An Experimental Investigation on the Mechanical Behavior of CP Titanium Grade 2 in Charpy Impact Testing

L.S Koveile, Rahul Davis

Abstract- Titanium is generally known for its high strength and light weight. Due to this fact, Charpy Impact tests are conducted to determine its impact toughness. Charpy Impact Test is a basic high-strain rate test which are used to find the amount of energy absorbed by a material during fracture, the energy absorbed by the material acts as a tool to study temperature-dependent ductile-brittle transition. In this present research work, the material specimen for the Charpy Impact testing was surface treated under ASC (Annealing → Stress Reliving → Cryogenic Treatment), CAS (Cryogenic Treatment → Annealing → Stress Reliving) and ACS (Annealing → Cryogenic Treatment → Stress Reliving) parameters.CharpyImpact Testing was done with various input control variables and its effect on CP Titanium Grade-2 was investigated. Minitab 17 software was used to calculate the statistical analysis and obtain combination of the optimum level of parameters of maximum impact.

Keywords: - Notch, Height of Hammer, Surface Treatment, CP Titanium Grade 2

1.INTRODUCTION

Titanium is a radiant transition metal with low density and high strength. It is also resistant to corrosion in sea water, aqua regia and chlorine (Andersson, N.; et al. 2003). Titanium can be alloyed with iron, aluminium, vanadium and molybdenum to produce strong and lightweight alloys for aerospace, military, medical and many other purposes. The most important properties of this metal is the highest strength to weight ratio of any metallic element. Ever since the discovery of metals, Surface Treatments have become a common trend to maximize the properties of the metals. Surface Treatment can be of any types mainly Heat Treatment, Chemical Coating, and Cryogenics etc.

Metals are surface treated to optimize their mechanical and physical properties. It is not necessary that heat treatments make the metals hard, many heat treatments are also used to soften the metal in order allow metal working operations such as deep drawing, cold forging and machining. Heat treatments are done in order to increase wear resistance and strength. There are also some solution heat treatments and ageing processes in order to increase some non-ferrous metals and precipitation hardening steels.

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2.METHODOLOGY

For this research, the experimental work was designed strategically DOE (design of experiment) statistical tool.

Design of experiments (DOE) is a systematic, rigorous approach to engineering problem-solving that applies principles and techniques at the data collection stage so as to ensure the generation of valid, defensible, and supportable engineering conclusionsTaguchi Orthogonal Array (OA) design is a type of general fractional factorial design. It is a highly fractional orthogonal design that is based on a design matrix proposed by Dr. Genichi Taguchi and allows you to consider a selected subset of combinations of multiple factors at multiple levels. Taguchi Orthogonal arrays are balanced to ensure that all levels of all factors are considered equally. For this reason, the factors can be evaluated independently of each other despite the fractionality of the design. In this research work L9 array was selected for Charpy Impact Testing and the following input control variable with different level has been used.

TABLE 1: IMPACT TESTING PARAMETERS AND THEIR LEVELS

FACTORS	NOTCH ANGLE (DEGREE)	HEIGHT OF HAMMER (MM)	SURFACE TREATMENT
LEVEL 1	30°	1370	ANNEALING→ STRESS RELIEVING → CRYO (ASC)
LEVEL 2	45°	1570	CRYO→ANNEALING→STRESS RELIEVING (CAS)
LEVEL 3	60°	1755	ANNEALING→CRYO→STRESS RELIEVING (ACS)

The output parameter measured was the Impact values. For this present work CP Titanium Grade 2 were chosen as test

specimen for Charpy Impact testing. For this research work. The purpose of this study was to determine the influence of heat treatment upon impact properties of CP Titanium Grade 2 and to determine the heat treatment parameter in which brittleness of the specimen was most effective.

TABLE 2: CHEMICAL COMPOSITION OF CP TITANIUM GRADE 2

COMPONENT	C	FE	H	N	O	TI
WT.%	MAX 0.1	MAX 0.3	MAX 0.015	MAX 0.03	MAX 0.25	99.2

TABLE 3: PROPERTIES OF CP TITANIUM GRADE 2

PHYSICAL PROPERTY	METRIC
DENSITY G/CC	4.51
MECHANICAL PROPERTY	
HARDNESS ROCKWELL B	80
TENSILE STRENGTH, ULTIMATE (MPA)	344
TENSILE STRENGTH, YIELD (MPA)	275 - 410
MODULUS OF ELASTICITY (GPA)	105
POISSON'S RATIO	0.37
FATIGUE STRENGTH (MPA)	300
SHEAR MODULUS (GPA)	45
ELECTRICAL PROPERTIES	
ELECTRICAL RESISTIVITY (OHM-CM)	5.2E-005
THERMAL PROPERTIES	
THERMAL CONDUCTIVITY (W/M-K)	16.4
MELTING POINT (°C)	MAX 1665

Dimension of specimen were: 55 X 10 X 10 mm

No. of specimen used were 9 pieces

Fig 1(a): - Heat Treatment Processes for Impact Testing

Fig 1(b):- Heat Treated Specimens

Impact tests were carried out on CP Titanium Grade 2 with varying level of controlled variables. The impact values were recorded and further analyzed.

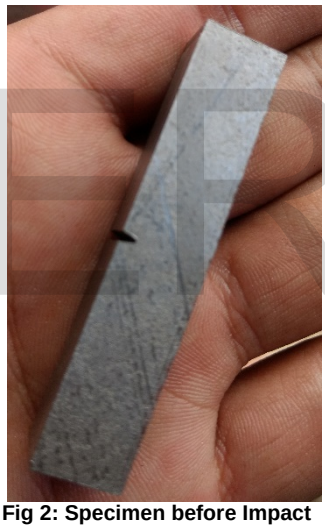

Fig 2: Specimen before Impact

Fig 3: Specimen after Impact

3. RESULTS AND DISCUSSION

All experiments have been performed on Impact Testing Machine of energy range 0-300J manufacture by Fuel instruments and Engineer Private Ltd. The response variable measured was Impact Value in Joule. Typically larger impact values are desirable. Thus the data sequences have the "Larger-The-Better" characteristics, the Larger-The-Better methodology.

TABLE 4 RESULTS OF IMPACT TESTS

S.no	Notch	Height of Hammer (mm)	Surface Treatment	Impact Energy (Joules)
1	30°	1370	ASC	202

2	30°	1570	CAS	242
3	30°	1755	ACS	236
4	45°	1370	CAS	234
5	45°	1570	ACS	201
6	45°	1755	ASC	239
7	60°	1370	ACS	295
8	60°	1570	ASC	288
9	60°	1755	CAS	204

From the tests conducted, it was found that the specimen with 60° notch (with Annealing-Cryogenic Treatment-Stress Relieving Heat Treatment Process) has the maximum impact energy when the height of hammer was at 1370mm. The specimen with 45° notch (with Annealing-Cryogenic Treatment-Stress Relieving Heat Treatment Process) has got the least impact energy at the time when the hammer is at the height of 1570mm.

TABLE 5: RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS (LARGER IS BETTER)

Level	Notch	Height of Hammer (mm)	Surface Treatment
1	47.08	47.63	47.64
2	47.01	47.64	47.62
3	48.26	47.07	47.08
Delta	1.25	0.57	0.56
Rank	**1**	**2**	**3**

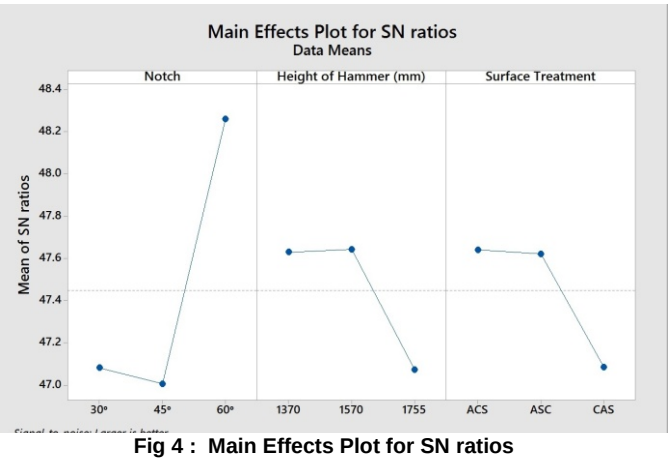

Fig 4 : Main Effects Plot for SN ratios

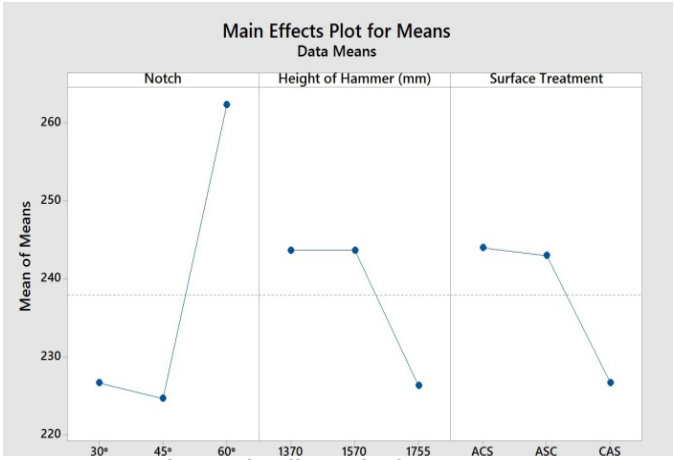

Fig 5: Main Effects plot for means

TABLE 6: ANNOVA FOR IMPACT VALUES

Source	DF	Adj. SS	Adj. MS	F-Value	P-Value
Notch	2	2694.9	1347.4	0.47	0.681
Height of hammer (mm)	2	600.9	300.4	0.10	0.905
Surface Treatment	2	568.2	284.1	0.10	0.910
Error	2	5742.9	2871.4		
Total	8	9606.9			

TABLE 7: OPTIMUM LEVELS OF THE PARAMETERS IMPACT VALUES

Parameters	Notch	Height of Hammer (mm)	Surface Treatment
Levels	3	2	1
Values	600	1570	ASC

4. CONCLUSION

The present research work was performed at Student's workshop, Shepherd School of engineering and technology at Sam Higginbottom Institute of Agriculture Technology and sciences, Allahabad, Uttar Pradesh, India.

Charpy Test was performed on a CP Titanium Grade-2 bar using Impact Testing machine at various levels of parameters and Impact Values was measured as the response data.

Table no. 7, duringCharpy Test through Impact Testing machine, the response to impact for signal–to-noise ratio "larger is better" factors were highly affected by Notch, Height of Hammer and Surface Treatment.

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