

The effect of impact energy in anisotropic sandwich plate

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Abstract :

The effect of anisotropic property in plates is very efficient in impact energy, recently the sandwich plates have been developed in order to reduce the weight of mechanical part and reduce the applied load in plastic forming. In this paper the effect of anisotropic property in izod impact energy for steel , aluminum and sandwich plates have been studied experimentally. Experimental results showed that the maximum value of impact energy at specimen with rolling direction(0°) and the minimum impact energy at specimen (90°) direction normal to rolling directing while the impact energy at specimen (45°) was found to be in between (0°) and (90°) .

Result also showed that the effect of temperature in izod impact energy is increase as the impact energy increase with neglect any significant change in anisotropic property.

Also it has been found that increase the thickness of specimen would increase izod impact energy.

Keywords : Sandwich plate, izod impact , Anisotropic property

تأثير طاقة الصدمة على الألواح المترابطة متباينة الخواص

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الخلاصة :

تأثير تباين الخواص في الألواح مهم في طاقة الصدمة. في السنوات الأخيرة تم تطوير الألواح المترابطة وذلك لتقليل الوزن للقطع الميكانيكية وكذلك لتقليل الحمل المسلط في التشكيل اللدن. في هذا البحث تم حساب تأثير خاصية تباين الخواص على طاقة الصدمة (ايزود) عمليا للألواح من الصلب والألومنيوم وكذلك الألواح المترابطة. فقد تبين من كافة المنحنيات إن أعلى قيمة لطاقة الصدمة كانت في النموذج باتجاه الدرفلة (0°) واقل قيمة للطاقة ظهرت باتجاه (90°) عمودية على اتجاه الدرفلة ، وقيمة الطاقة في النموذج باتجاه (45°) بين الاتجاهين (0°) (90°). وكذلك النتائج اظهرت ان تأثير الحرارة على طاقة الصدمة (ايزود) كلما ازدادت درجة الحرارة للنموذج ازدادت طاقة الصدمة وباهمال تأثير الحرارة مع خاصية تباين الخواص. وكذلك وجد ان كلما ازداد سمك النموذج زادت طاقة الصدمة (ايزود).

1. Introduction :

An isotropic material, by definition is one which has the same properties in all directions. An anisotropic material in contrast is one which has unequal properties in at least two directions. Many hot rolled , normalized ,annealed ,quenched ,tempered structure and pressure vessel steels are three dimensionally anisotropic^[1] .

Kage and Nisitani studied anisotropy in low carbon rolled steels under tension-compression, torsion and rotating bending loading conditions. Monotonic tension tests were conducted on specimens oriented at 0°,22.5°, 45°, 67.5° and 90° to the rolling direction. These tests revealed that the yield strength was reduced in the 67.5° and 90° oriented specimens by about 25% when compared to the specimen oriented at 0°, the ultimate tensile strength reduced by 8%, the area contraction reduced by about 23% and the true stress at fracture by about 26% ^[2]. Sandwich constructions have proven to be very useful in many application areas due to their high stiffness and strength to weight ratios. However, their production is limited to flat plates. A further expansion of their use is only possible if they can be formed into complex shaped parts ^[3].

Understanding the characteristics of failure behavior of steel and aluminum under impact load is interest in many civil and military applications. Extensive investigations of dynamic behavior of metallic materials, such as steel and aluminum materials, in the past two decades have focused on understanding their mechanical properties such as shearing, fatigue, elastic, transverse and tensile properties relative to other materials. Aluminum is considered as a ductile light metal with FCC crystal structure whose behavior under high strain rate load is important for aerospace industries and ferritic steel with BCC crystal structure is the most applicable metal in the industry^[4]. Subhash (2000)^[5] compared the static and dynamic indentation and observed that static results may not be appropriate to use as dynamic material properties such as hardness for high velocity conditions. Wosu et al. (2006)^[6] used a modified SHPB bar for studying penetration and fracture mechanics of a variety of materials at high strain rate. Their method showed energy absorbed as an important measure of levels of failure. However, the penetrating Hopkinson bar underestimates the stress-strain curve and absolute mechanical material properties of the test specimen. This is mainly due to the attenuation of the transmitted wave and the inadequacy of the governing equations to account for the corresponding energy losses due to non-linearity in the system. A great deal of research work (Yang, 1988^[7]; Nagashima S., 1984^[8]; Jiao et al., 2006^[9]) has been carried out for better understanding of the mechanical properties of steel. Yu and Topper (1985)^[10] studied the effect of compressive load for the tempered and quenched steel's mechanical behavior. They found that both compressive and intermittent compressive loads decrease the threshold for crack growth. Lee et al. (2003)^[11] studied the high strain rate behavior of aluminum foam material and 304 stainless steel using dynamic loading and quasi-static loading to investigate different failure mechanisms. It was observed that the deformation caused by quasi-static loading was more concentrated than that of dynamic loading. Jia et

al.(2004)^[12] and Lee et al. (2003)^[11] have investigated the stress-strain relationship for aluminum at high strain rate.

The purpose of this paper are to determine the impact energy experimentally for anisotropic steel, aluminum and sandwich plates, and also determine the impact energy for plate in different condition.

2. Chemical composition and Experimental Procedure :

The chemical composition of two type of metals Steel and aluminum are used in this study shown in **table 1** and **2**.

Table (1) The chemical composition of Steel

Material	C%	Mn%	Si%	P%	Cr%	S%	Mo%	Ni%	Fe
Mild Steel	0.2	0.1	0.02	0.005	0.03	0.01	0.006	0.05	Rem.

Table(2) Chemical analysis of Aluminum skin sheet

Material	Mg%	Mn%	Fe%	Si%	Cu%	Cr%	Ti%	Al%
Aluminum	0.01	0.015	0.18	0.2	0.15	0.009	0.016	Rem.

Anisotropic specimens(three specimens from rolling direction 0°,45°,90°) izod V-notch were machined from plate have thickness (10mm) shown in **figure(1)**.

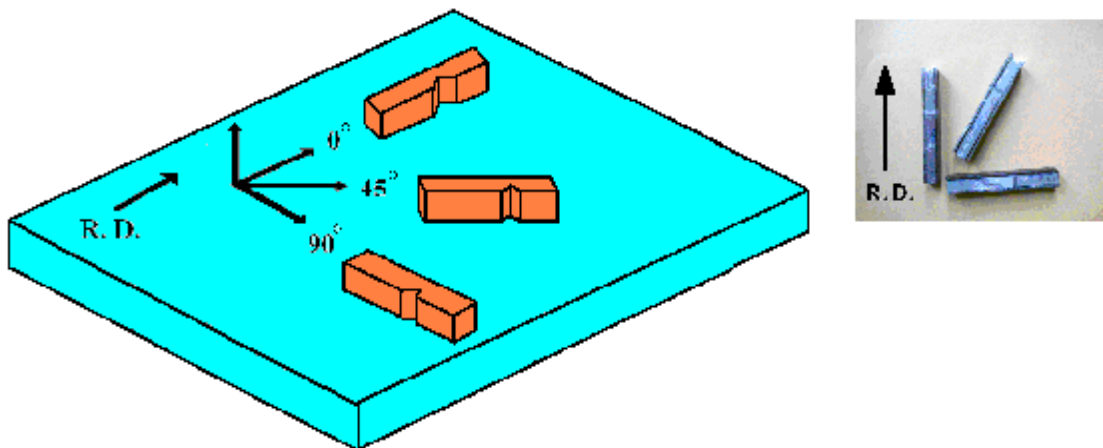
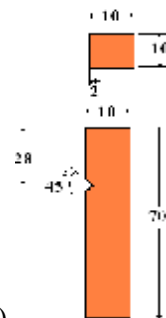


Fig.(1) Plate using to cut specimens

The specimens were used in this study with standard specimen of izod impact shown in



figure(2)

Fig.(2) Standard specimen (BS-131) of izod impact

The impact test equipment using in research are shown in **figure(3)**.



Fig. (3) Image of equipment for impact

The Steel/Aluminum/Steel sandwich plate with 10mm thickness consists of two Steel skins and Aluminum core using epoxy between plates, which are 2 and 5.5mm in thickness, respectively, as shown in **Figure (4)**. The sandwich plate has achieved about 48% weight saving .

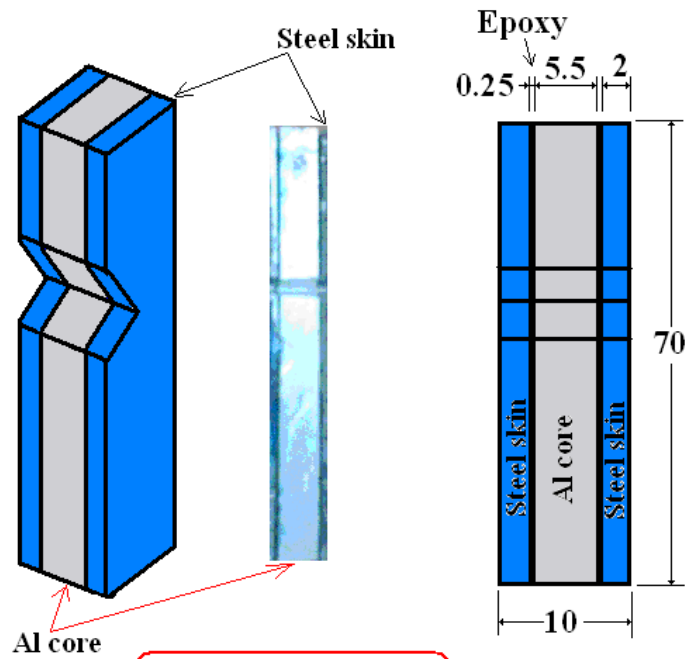


Fig.(4) Sandwich plate (Steel /Al / Steel)

3. Theoretical of impact test :

In a typical pendulum machine, the mass of the hammer (striking edge) mass (m) is raised to a height (a), Before the mass (m) is released, the potential energy will be:

$$E_p = m g a \text{ -----(1)}$$

After being released , the potential energy will decrease and the kinetic energy will increase . At the time of impact , the kinetic energy of the pendulum :

$$E_k = \frac{1}{2} m v^2 \text{ -----(2)}$$

And the potential energy

$$E_p = m g a$$

Will be equal $E_k = E_p$

$$\begin{aligned} \frac{1}{2} m v^2 &= m g a \\ v^2 &= 2 g a \end{aligned}$$

At impact velocity will be

$$V = (2 g a)^{1/2} \text{ -----(3)}$$

$$a = R(1 - \cos\alpha)$$

$$b = R(1 - \cos\beta)$$

$$\text{Initial energy} = E_i = m g R(1 - \cos\alpha) = W R(1 - \cos\alpha)$$

$$\text{Energy after impact} = E_m = m g R(1 - \cos\beta) = W R(1 - \cos\beta)$$

$$\text{Energy absorbed by the specimen} = E_{abs} = W R(\cos\beta - \cos\alpha)$$

OR

$$\text{Initial energy} = E_i = m g a$$

$$\text{Energy after impact} = E_m = m g b$$

$$\text{Energy absorbed by the specimen} = E_{abs} = m g (a - b) = W (a - b)$$

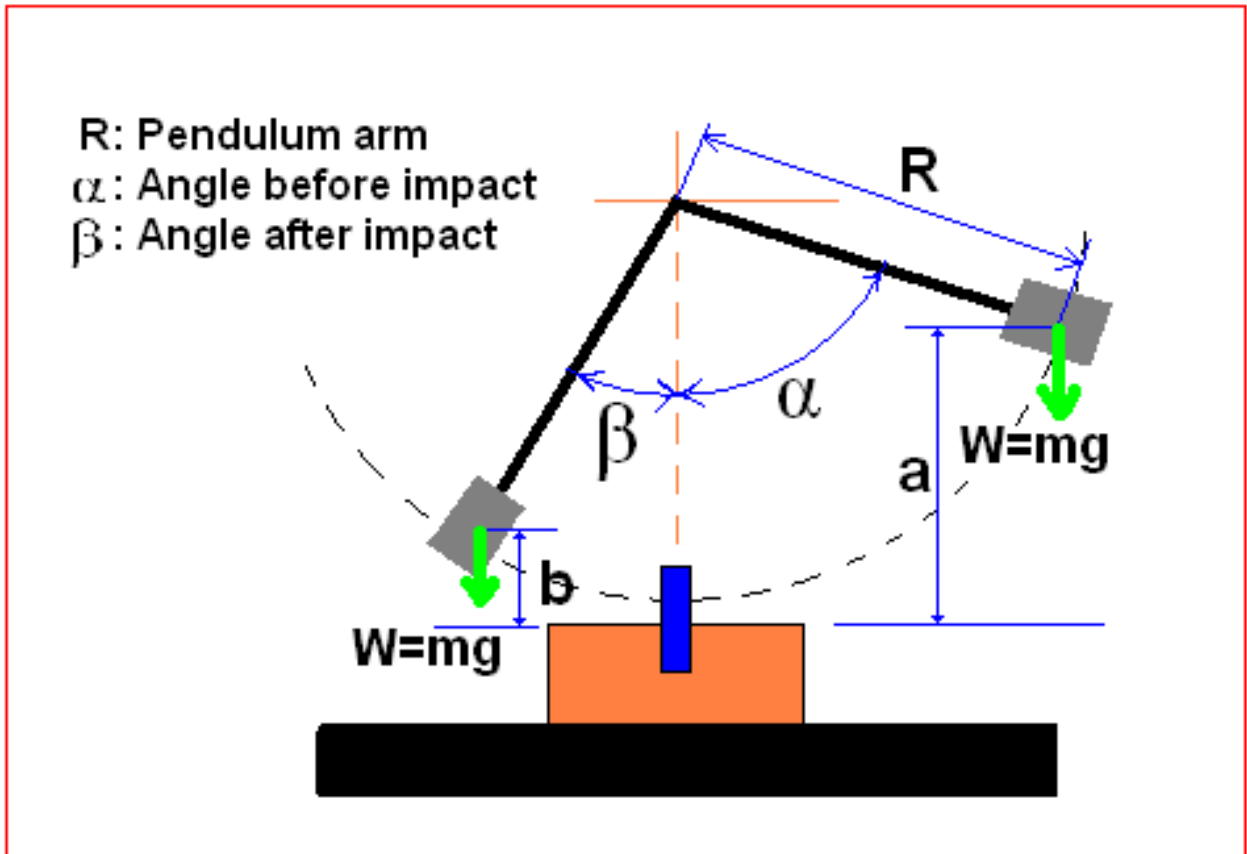


Fig. (5) Impact test machine

4. Results and discussion :

Figure(6) shows the effect of specimen orientation ($0^\circ, 45^\circ, 90^\circ$) in izod impact for aluminum, It can be seen from curve the higher value of impact energy at (0°) specimen with rolling direction and the lower impact energy at (90°) specimen with transverse direction, and the value of impact energy at (45°) specimen were between two angles .

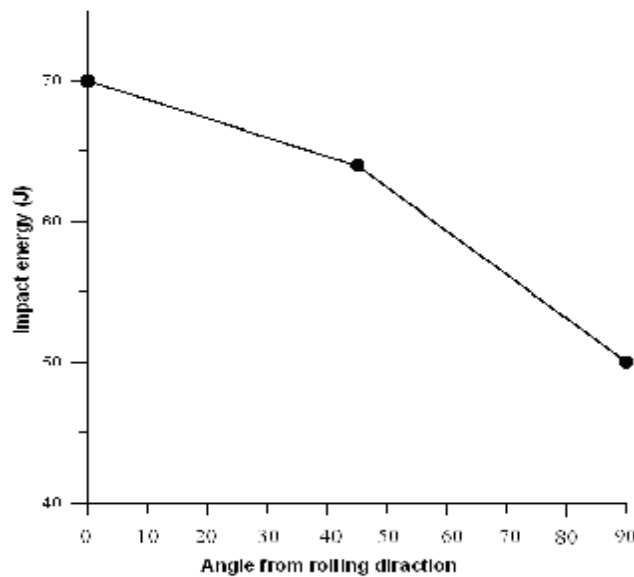


Fig.(6) shows the effect of specimen orientation in izod impact for aluminum

Figure(7) shows the effect of specimen orientation ($0^\circ, 45^\circ, 90^\circ$) in izod impact for aluminum (cutting face). It can be seen from curve the impact energy decrease with increase the angle from rolling direction.

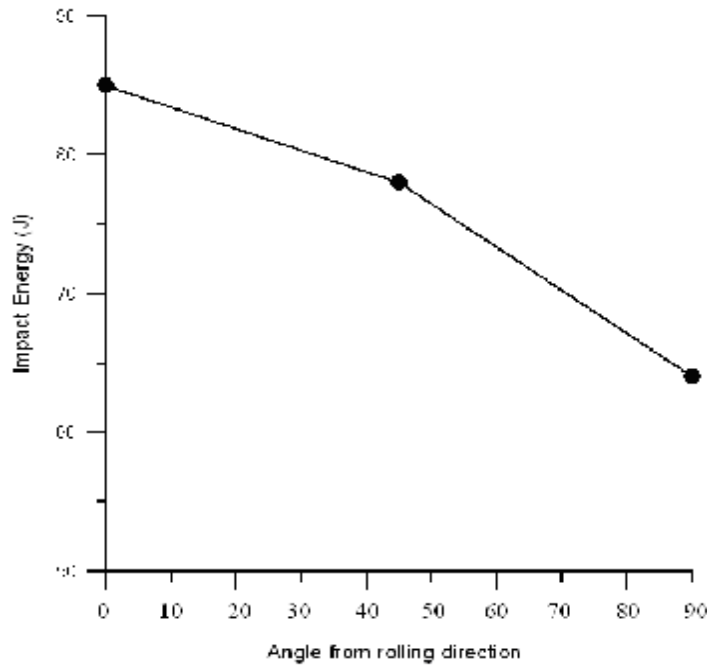


Fig.(7) shows the effect of specimen orientation in izod impact for Aluminum (cutting face)

Figure(8) shows the effect of specimen orientation ($0^\circ, 45^\circ, 90^\circ$) in izod impact for aluminum with different thickness. It can be seen from curves the impact energy decrease with increase the angle from rolling direction, and also the effect of thickness for specimen is significant with high impact energy for specimen thickness (14mm) for different angles.

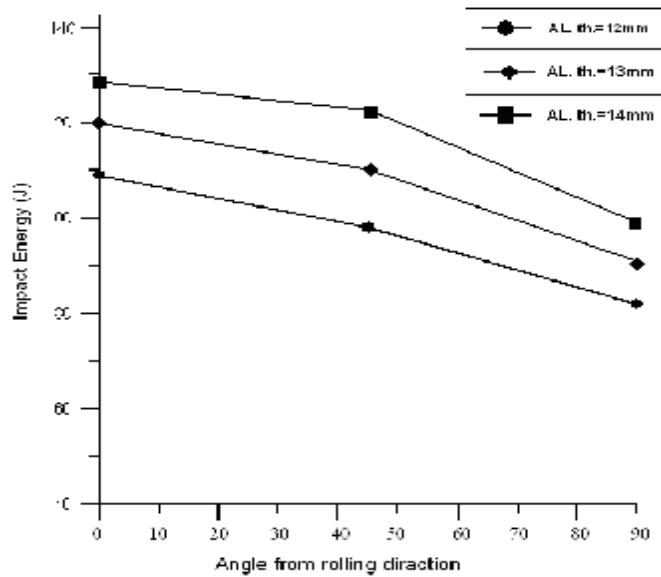


Fig.(8) shows the effect of specimen orientation in izod impact for AL with different thickness

Figure(9) shows the comparison between three curves, It can be seen from comparison that the highest curve using aluminum specimen thickness=12mm and the lowest normal aluminum specimen, and curve between them using aluminum cutting face specimen.

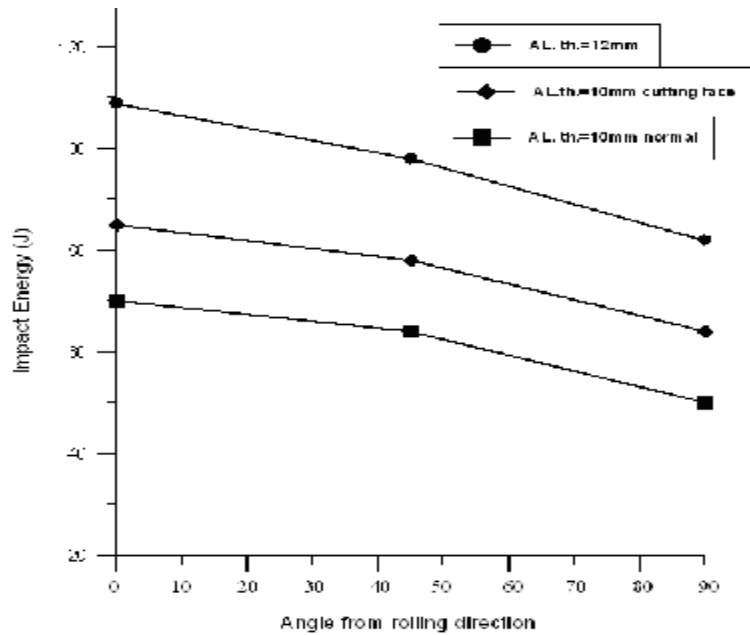


Fig.(9) Comparison between aluminum curves

Figure(10) shows the effect of specimen orientation(0°,45°,90°) in izod impact for steel, It can be seen from curve the higher value of impact energy at (0°) specimen with rolling direction and the lower impact energy at (90°) specimen with transverse direction, and the value of impact energy at (45°) specimen were between two angles .

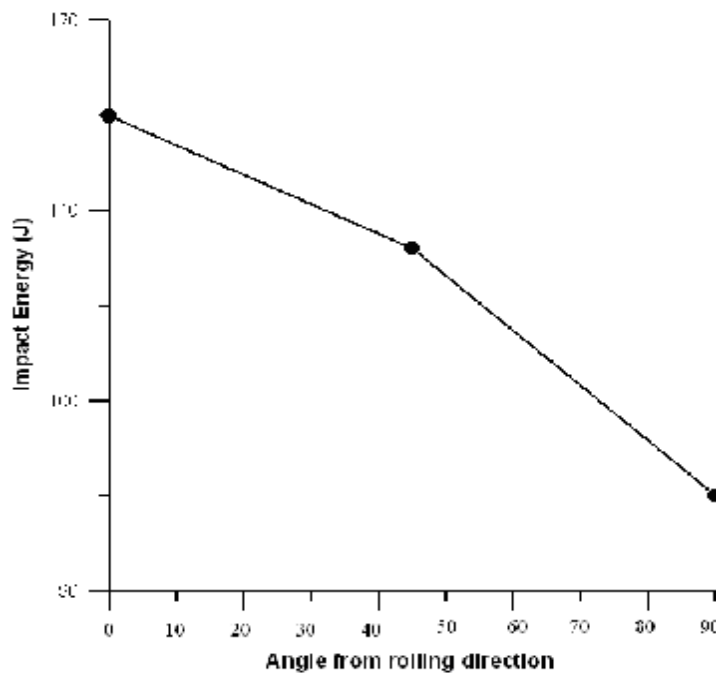


Fig.(10) shows the effect of specimen orientation in izod impact for steel

Figure(11) shows the effect of specimen orientation ($0^\circ, 45^\circ, 90^\circ$) in izod impact for mild steel (cutting face). It can be seen from curve the impact energy decrease with increase the angle from rolling direction.

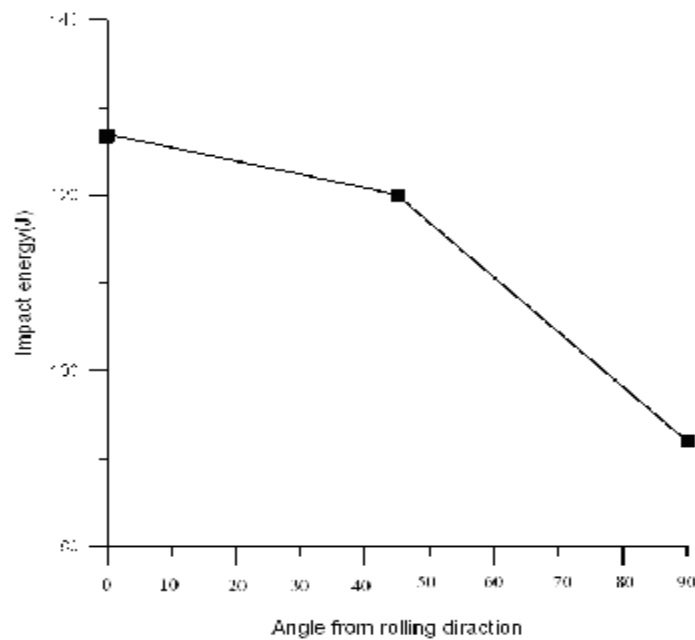


Fig. (11) shows the effect of specimen orientation in izod impact for steel (cutting face)

Figure(12) shows the effect of temperature in specimen orientation ($0^\circ, 45^\circ, 90^\circ$) of izod impact for steel. It can be seen from curve the impact energy increase with increase the temperature and no change with angles from rolling direction.

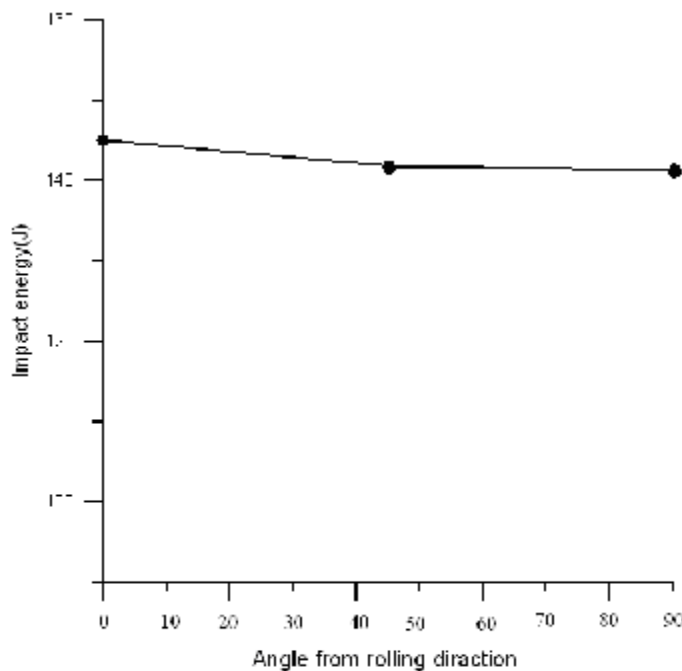


Fig. (12) shows the effect of specimen orientation in izod impact for steel (at temp.= 350°)

Figure(13) shows the effect of specimen orientation($0^{\circ}, 45^{\circ}, 90^{\circ}$) of izod impact for sandwich plates, It can be seen from curve the impact energy decrease with increase the angle from rolling direction.

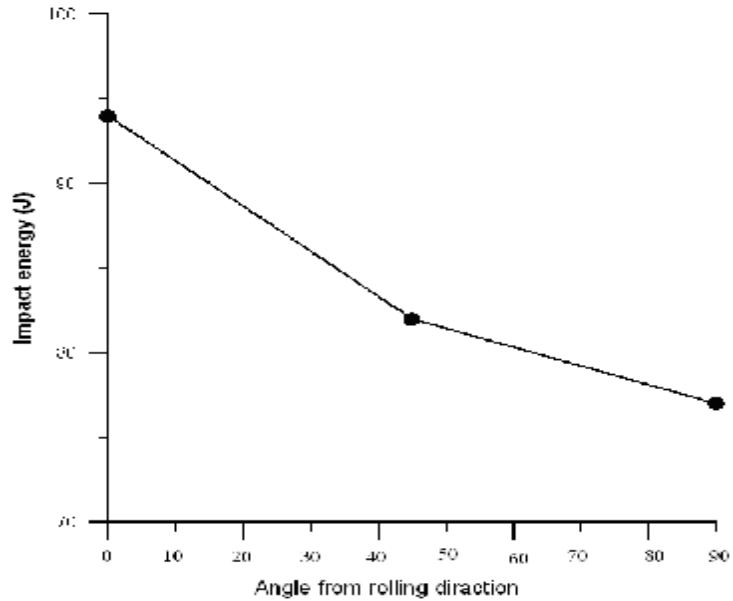


Fig .(13) the effect of specimen orientation in izod impact for sandwich plate

Figure(14) shows the comparison between three curves, It can be seen from comparison that the highest curve using steel specimen and the lowest aluminum specimen, and curve between them using sandwich specimen.

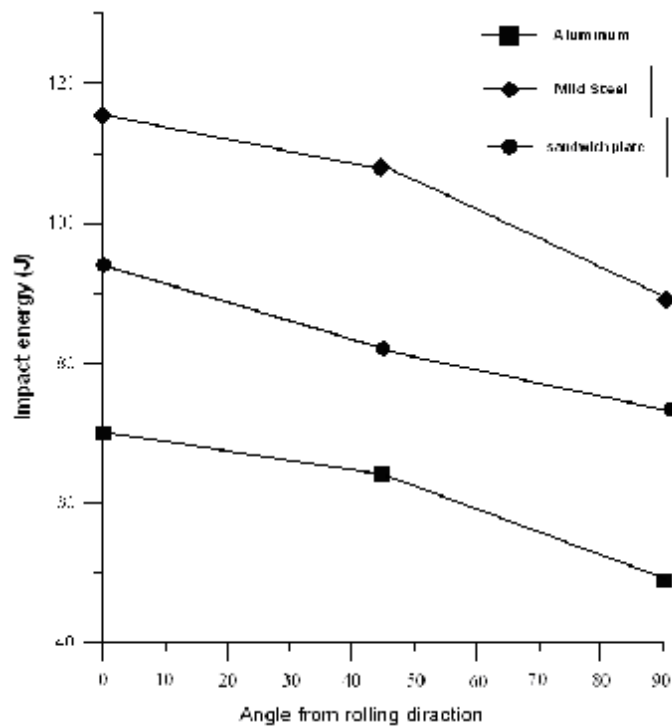


Fig. (14) comparison between Steel , Aluminum and sandwich plates.

Figure(15) shows the comparison between three curves, It can be seen from comparison that the highest curve using steel specimen and the lowest aluminum specimen(cutting face), and curve between them using sandwich specimen (cutting face).

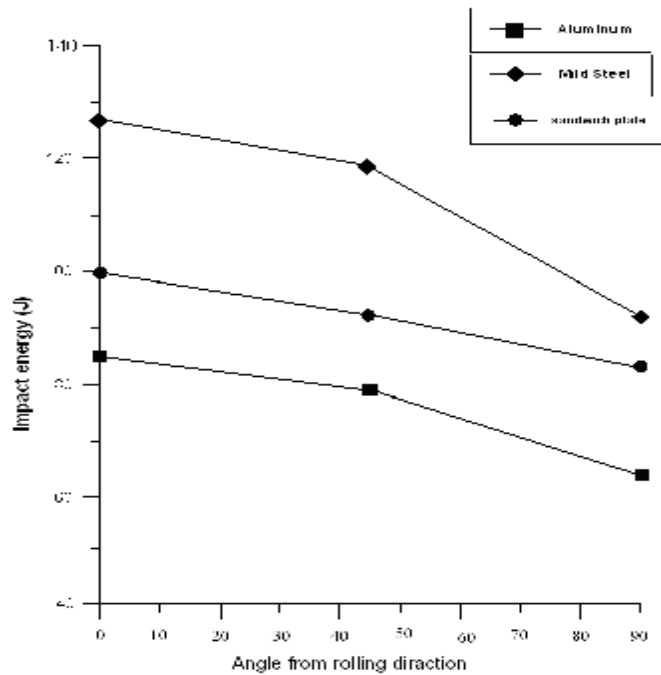


Fig. (15) comparison between Steel , Aluminum and sandwich plates(cutting face).

Figure(16) shows the image of three sandwich specimens(different angles)after izod impact.



Fig. (16) image of sandwich specimens after impact

5 .Conclusions :

1. The highest izod impact energy were shown in (0°)direction and lowest in(90°) direction .
2. The effect of cutting face gave highest izod impact energy.
3. The effect of thickness at increase thickness gave highest izod impact energy.
4. The effect of temperature gave highest izod impact energy and no change in angles with rolling direction.

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