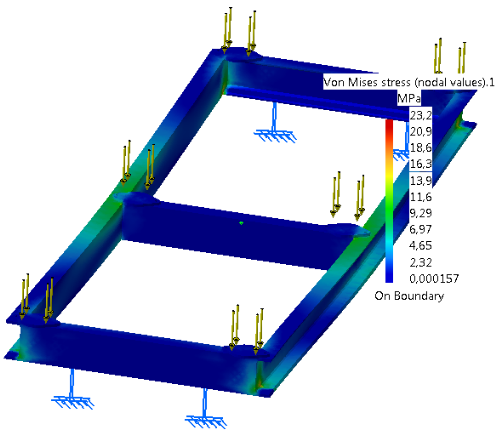

Figure 7. Design I - Stress Analysis

Maximum displacement value for Design I 0.25 mm (Figure 8).

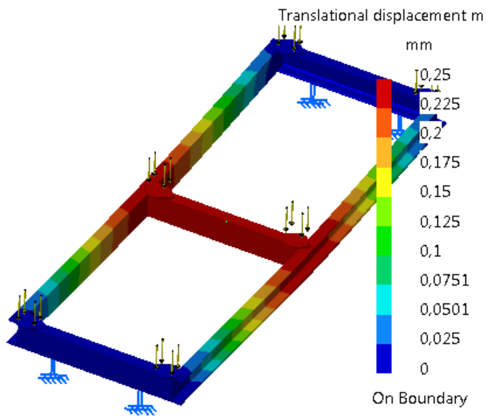

Figure 8. Design I - Displacement value

DESIGN II

Design II has a length of 2950 mm. The top view of the construction created for this layout is shown. A total of 4 (four) crosswise profiles are used (Figure 9).

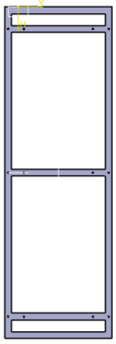

Figure 9. Design II - Top view

The system formed from U-section profile of standard 140 size is demonstrated in Figure 10. Additional joint plate is not used in the system.

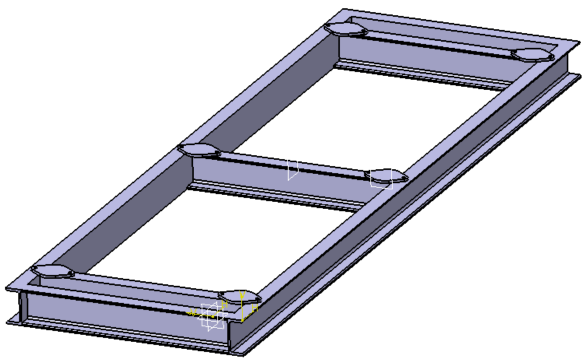

Figure 10. Design II - Solid model

The stress analysis of the design II is shown in Figure 11. The maximum stress value is 13.3 MPa. The safety factor is 12.

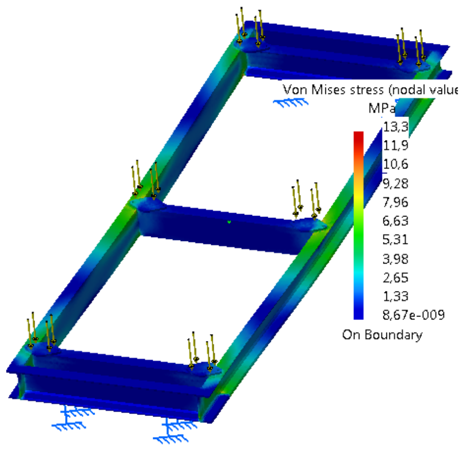

Figure 11. Design II - Stress Analysis

The displacement value for Design II is shown in Figure 12. Maximum displacement value is 0.184 mm.

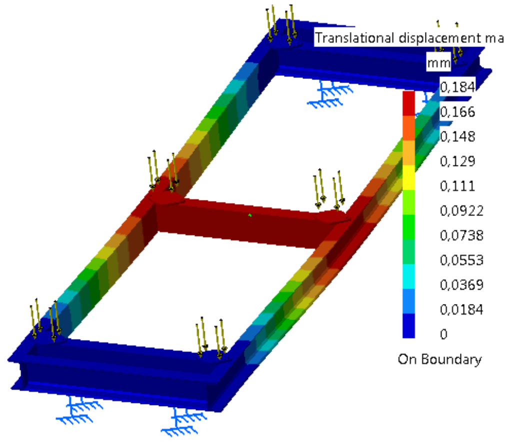

Figure 12. Design II - Displacement value

DESIGN III

In this design, weld joint plates are used. During the welding of the U-section profiles, weld mouth opening was not made. For this reason, weld filling (blue fillers) will occur at the joining sections (Figure 13). The only way to mount the connection plate over the surface where this filling is present is to form a gap in the plate. Plate thickness is selected to be 10 mm. This gap will be filled later with welding as needed.

Welding construction must comply with the flow of force principles as in other machine elements. Therefore, 45-degree angled plate geometry is preferred at the corners. In addition, the plate shown in yellow color in Figure 13 is welded into the U-section profile and its thickness is 10 mm.

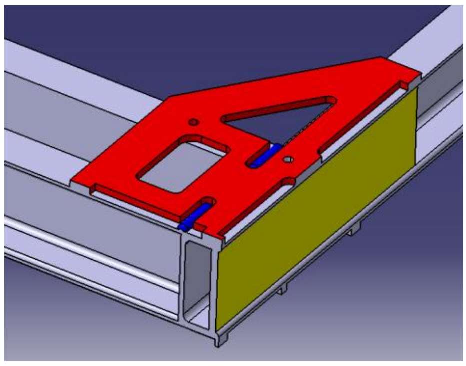

Figure 13. Design III - Design of Corner Joining Plate

The 45-degree angled plates are also used in the central portion (shown in red) of the carrier where the displacement is maximum. A rectangular plate (in yellow color) is placed inside the U-section profile, as in the corners. An additional joint plate (orange color) was added between the lower and upper plates due to exposure of the joining plates to bending in the middle section. These plates can be seen in Figure 14.

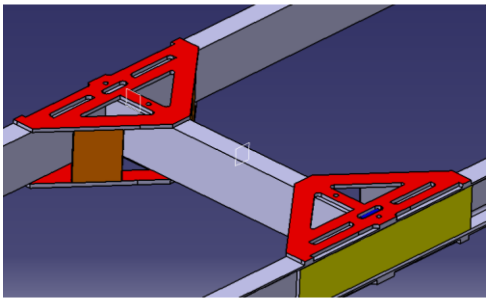

Figure 14. Design III - Middle Section Joining Plates

The weld joint area of the joining plate of the plates with U-section profiles is shown in Figure 15,16 (in green color) in the corner plate on the left. Plates were joined by also applying welding over the welding fillers (in blue color) formed when joining the U-section profiles without plates.

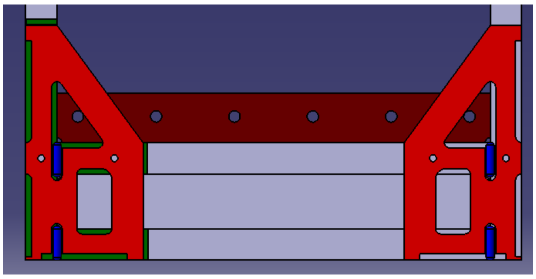

Figure 15. Design III - Corner joining plates geometry and welding areas

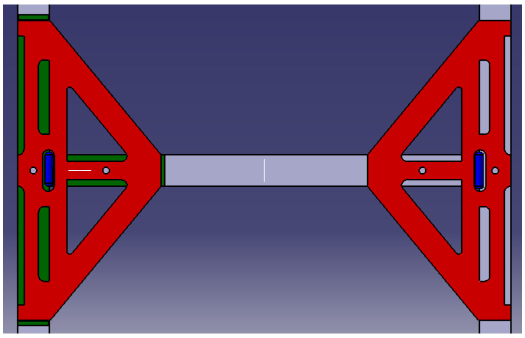

Figure 16. Design III - Plate design and welding gaps for the middle section of the carrier

For Design III, the design of carrier - I-section profile contact plate (in claret color) and the welding gaps (in green color) are shown in Figure 17.

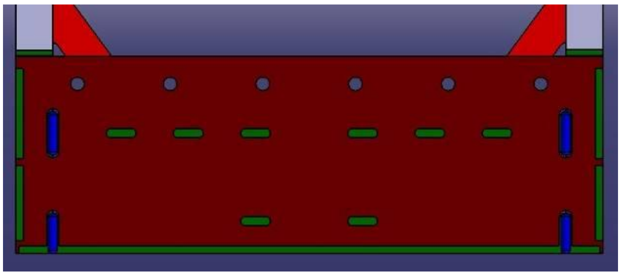

Figure 17. Design III - I-section profile contact plate of 300 size

Design III is shown in Figure 18 together with the colored plates. Its weight is 246 kg.

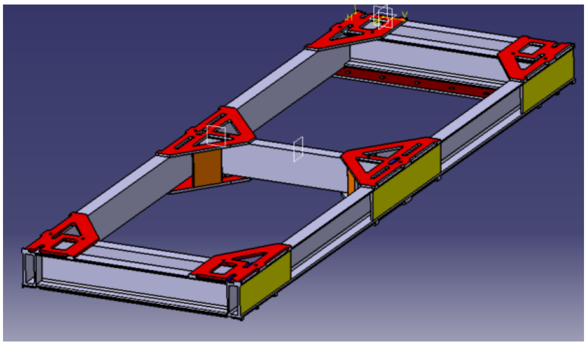

Figure 18. Design III - CATIA solid model

For the stress analysis of Design III, 121364 elements 39384 nodes were used and the mesh structure was obtained with a good spread of 99.84%. The model in one piece in 1200 kg weight was loaded from 6 points (Figure 19).

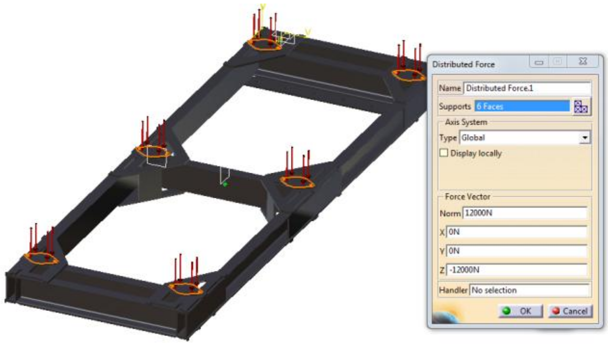

Figure 19. Design III - Applying force for stress analysis

The dissolution made following the fixing / securing required for the analysis, the maximum stress value of the solution was obtained as 6.1 MPa. The safety factor (for 160 MPa) is 26 (Figure 20).

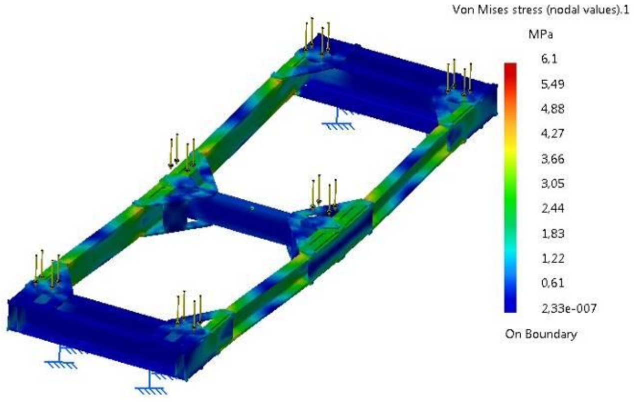

Figure 20. Stress analysis for the Design III with a joining plate

Maximum displacement value of Design III is shown in Figure 21.

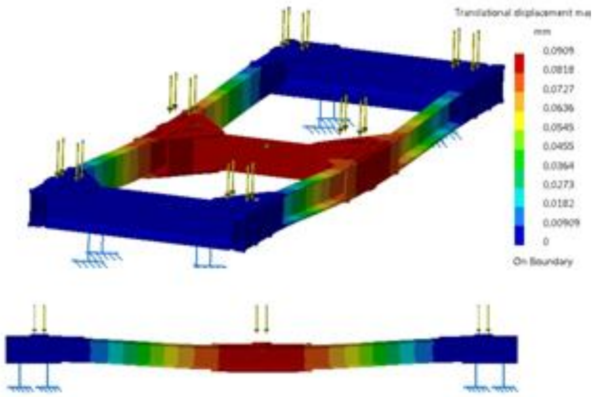

Figure 21. Design III - Displacement value

Results and Discussion

Safety factor the vibrating systems must be taken twice of the value compared to the value of a static system.

For a construction resistant to even in earthquake and disaster, the safety factor for must be taken 10.

Under these circumstances, a 20-fold safety should be taken for the system. Design III is 26 times safer. And appropriate. Table I shows the values for the three different designs. When these values are analyzed;

Design I and Design II are not suitable in terms of the safety factor.

The carrier profiles and their dimensions are the same for Design II and Design III. Joining plate are used in Design III.

The stress value in Design II has decreased by 43% compared to Design I while the weight has increased by 33% and the displacement value has decreased by 26.4%.

The stress value in Design III has decreased by 73% compared to Design I while the displacement value has decreased by 63.64% and the weight has increased by 88%.

Table I. Maximum stress - weight values of the designs

	Design I	**Design II**	**Design III**
Maximum Stress (MPa)	23.2	13.3	6.1
Maximum Displacement (mm)	0.25	0.184	0.0909
Weight (kg)	130.6	173.8	246.0
Safety factor	6.7	12	26.2

Production of the Design

The plate geometries obtained during the design process have been transferred to the two-dimensional CAD environment. The plates were cut in the laser-cutting device with the two-dimensional drawing files. The accuracy in the plates cut with the laser-cutting device is less than 0.5 mm (Figure 22).

Figure 22. Design III - Cutting the plates with the laser-cutting device.

The plates cut with the laser-cutting device should be staked (punched) for the assembly (Figure 23).

Figure 23. The welded joint of the structural system

Staking (punching) is an important step for welding. Thermal stresses cause distortions and wastes in the parts when joining parts with welding. Therefore, we should first stake the parts (Figure 24).

Figure 24. Mounting of the plates at the middle section of the carrier system

Due to the fact that the Refrigerator unit generates vibration, plastic damping elements were used in the connections with the carrier (Figure 25).

Figure 25. Refrigerator assembly test in the Carrier System

An inspection was made to see whether there are any dislocations in the installation connections of the carrier during the welding process. Assembly test is successful (Figure 26).

Figure 26. Assembly test for the industrial refrigerator unit

The carrier was positioned and mounted in the process and currently it is operated.

CONCLUSION

The details believed to be important for the design should be revealed before starting the design. The idea of a change in the conditions should be considered before commencing the project work.

Production should never be started unless CAD data for design has been completed by 100%.

In this study, the change made in the project layout area boundaries and the elongation of the carrier standard profile have reduced the maximum stress value of the system by 43%.

The targeted minimal labor has been achieved in the design. The metal sheets cut by laser have both facilitated mounting task and included line gaps.

The plates with gaps also provide guidance for workers in the manufacturing task in standard weld section and length. This standardization is an advantage for a desired production.

Plasma and laser cutting technology has become today the most practical way of obtaining welded constructions in accordance with the technical drawings, and so this technology is now recognized as one of today's traditional manufacturing methods.

Welding is a machine component. Using this fastening element in constructions requires calculation ability and experience.

In the welding process, handcraft as well the combination of gas pressure setting, ampere setting and wire speed setting is equally important. Several parameters are important for a good welding such as the welding area, wire diameter, welding torch, gas type, metal temperature, and surface cleanliness. Preparing a suitable welding bath is a must for a very smooth and penetrating weld.

Joining plates perform the task of setsquare when joining the profiles, simplify the assembly and minimize errors.

Thanks to the fact that corner steepness is ensured by the plate, weld seams are not exposed to torsion.

Maximum stress has not occurred on the weld joints.

The load falling on the joining plants and welding seams are spread over the plates. Thus, a force flow balance is maintained on the system. The stress analyses performed for the systems with appropriate mesh study made with CATIA gives reliable results with an accuracy of 98%.

The welding design module and the welded connection stress analysis module of CATIA also provide ergonomic and accurate results as do the other modules of CATIA.

In this study, the weight of the existing carrier system was 173 kg and with the use of 73 kg joining plate, the stress value was reduced from 13.3 MPa to 6.1 MPa. Use of 43% extra plate on the existing weight reduced the stress by 54%. This way, a more rigid and secure system was obtained.

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