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Crash Performance of Double Hat Column Subjected to Compression Loading

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Abstract. There are many types of structure designed to act like an energy absorber. Energy absorber is the one that responsible to absorb energy during crashes. An energy absorber is a system that converts, totally or partially, kinetic energy into another form of energy. Energy converted is either reversible or irreversible. One of the examples of the most important structure to absorb energy is the crash box. Crash box can be found in many shapes, and double hat column is the common one. The objective of this study is to study the effect of heat treatment and notch on the performance of the double hat column structure. The results of different specimens were compared in terms of tensile strength and also energy absorbed. It was found that the tensile strength and energy absorbed was slightly higher for specimens that were quenched in lower temperature and longer time and for notching distance of 20mm.

1. Introduction

Energy absorber is the one that responsible to absorb energy during crashes. Crash box is an example of energy absorber. Crash boxes can comes in various geometrical design and hat section among the common one [1]–[5]. Double-hat column design is an upgrade version of the single-hat column. The double-hat column looked like a single-hat column structure being attached together. On a single-hat column, the fin will be at the bottom of the structure. Meanwhile on a double-hat column, the fin points out at the center of the structure.

Nowadays boron steel, as the conventional lightweight materials that increasing use in automotive industry due to their high and ultra-high strength steel. The properties of the boron steel will increase when it go through the heat treatment process. The heat treatment process produced parts with extremely high strength and good ductility [6]. This fact inspires the use of boron steel to produce hat column in this study.

Combination of good crash box design and high strength material was expected to produce highly efficient energy absorber, thus reducing the risk of occupant injury during crash. The use of high strength steel such as boron steel however may increase the peak force. Thus, notch is introduced. In this study, boron steel sheet formed into double-hat column was analysed in terms of strength and energy absorption capability.

2. Methodology

2.1. Specimen preparation

From a large piece of sheet metal that we obtain from the manufacturers, we have to size it down to the planned size by using the shearing machine. The plate was undergone the bending process. The



plate was bent to form the fin first. The size of the fin would be 20mm on both ends. When bending the sheet metal, be sure to bend it on line. Align the line well with the die of the bending machine. Make sure the angle is right if not, the shape will be crippled and we have to do it again starting from sheet metal cutting.

For specimen tagging, it consist of numbers. As example “2 10 3” means that the specimen thickness is 2mm and it is quenched in 10°C water and the quenching time is 3 seconds. Also note that “NN” stands for no notch and “NH” stands for no heat treatment.

2.2. Notching

For the next step, trigger was made for the specimens. This trigger is also known as notching. Different notching distance will give different effect. For this specimen, we have two distances for the trigger which is 10 mm and 20 mm. To make this notching, grinder was used. The width is about 1.3 mm and the depth is 0.5mm.

2.3. Welding

In this study, Metal Inert Gas (MIG) technique was used to join the plate together. The part that will be welded is at the fin. Note that we did not weld all the way through the fins. There are distances between each points of welding. Before welding, mark the distance that we need want to weld. There will be 13 points. Start with 6mm on the first point then 25mm until the last point. Note that last point distance is also 6mm. To finish, weld one spot at top of each fin with 10mm center.

2.4. Heat treatment

For the heat treatment process, it involved a furnace for heating up the specimens including the one for the tensile testing. For the tensile testing specimens, from a piece of boron sheet metal, we need to cut it into bone shape. The way the heat treatment is done is by heating the specimens at least 20 minutes and then quenched with certain temperature and time. We will need ten specimens for tensile testing which is five from 2mm thickness and five from 3mm thickness. For 2mm thickness, one specimen is not heat treated. The second one is quenched at 10C in a bucket of water with ice for 3 seconds. Third one is 10C for 8 seconds. The fourth one is quenched at 15C in a bucket of water with ice for 5 seconds. Fifth one was quenched at 15C for 8 seconds. For 3mm thickness, one specimen is not heat treated. The second one is quenched at 10C in a bucket of water with ice for 3 seconds. Third one is 10C for 8 seconds. The fourth one is quenched at 15C in a bucket of water with ice for 5 seconds. Fifth one was quenched at 15C for 8 seconds.

3. Result and Discussion

Figure 1 and Figure 2 shows stress-strain curve for 2mm tensile test and 3 mm sheet.

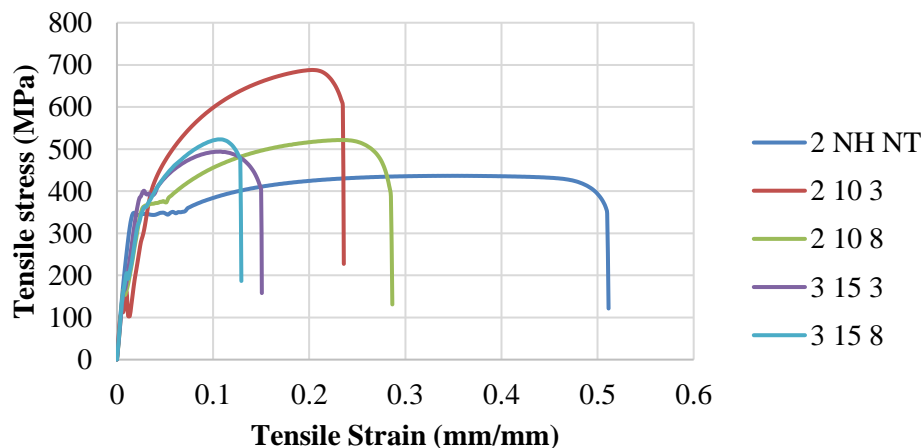


Figure 1. Graph of the 2mm stress strain

It can be seen from Figure 1, the highest tensile strength is specimen 2 10 3, which the tensile strength is 685.236MPa and the lower one is specimen 2 NN NT which just have 435.477MPa. The specimen 2 10 3 also have the higher break point compare to other. The specimen 2 10 3 have the higher tensile strength and break point may due to some error when running the test. If the tensile strength higher, the more force need to break the thing is higher.

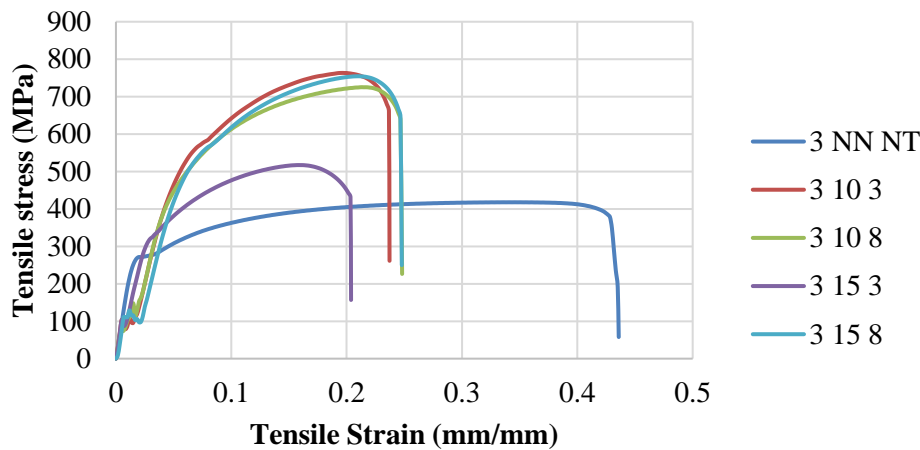


Figure 2. Graph of the 3mm stress strain

From Figure 2, the highest tensile strength is specimen 3 15 8, which the tensile strength is 752.782MPa and the lower one is specimen 2 NN NT which just have 417.709MPa. The specimen 3 15 8 also have the higher break point compare to other.

Based on Table 1 and Table 2, if we compare specimens without heat treatment and without notching, we could see that 3mm thick specimen have bigger energy absorbed value. So we can conclude that the thicker the specimen, the higher the value of energy absorbed. From the data obtained, supposedly the value of energy absorb would be bigger for the specimens that have longer quenching time.

Table 1. 10mm Notching Distance

Specimen	Energy absorbed (kJ)
2 NH 10	0.805
2 10 3	0.763
2 10 8	1.020
2 15 3	0.808
2 15 8	0.925
3 NH 10	0.945
3 10 3	1.403
3 10 8	0.846
3 15 3	1.426
3 15 8	0.982

Also from the data obtained, the energy absorbed should be slightly higher for specimens that were quenched in lower temperature. However, some specimens did not show such pattern also due to some errors during other process. If we compare between 10mm notching distance and 20mm notching distance, we could see that almost all specimens with 20mm notching distance has higher energy absorbed value. We can conclude that the distance of notching has effect on energy absorbed.

Table 2. 20mm Notching Distance

Specimen	Energy absorbed (kJ)
2 NH 20	0.792
2 10 3	0.956
2 10 8	1.144
2 15 3	1.210
2 15 8	0.959
3 NH 20	1.01
3 10 3	1.605
3 10 8	1.501
3 15 3	0.806
3 15 8	1.150

Table 3. No Notching, No Heat Treatment

Specimen	Energy absorbed (kJ)
3 NH NN	1.148
2 NH NN	1.007

Conclusion

Based on the works done, specimen heat treatment process and notching significantly affect the tensile strength and energy absorption of the material. It was found that the tensile strength and energy absorbed was slightly higher for specimens that were quenched in lower temperature and longer time and for notching distance of 20mm.

Acknowledgments

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