A PROTOTYPE CHARPY AND IZOD IMPACT TESTER DESIGN AND IMPACT TEST ANALYSIS OF DIFFERENT ALUMINUM ALLOYS

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Abstract

Different international standards have been established to determine the fracture energy of materials. In this study to determine the fracture energies of aluminum materials in different alloys, a prototype of Charpy and Izod impact tester was designed and manufactured. This tester were been designed and manufactured by ASTM E23 and TS EN ISO 148-1 standard. This study was completed during the postgraduate period. The Charpy and Izod impact energies of ETIAL-160, ETIAL 171, ETIAL 177, ETIAL 195, and AC2A which are aluminum materials commonly used in the manufacturing industry, were determined by the designed machine.

Keywords: Impact test, impact energy, Charpy impact test, Izod impact strength test

INTRODUCTION

The rising cost of steel has had a substantial impact on manufacturing costs in the industries, making a compelling case for replacing steel with materials that are lightweight and have a high strength-to-weight ratio [1]. These pressures paved the way for the industry to use aluminum as an alternative to steel. Aluminum is one of the most widely preferred light metals owing to its easy castability, good corrosion properties as well as sufficient specific strength [2-4]. These properties of aluminum ensure its wide use in industrial products such as machine bodies.

Various research has been carried out on the production and usage areas of impact testers which are widely used in the industry. In the study conducted by Mustapaevich et.al. (2022), impact testing machine the fracture toughness of as-cast and aged as-cast samples were tested using the Charpy Impact test machine. As demonstrated, Charpy Impact specimens were manufactured according to ASTM E23-12c standard. The impact test specimen is struck in the direction by the striking pendulum of the machine with a capacity of 300 J and no additional weights. The amount of energy absorbed throughout the test, as well as the fracture initiation and propagation energies, were all measured. The tests were performed in line with "ASTM D 256" using an impact tester. The impact test specimen was 10mm X 10mm X 55mm thick and measured 10mm X 10mm X 10mm thick. The specimen was placed horizontally in the testbed, as seen in the photograph. The pendulum was lifted from its standard height and made to strike the specimen [1]

By using an instrumented impact pendulum, the force versus time curves of 7075-T651aluminum welds was obtained from standard Charpy-V samples. Considering the force-time curves and constant impact velocity, the fracture energies for different zones were quantified. A fracture energy improvement for the HAZ (33.6 J) was observed in comparison with the weld metal (7.88 J), and base metal (7.37 J and 5.37 J for transverse and longitudinal directions, respectively [5].

The instrumented impact tester pendulum [6−8], and three-point bending tests have been used to determine the dynamic fracture behavior of aluminum alloys. An experimental study on the dynamic fracture of extruded 7xxx aluminum alloys was carried out by CHEN et.al. [6]. They used an instrumented Charpy pendulum to determine the total energy absorbed on 7003-T6 and 7108-T6 aluminum alloys [5].

In this study, the impact tester were been designed and manufactured by ASTM E23 and TS EN ISO 148-1 standard. Charpy test samples taken according to ASTM E23 and ASTM D 256 from the bodies of aluminum-bodied attaching machine frames (body), product-feeding hoppers, and product-feeding shute machines which are widely used in the zipper industry, were used.

In the literature survey, it has been seen that the intensity of academic studies on impact testing and material properties is enormous. In this study, a Charpy and Izod impact test machine was designed and test implementation on Etial-160, Etial 171, Etial 177, Etial 195, and Ac2a alloys was done.

MATERIAL AND METHOD

In this experimental study, a prototype Charpy-Izod impact test device was designed and manufactured to determine the fracture toughness of aluminum alloys. This assembly has been designed and manufactured by considering ASTM E23 and TS EN ISO 148-1 standards.

Technical drawings of the designs completed via Solidworks were created and they went into production. The parts to be produced were separated according to the production methods and their production was completed in this direction.

The designed and manufactured impact test machine is presented in Fig. 1. The figure shows the impact testing machine arranged according to two standards designed according to Charpy and Izod standards.

This mechanism works by releasing the hammer of mass "m" attached to the impact arm from the height of "h0", which has maximum potential energy, with a determined lock mechanism, by transferring its maximum kinetic energy to the sample in the "h1" position, and accordingly, showing the breaking energy in the energy scale.

Vibration wedges are used to balance the machine and adjust it according to the ground conditions. An enclosure was designed to prevent the parts from scattering around and also to protect the employees around them. A lever locking mechanism has been designed and manufactured to fix and suspend the lever and hammer before releasing it into free fall. A brake lever is designed to stop the swing of the striker's arm after the free fall has been initiated and the breaking process has taken place.

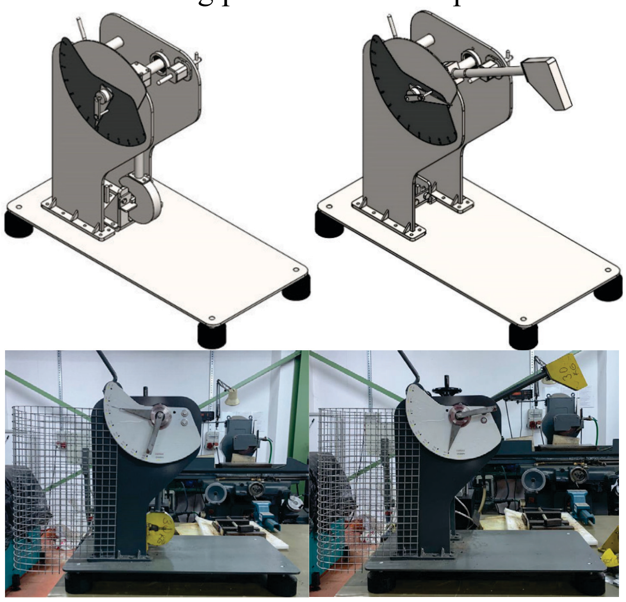

Fig. 1. *Designed Charpy & Izod impact tester*

Charpy hammer mass was completed as 3 kg in total. The Izod hammer was also produced in the same mass by the design. According to ASTM E23 standards, it was determined that the machine had 30 and 32 Joules of impact energy for Charpy and Izod notch impact tests, respectively, in calculations made according to 3 kg hammer weights. The energy indicator of the machine prepared according to the impact energy values is presented in Fig 2.

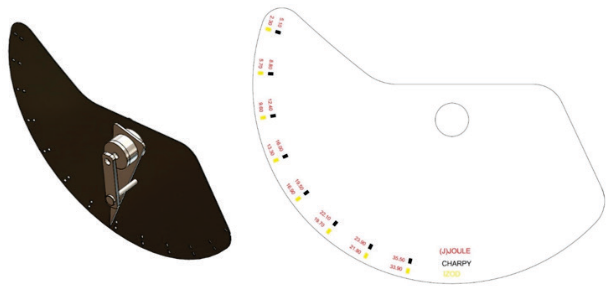

Fig. 2. *Charpy & Izod impact energy indicator (J)*

The fracture regions of Charpy and Izod samples produced separately differ. The Charpy sample should be placed freely in the fracture area, while the Izod sample should be clamped in a brace or vise. Due to this difference, separate apparatus has been designed and produced to connect both different samples. The designed Charpy and Izod specimen clamps are present respectively in Fig 3.

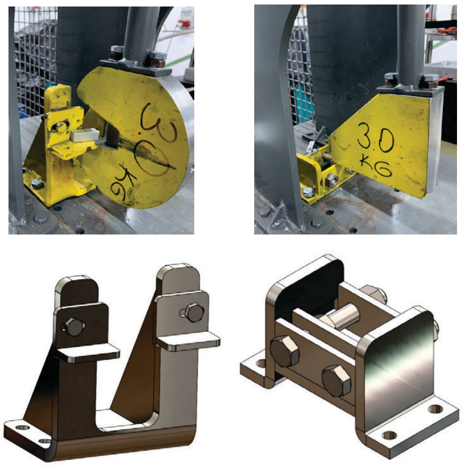

Fig.3. *Charpy and Izod specimen clamps*

Köger Charpy Impact testing machine was used for the verification experiments of the prototype design. In the validation studies, it was seen that the results of the Charpy mechanism produced as a standard and the prototype we designed overlapped.

In these experiments, uniform control was ensured because the standard machine only performed Charpy tests. Since the energies were matched in the Charpy tests, the Izod test results were also accepted as correct in the design setup.

In the research, test samples produced from Etial-160, Etial 171, Etial 177, Etial 195, and Ac2a aluminum alloys were used. The chemical contents of the aluminum alloys used are presented in Table 1.

Table 1. *The chemical compositions of aluminum alloys[8]*

ETİNORM	Fe	Si	Cu	Mn	Mg	Zn	Ni	Ti	Pb	Sn
ETİAL-160	1	7,50-9,00	3,00-4,00	0,5	0,3	1	0,2	0,15	0,1	0,1
ETİAL-171	0,5	9,00-10,00	0,1	0,40-0,60	0,30-0,45	0,1	0,1	0,15	0,05	0,05
ETİAL-177	0,2	6,60-7,40	0,02	0,03	0,30-0,45	0,04	0,02	0,80-0,14	0,05	0,05
ETİAL-195	0,6	17,00-19,00	0,8-1,5	0,2	0,80-1,30	0,2	0,80-1,30	0,1	0,1	0,05
AC2A (JIS)	0,8	4,00-6,00	3,0-4,5	0,55	0,25	0,55	0,3	0,2	0,15	0,05

For experimental studies, Charpy and Izod notch impact test specimens were prepared according to ASTM E23 standards, with dimensions of 10x10x55mm and 10x10x75 mm, respectively. Test specimens prepared according to ASTM E23 standards are presented in Fig 4.

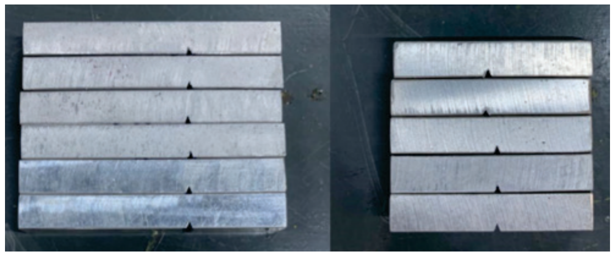

Fig.4. *Charpy and Izod test specimens*

RESULT AND DISCUSSION

The Webster hardness measurement of Charpy and Izod notch impact test specimens was made, and the measurement data are presented in Fig 5. Experiments were performed in triplicate for each test material.

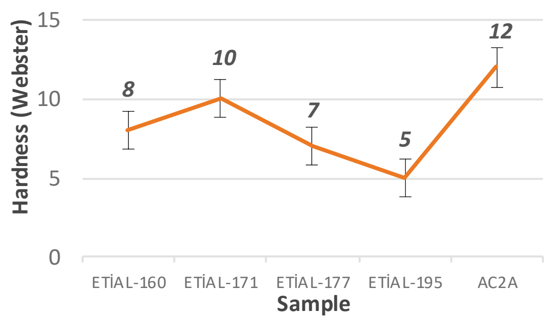

Fig. 5. *Hardness of the Charpy and Izod notch impact test specimens*

Charpy Impact Test Results

Fig. 6. shows the relationship between absorbed impact energy and hardness. It is apparent that as the hardness of the samples increases, their absorbed energy decreases in accordance with the literature. Experiments were performed in 5 replications for each test material. The values given in the graphs represent the average of 5 measurements.

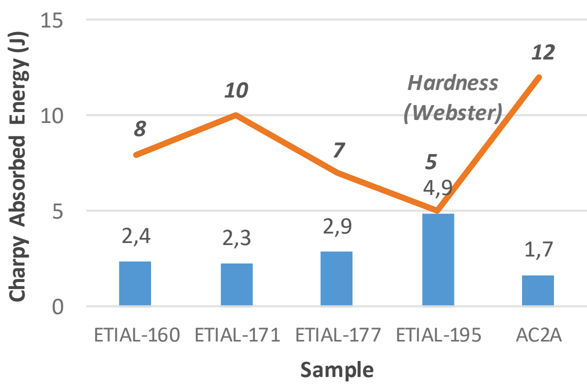

Fig. 6. *Relation between absorbed impact energy and hardness.*

Fig. 7. shows the fractured Charpy V-notch specimens.

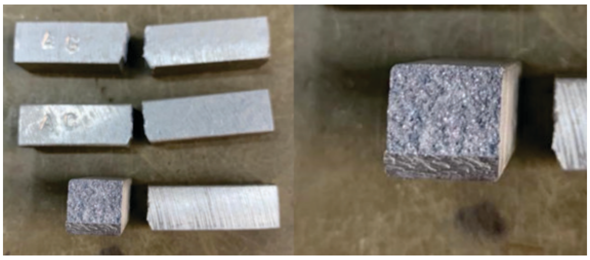

Fig. 7. Crack propagation in Charpy V-notch specimens

Izod Impact Test Results

Fig. 8. shows the relationship between absorbed Izod impact energy and hardness. It is apparent that as the hardness of the samples increases, their absorbed energy decreases in accordance with the literature. Experiments were performed in triplicate for each test material. The values given in the graphs represent the average of three measurements.

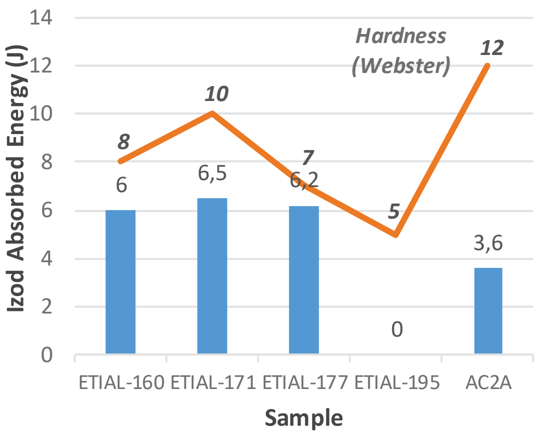

Fig. 8. Relation between absorbed Izod impact energy and hardness

As a result of the tests, the ETIAL-195 sample could not be broken in the Izod impact tests. As a result of the test, the material started to separate, but it was not completely broken (Fig.10.). Therefore, its value is seen as "0" in Figure 8.

Fig. 9. shows the fractured Izod V-notch specimens.

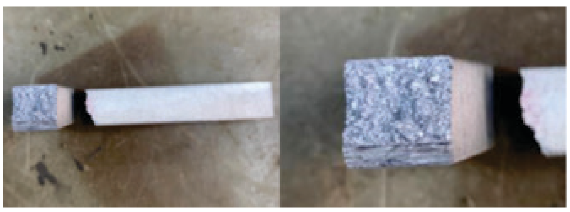

Fig. 9. Crack propagation in Izod V-notch specimens

Fig. 10. Crack propagation in Izod V-notch specimens of ETIAL 195

Microscopic examination

Fracture surfaces of the impact specimens were examined by utilizing a metallurgical microscope (Fig.11).

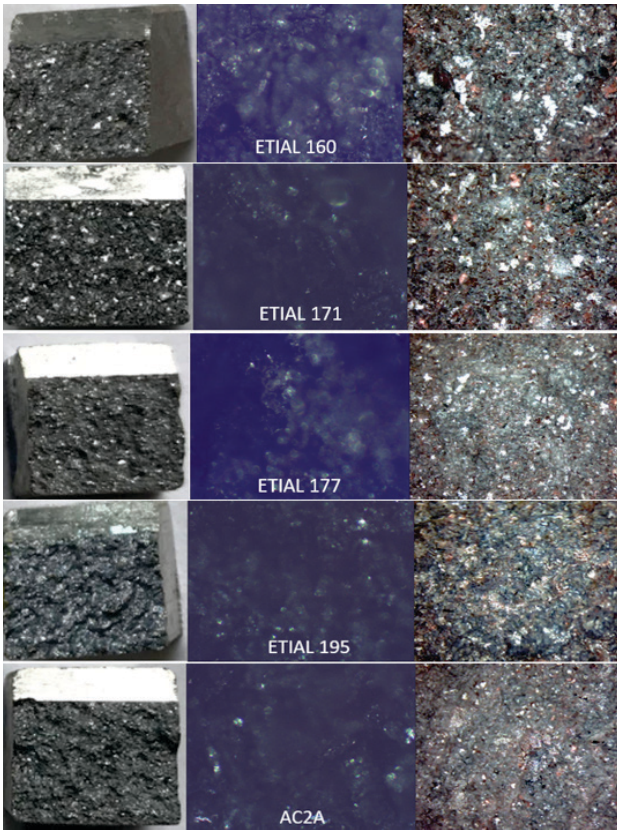

Fig. 11. Fracture surfaces of the impact specimens

It is thought that the inverse ratio between the hardness of the test specimens and the fracture energies depends on the differences in the toughness properties of the specimens. In the optical examinations (Fig. 11) it was observed that the porous structure in the internal structures of the material also had a negative effect on the absorbed energy. As the porosity in the structure increased, the fracture energy decreased.

CONCLUSION

It has been observed that the prototype pendulum-type impact testing machine designed and manufactured in the research works properly.

Experimental studies were carried out using aluminum materials Etial-160, Etial-171, Etial-177, Etial-195, and Ac2a. As a result of the Charpy and Izod tests, it was determined that aluminum with the highest fracture energy was Etial-195 and aluminum with the lowest fracture energy was AC2A.

When all the results were evaluated, it was observed that the energy required to fracture the Izod specimens was higher than the energy required to fracture the Charpy specimens.

Developing sample clamping apparatuses with an easier and more effective assembly and disassembly design to improve the placing of specimens will accelerate the Izod and Charpy impact tests.

The prototype can be improved with pneumatic and electronic systems.

Higher impact energies can be obtained by adding additional weights.

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