iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: V Month of publication: May 2017

DOI:

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Effect of Chemical Composition on Impact Strength of Steel

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Abstract: Steel being a versatile material is exposed to different kinds of environment. Sometimes steel needs to be used at sub-zero temperatures. Steel which is ductile at room temperature may become brittle at sub-zero temperatures. So properties of the steel at sub-zero temperatures must be studied before using the steel. Impact test is generally used to know the properties of the steel at sub-zero temperatures. Chemical composition, finishing temperature, coiling temp etc are some of the important factors which affect the impact of the steel. Use of micro alloys to improve impact toughness is increasing.

I. INTRODUCTION

Plate and hot strip occupy large share of steel products in the world. Applications of flat steels range from ship hulls, petroleum pipes to floor plates. Various end uses of flat processed sheet and strips require a wide range of physical and metallurgical properties in hot rolled product. By varying chemistry and processing conditions, it is possible to produce steels with wide range of microstructures and properties. Typical hot processing of plate and strip consists of reheating of slabs, successive reduction of slab thickness in rolling mill, finishing the rolling at specific temperatures and accelerated water cooling on run-out table. Through these steps an attractive combination and range of tensile and impact properties can be developed. The control that can be exercised at various stages of modern plate and hot strip mill enables achievement of a higher degree of consistency in mechanical properties and microstructure.

II. HOT STRIP MILL

Hot strip mills play a key role in the finishing of continuous cast steel slabs. Slabs from the continuous caster are reheated and sent to a series of rolls that converts them into hot-rolled sheets and coils. Hot-Strip mill elongates the slabs longitudinally between horizontal rolls with a progressively smaller space between them, while vertical rolls regulate the slab's width. After cooling, hot rolled coils and sheets may undergo additional forming and finishing operations within the steel mill (e.g., cold rolling, pickling, heat treating), or may be sold as they are. Hot rolling is one of the most complicated processes in the making and finishing of steel. Hot Rolling: A slab is passed or deformed between a set of work rolls and the temperature of the metal is generally above its recrystallization temperature, as opposed to cold rolling, which takes place at room temperature. Hot rolling is primarily concerned with manipulating material shape and geometry together with desired mechanical properties. This is achieved by heating a component or material to its upper critical temperature and then applying controlled load which forms the material to a desired specification or size. Hot strip mills must: Roll a wide range of width & slab thicknesses Process numerous grades of steel, Simultaneously govern both width and thickness, and Continuously operate for extended periods of time.

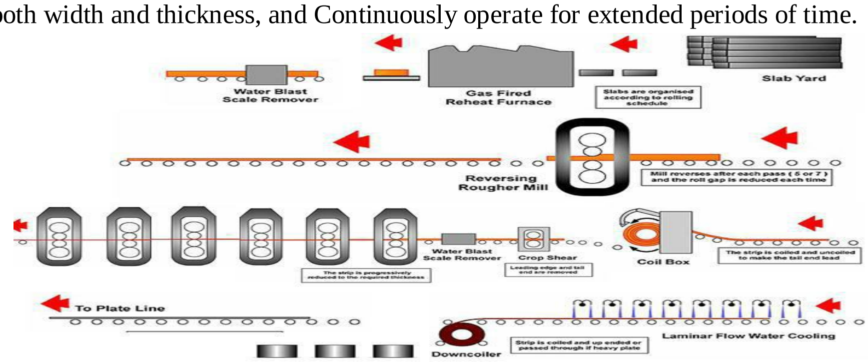

Figure 2.1 Schematic diagram: Hot strip mill layout.

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

III.LITERATURE STUDY

A. Impact Test

In order to know the whether a material withstands sudden intense blow; it is required to measure material's resistance to failure in an impact test. Shock load or sudden load is referred as impact load. The ability to withstand an impact blow is referred as toughness of the material. This test is used to measure the energy required to fracture a standard notched bar by an impulse load. The notched test specimen is struck and fractured by a heavy pendulum after release from a known height, at the lowest point of its swing. From the knowledge of the mass of the pendulum and the difference in the initial and final heights, the energy absorbed in fracture is calculated. Schematic diagram of impact testing machine and impact test sample are **shown in figure 3.1.**

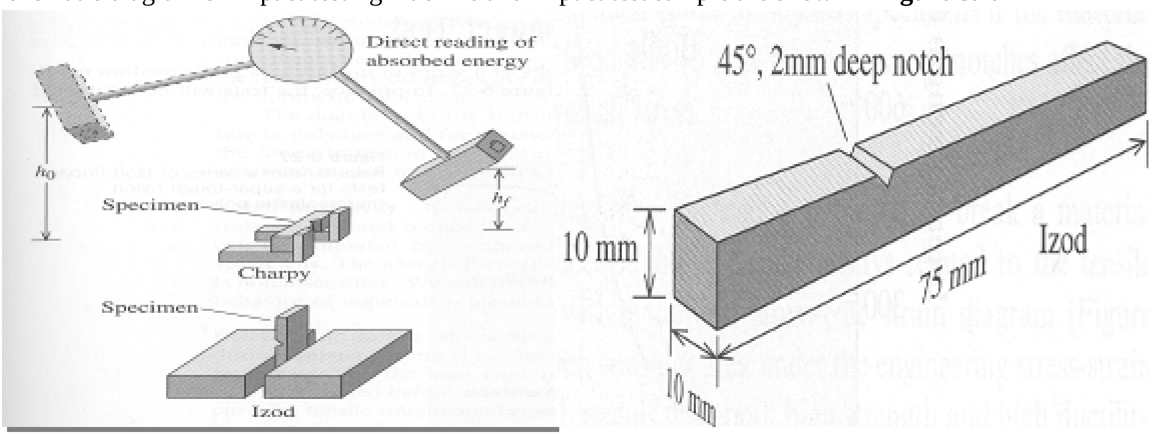

Figure-3.1 Schematic diagram for Impact test machine and impact sample

As temperature decreases a ductile material can become brittle because of ductile-to-brittle transition. Transition temperature is the temp at which a material changes from ductile-to-brittle behaviour. FCC metals remain ductile down to very low temperatures. For ceramics, this type of transition occurs at much higher temperatures than for metals. The ABSORBED ENERGY vs. TEMPERATURE curves for many materials will show a sharp decrease when the temperature is lowered to some point. This point is called the ductile to brittle transition temperature. This ductile to brittle transition temperature is very important if a material is to be used for subzero temperature applications. Schematic diagram of ductile -to-brittle transition curve is given in figure 3.2

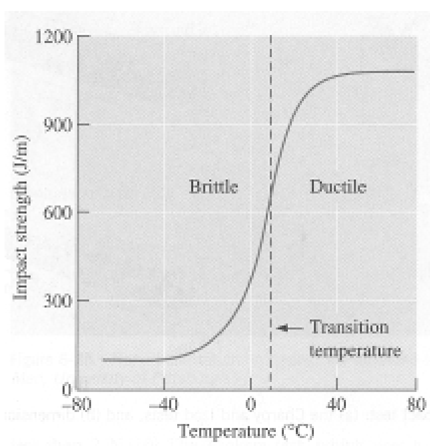

Figure-3.2 Schematic diagram for DBTT curve

B. Types Of Impact Tests

There are two types of impact tests – Charpy impact test and Izod impact test. Izod and Charpy tests differ in terms of the configuration of the notched test specimen. Steel is a versatile material and its applications range from building construction purposes to kitchen utensils. To be suitable for various kinds of applications, its properties need to be modified according to the purpose and end applications. This is achieved by alloying it. Alloyed steel is made by adding small percentages of alloying metals to liquid steel to subsequently alter the hardness, toughness, elasticity or durability. Naturally each of the alloying elements will have

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

a specific effect on the steel when added to it, in certain proportions. Alloying elements usually increase the ductile-to-brittle transition temperature.

1) The different alloying elements in steel are

The effects of the above main alloying elements in steel are

a) Carbon: Carbon is an element whose presence is imperative in all steel. Carbon is the principle hardening element of steel. That is, this alloying element determines the level of hardness or strength that can be attained by quenching. Furthermore, carbon is essential for the formation of cementite (as well as other carbides) and of pearlite, spheridite, bainite, and martensite, with martensite being the hardest of the microstructures. Carbon is also responsible for increase in tensile strength, hardness, resistance to wear and abrasion. However, when present in high quantities it affects the ductility, toughness and the machinability of steel. Effect of carbon on impact properties of plain carbon steel is shown in figure 3.3.

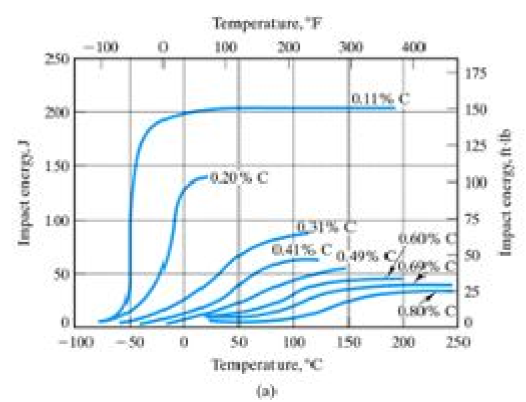

Figure 3.3 variation ductile to brittle transition temperature with carbon, Charpy V-notch impact energy with temperature for plain carbon steel

b) *Manganese*: Manganese also contributes greatly towards increasing strength and hardness, but to a less extent than carbon. To be more precise, the degree to which manganese increases hardness and strength is dependent upon the carbon content of the steel. In fact, manganese contributes to the increasing the strength of the ferrite, and also toward increasing the hardness of penetration of steel in the quench by decreasing the critical quenching speed. Moreover, still consisting of a considerable amount of manganese can be quenched in oil rather than in water, and are therefore less susceptible to cracking because of reduction in the shock of the quenching. This alloying is also considered as a degasifier reacting favorably with sulfur to improve forging ability and surface quality. This is achieved by interacting with the sulphur to give manganese sulphide. Naturally in doing so, the risk of hot shortening is considerably decreased. In addition, manganese enhance the tensile strength, the hardness, the hardenability, the resistance to wear, but is detrimental to both thermal and electrical conductivity.

c) *Vanadium:* The main effect of Vanadium on steel is that it helps controlling the grain growth during heat treatment. It is used in medium carbon steel. When added in relatively large quantities it causes a reduction in the hardenability of the steel. Vanadium is a strong carbide former and these vanadium carbides are very difficult to dissolve in austenite. Vanadium helps in restricting the grain growth, thereby finer grain size in the material. This finer grain sizes will result in increased impact energies.

d) *Molybdenum:* Molybdenum is an alloying element which is seldomly used on its own. In fact, molybdenum is used in combination with other alloying elements. This alloying element increases the hardness penetration of steel and also contributes in slowing down the critical quenching speed. Molybdenum proves to be useful for increasing tensile strength of steel. Furthermore, it prevents temper brittleness and it favors the formation of a fine grain structure. It is good also to mention that molybdenum forms carbides readily and it thus improves the cutting properties in high-speed steels. Hence, it can be said that molybdenum helps much in increasing machinability.

e) *Titanium:* Titanium retards grain growth and thus improves toughness. It fixes Carbon in inert particles. Titanium is also used to achieve improvements in inclusion characteristics. Titanium causes sulphide inclusion to be globular rather than elongated thus improving toughness and ductility in transverse bending

f) *Niobium:* In low carbon alloy steels Niobium lowers the transition temperature and aids in fine grain structures. Nb increases yield strength and to a lesser degree tensile strength. Addition of small amount of Nb significantly increases the yield strength of steel. Nb also has a moderate precipitation strengthening effect. Nb main contribution is to form precipitates above the transformation temperature and to retard the recrystallization of austenite, thus promoting a fine grain microstructure with improved strength and toughness.

g) Effect of grain size: Grain boundaries are the area where atomic arrangement is disturbed. so grain boundary act as barriers for dislocation movement. Finer the grain size higher will be the grain boundary area and there is higher probability for dislocation to be stopped by grain boundary. This result in higher impact energy in finer grain size materials compared to coarse grain size material.

IV. EXPERIMENTAL WORK

Selection of the sample: To know the effect of chemistry on impact properties of steel, grades with varying chemistry were chosen. Different grades which were chosen for doing this project were given below. From these grades HR coils, samples are collected at coil yard and specimens were prepared for impact test and metallography.

GRADE	BASIS OF CHEMISTRY
STRUCTURAL	C-MN (MILD STEEL)
HIGH TENSILE	C-MN + V & TI
TRANSPORT	LOW CARBON + NB AND OR TI
DRAWING	LOW CARBON OR C-MN BASED ON STRENGTH
WELDED TUBE	LOW CARBON OR C-MN BASED ON STRENGTH
WEATHER RESISTANCE	LOW CARBON + CU, CR & NI

A. Sample preparation

1) Impact testA total of (12*27) 324 impact specimens were prepared to the standard size of 5*10*55mm and are tested at different temperatures 20°, 0°, -20° & -40°C. Three specimens were tested at each temperature and average values of the impact : strength were noted for doing analysis. Impact tests were carried out on (ASTM-type) Charpy impact tester with facility to soak specimens up to -80°C, 0.2 - 650 Joules capacity, ZBC2602, MTS system China. For doing impact test at sub zero temperatures, samples were soaked for 15 minutes at that temperature and were transferred to the impact test die within 2-3 seconds.

2) Metallographic work: Samples were also prepared for metallographic observation under the microscope. Small pieces cut were inserted in Bakelite mold powder and were heated to 175°C. After keeping at that temperature for three minutes samples were cooled in air for 10 minutes. Cooled samples were rough polished on 60 grit size emery paper in pedestal grinding machine and 180, 400, 1000 grit size twin disc polisher. After paper polishing, disc polishing was done using diamond paste solution. Samples were polished still they achieved mirror finish. These samples were etched using NITAL solution. After etching for 1 minute sample were water washed and dried. After drying samples were observed under Axiovert 4C microscope, at 500X magnification. Micro structure of the core was photographed for analysis purpose

V. RESULTS AND DISCUSSION

SAMPLES WERE COLLECTED FROM THE SELECTED GRADES COILS IN HSM COIL YARD. CHEMICAL COMPOSITIONS OF THE SAMPLES COLLECTED WERE GIVEN IN TABLE 5A.

Sl no	Coil No	Grade	Heat no	Thickness mm	C%	Mn%	V%	Ti%	Nb%	C Eq%
1	15059997	JVHWRP8A00	B299857	7.2	0.196	0.79	0.002	0.004	0.015	0.328
2	15057107	JVHDRA8BJ0	C299369	6	0.083	0.46	0.001	0.033	0.001	0.165
3	15056745	JVHWT02A00	A299297	7	0.059	0.036	0.001	0.001	0.001	0.119
4	15567601	JVHTR02CES	F643139	20	0.077	1.06	0.001	0.017	0.023	0.254
5	15567621	JVHDR11AJS	B299443	11.6	0.079	1.28	0.042	0.001	0.017	0.292

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6	15566206	JVHHTA1CES	D645767	15	0.185	1.5	0.048	0.025	0.001	0.436
7	15567088	JVHHTA1CES	D645768	15	0.178	1.42	0.049	0.025	0.001	0.415
8	15567103	JVHDR09D0S	F645808	20	0.168	1.15	0.001	0.001	0.001	0.36
9	15563685	JVHWT03D1S	F645115	12	0.163	0.93	0.001	0.001	0.001	0.318
10	15563998	JVHST01D00	D645460	10	0.175	0.89	0.001	0.001	0.001	0.323
11	15563996	JVHST01D00	F645458	10	0.163	0.87	0.001	0.001	0.001	0.308
12	15567796	JVHDR08BES	G645862	12	0.07	0.85	0.001	0.001	0.001	0.212
13	15566734	JVHLNS1AOS	F645408	9.53	0.073	1.05	0.022	0.002	0.011	0.248
14	15566183	JVHHTF1CES	F645488	12	0.166	1.42	0.046	0.046	0.001	0.403
15	15569913	JVHHTA1BES	D644009	6	0.171	1.4	0.043	0.043	0.001	0.405
16	15569952	JVHDR05A00	F643773	6	0.029	0.21	0.001	0.007	0.001	0.064
17	15569927	JVHST01D00	F645950	15	0.079	1.17	0.003	0.013	0.17	0.266
18	15563648	JVHWT03E1S	E645375	14	0.177	1.01	0.001	0.034	0.001	0.345
19	15565203	JVHDR08AES	D645684	6	0.07	0.79	0.001	0.001	0.001	0.204
20	15565150	JVHST01C00	D645662	6	0.142	0.78	0.001	0.001	0.001	0.272
21	15058204	JVDRA8BJ0	C299643	6	0.089	0.45	0.001	0.001	0.001	0.164
22	15056756	JVHWT02A00	B299304	6	0.053	0.39	0.001	0.001	0.001	0.118
23	15567704	JVHDRA9B00	F646100	6	0.173	0.85	0.001	0.001	0.001	0.315
24	15563494	JVHDRA7AES	E644681	6	0.077	0.52	0.001	0.001	0.001	0.164
25	15059019	JVHST15BSS	C299378	6	0.131	0.44	0.001	0.001	0.001	0.204
26	15563946	JVHHTD1AES	A298551	6.4	0.208	1.37	0.001	0.001	0.001	0.436
27	15056851	JVHTR11BSS	A298867	6	0.141	0.87	0.002	0.016	0.001	0.283
28	15057935	JVHDR09CE0	A299508	8	0.161	1.01	0.001	0.001	0.001	0.33
29	15059989	JVHWR07AEF	C297695	7.2	0.145	1.05	0.003	0.016	0.001	0.32
30	15059995	JVHWRP8A00	B299860	7.2	0.198	0.8	0.002	0.002	0.001	0.331
31	15566738	JVHHTK1BOS	E645887	10	0.189	1.36	0.001	0.001	0.001	0.417
32	15056741	JVHDM07B0S	C298721	8.7	0.085	0.86	0.001	0.02	0.001	0.228
33	15059500	JVHDM09A0S	C299477	8.2	0.084	0.96	0.025	0.001	0.001	0.242
34	15057382	JVHTR26AS0	B299421	7	0.25	0.73	0.001	0.002	0.001	0.372
35	15566210	JVHDR08BES	D645850	10	0.072	0.8	0.001	0.001	0.001	0.205
36	15565725	JVHDR09DES	E645251	15	0.155	1.18	0.001	0.002	0.001	0.352
37	15059776	JVHSTA1D20	B298823	10	0.177	0.91	0.001	0.002	0.001	0.329
38	15563690	JVHWT03D1S	E645086	12	0.18	0.89	0.001	0.001	0.001	0.328
39	15567820	JVHTR02CES	F645816	20	0.074	1.03	0.001	0.016	0.027	0.246
40	15567873	JVHDR11AJS	A299438	11.6	0.078	1.22	0.039	0.002	0.016	0.285
41	15566139	JVHHTA1CES	E645768	6	0.165	1.43	0.05	0.03	0.002	0.403
42	15563723	JVHWT03D1S	D645101	12	0.17	0.87	0.001	0.001	0.002	0.327
43	15565169	JVHDR09BES	D645513	10	0.144	0.87	0.001	0.001	0.001	0.286
44	15570358	JVHTR26BS0	E644445	7.15	0.2718	0.71	0.001	0.002	0.001	0.39

Out of the 44 samples collected 27 were chosen for doing impact test in such a way that samples vary in chemical composition and have similar Finishing temperature and coiling temperatures. From each chosen sample 12 impact specimens were prepared in standard sizes by milling top and bottom surfaces. Samples were tested by Charpy impact test method. Average values of each sample at 4 different temperatures were shown in below table 5B.

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Sl no	Coil no	Grade	Heat no	Rolled Thk mm	Avg20°C	Avg 0°C	Avg-20°C	Avg-40°C
1	15565203	JVDR08AES	D645684	6	127	131	120	108
2	15565150	JVHST01C00	D645662	6	85	72	70	65
3	15058204	JVDRA8BJ0	C299643	6	131	122	118	110
4	15056756	JVHWT02A00	B299304	6	125	124	124	107
5	15567704	JVHDRA9B00	F646100	6	90	90	89	86.5
6	15563494	JVHDRA7AES	E644681	6	130	124	120	110
7	15059019	JVHST15BSS	C299378	6	92	85	81.5	70
8	15563946	JVHHTD1AES	A298551	6.4	63.5	57	58	51
9	15056851	JVHTR11BSS	A298867	6	99	103.5	90	90.5
11	15059989	JVHWR07AEF	C297695	7.2	118	121	118	107
12	15059995	JVHWRP8A00	B299860	7.2	59.5	61.5	49	41.5
13	15566738	JVHHTK1BOS	E645887	10	84	79	65.5	60
14	15056741	JVHDM07B0S	C298721	8.7	148	150	147	141.5
15	15059500	JVHDM09A0S	C299477	8.2	122	120	114	100
16	15057382	JVHTR26AS0	B299421	7	69	70.5	67	57.5
17	15566210	JVHDR08BES	D645850	10	140	139	136.5	130
18	15565725	JVHDR09DES	E645251	15	115	106	84	63
19	15059776	JVHSTA1D20	B298823	10	81.5	95.5	75	65.5
20	15563690	JVHWT03D1S	E645086	12	72.5	70	69	35
21	15567820	JVHTR02CES	F645816	20	129	110	106	83
22	15567873	JVHDR11AJS	A299438	11.6	145	142	132.5	124.5
23	15566139	JVHHTA1CES	E645768	6	133.5	110	94	87.5
24	15563723	JVHWT03D1S	D645101	12	77.5	76	62	42
25	15565169	JVHDR09BES	D645513	10	83	70	66	63
26	15570358	JVHTR26BS0	E644445	7.15	78	82.5	48.5	27
27	15566734	JVHLNS100	F645408	9.53	143	140	128	125

Samples were also prepared for metallographic observations. Samples prepared were observed under the microscope to know the average grain size, Ferrite and pearlite percentages

B. Effect of Manganese

To know the effect of Manganese, samples with similar carbon and different Manganese percentages without micro alloying elements were chosen. Impact samples are grouped into three categories based on the carbon as given below.

Carbon is mainly divided into 3 groups

Group A, Carbon percentage from 0.07 to 0.085%

Group B, Carbon percentage from 0.13 to 0.145%

Group C, Carbon percentage from 0.16 to 0.19%

All the samples were tested at different temperatures mainly 20°C, 0°C, -20°C and -40°C. Samples were also prepared for metallographic observations under microscope. Results of them are shown below.

Group A - Carbon kept constant and Manganese varied from 0.52 – 0.95%

Sl no	Coil NO	Grade	%C	%Mn	Avg 20°c	Avg 0°c	Avg-20°c	Avg-40°c	Grain size	% Ferrite	% Pearlite
1	15563494	JVHDRA7AES	0.077	0.52	130	124	120	110	10.5	91	9
2	15565203	JVDR08AES	0.07	0.79	127	131	120	108	11	90	10
3	15059500	JVHDM09A0S	0.084	0.95	122	120	114	100	10.9	87	13

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Table 5.1: Group A - Impact energy avg value at different temp

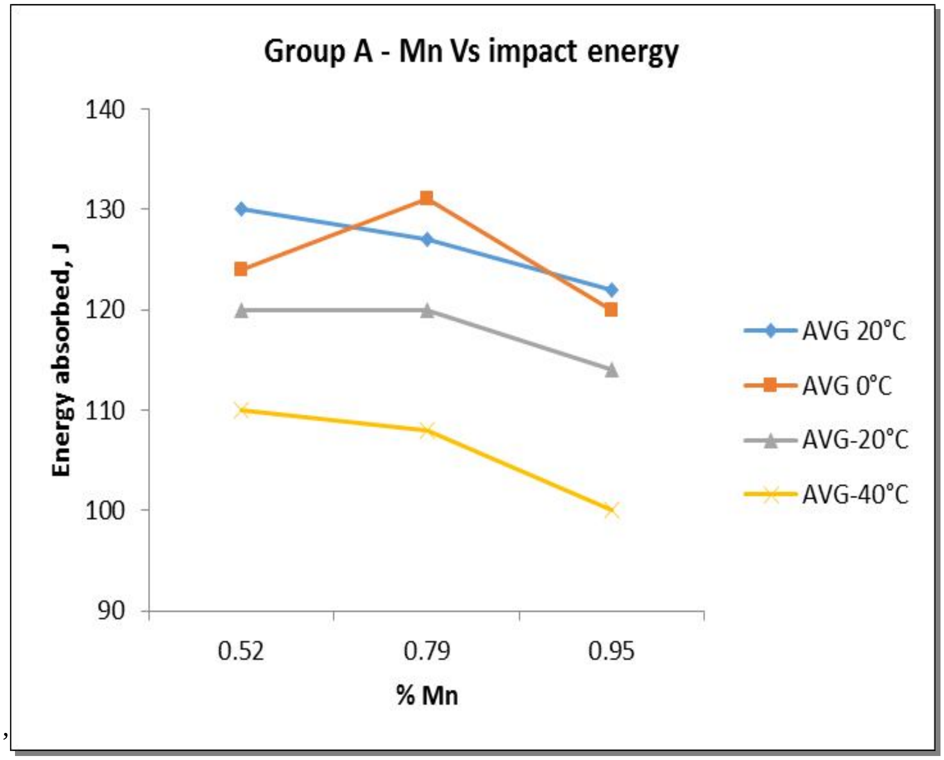
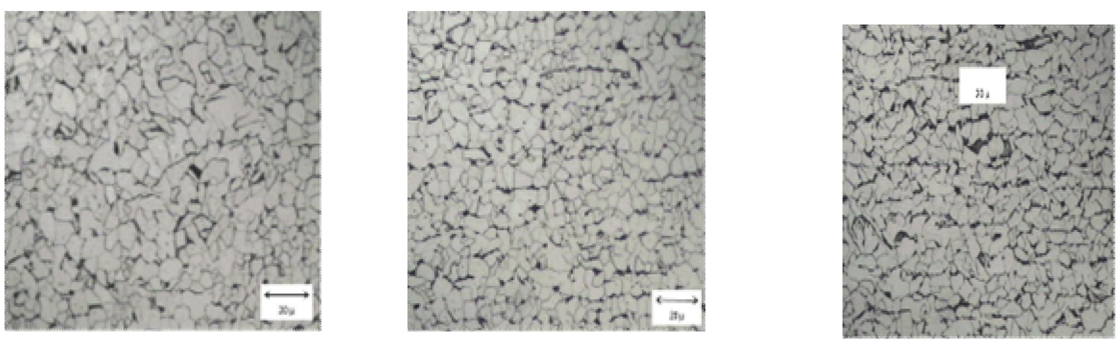


Figure 5.1: Group A (Carbon, 0.07-0.85%) Manganese Vs Impact energy.



(a) 0.5% Mn, 15563494 (500X), (b) 0.79% Mn, 15565203 (500X) (c) 0.95% Mn, 15059500 (500X)

Figure 5.1M: Group A (carbon 0.07-0.85%) microstructures (a) 0.5% Mn, (b) 0.79% Mn, (c) 0.95% Mn

In group A (Carbon kept const ant 0.07-0.85%), Mn varied from 0.54-0.95%. Increasing Mn from 0.54 to 0.95% increased perlite percentage approximately by 4%. Effect of Manganese on grain size is not observed. As Manganese increases, Impact energy decreased approximately by 10 Mpa irrespective of impact test temperature.

Group B - Carbon kept constant and Manganese varied from 0.44 - 0.87%

Sl no	Coil No	Grade	%C	%Mn	Avg 20°c	Avg 0°c	Avg-20°c	Avg-40°c	Grain size	% ferrite	% pearlite
1	15059019	JVHST15BSS	0.131	0.44	92	85	81.5	70	10.75	84	16
2	15565150	JVHST01C00	0.142	0.78	85	72	70	65	10.6	83	17
3	15565169	JVHDR09BES	0.144	0.87	83	70	66	63	10.1	78	22

Table 5.2: Group B - Impact energy avg value at different temp

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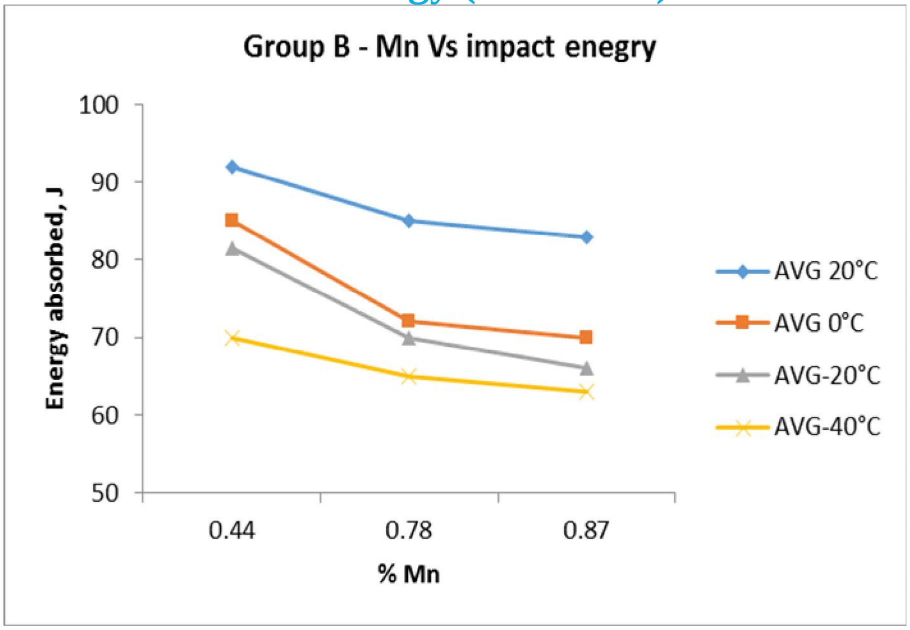
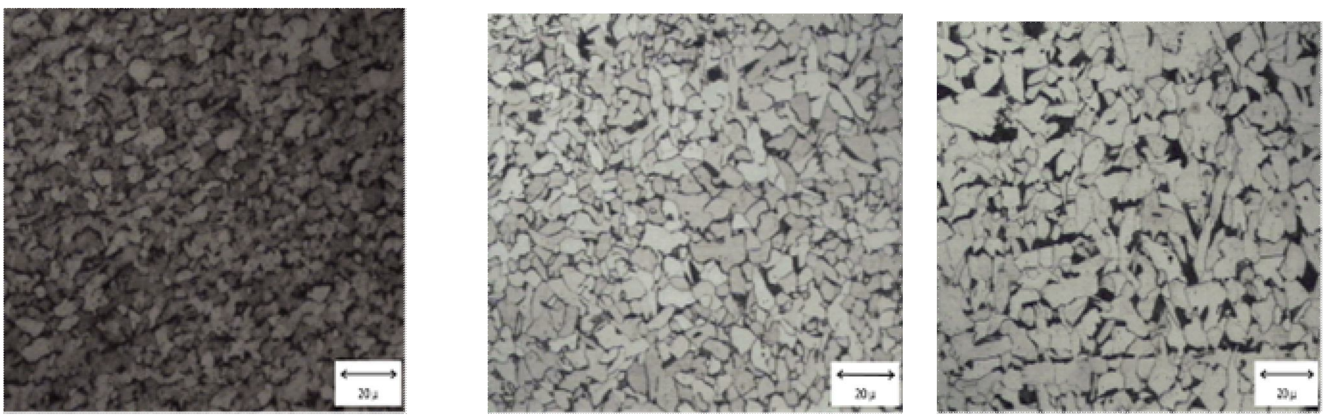


Figure 5.2: Group B (Carbon, 0.130-0.145%) Mn Vs Impact energy



(a) 0.44% Mn, 15059019 (500X) (b) 0.78%Mn, 15565150 (500X) (c)0.89% Mn, 15565169(500X)

Figure 5.2M: Group B (carbon 0.130-0.145%) microstructures (a) 0.44%Mn, (b) 0.78%Mn, (c) 0.89%Mn

In group B (Carbon kept const ant 0.13-0.145%), Mn varied from 0.44-0.89%. Increasing Mn from 0.44 to 0.89% increased perlite percentage approximately by 6%. Effect of Manganese on grain size is not observed. As Manganese increases, Impact energy decreased approximately by 10-15 Mpa irrespective of impact test temperature.

Group C - Carbon kpt constant and Manganese varied from 0.85 – 1.36%

Sl No	Coil NO	Grade	%C	%Mn	Avg 20°c	Avg 0°c	Avg-20°c	Avg-40°c	Grain size	% ferrite	% pearlite
1	15567704	JVHDRA9B00	0.173	0.85	90	90	89	86.5	11	78	22
2	15057935	JVHDR09CE0	0.161	1.01	97	85	82	80	11.1	79	21
3	15566738	JVHHTK1BOS	0.189	1.36	84	79	65.5	60	10.7	72	28

Table 5.3: Group C - Impact energy avg value at different temp

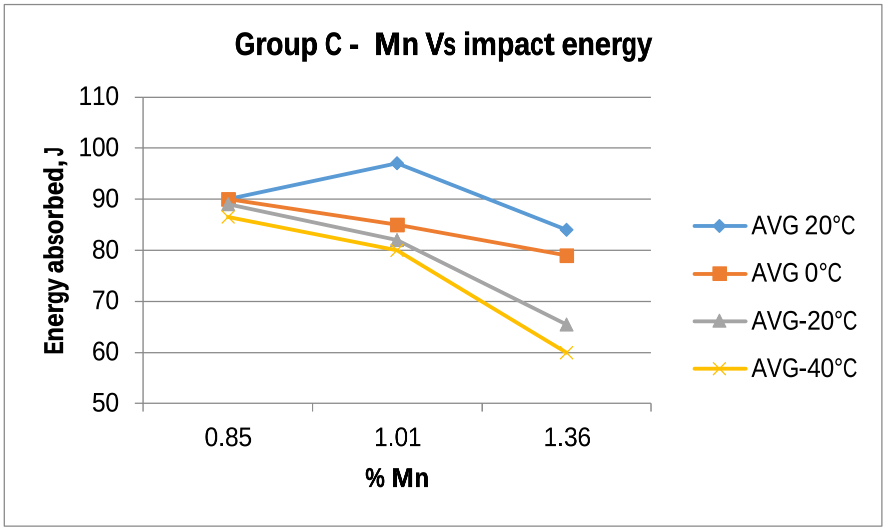
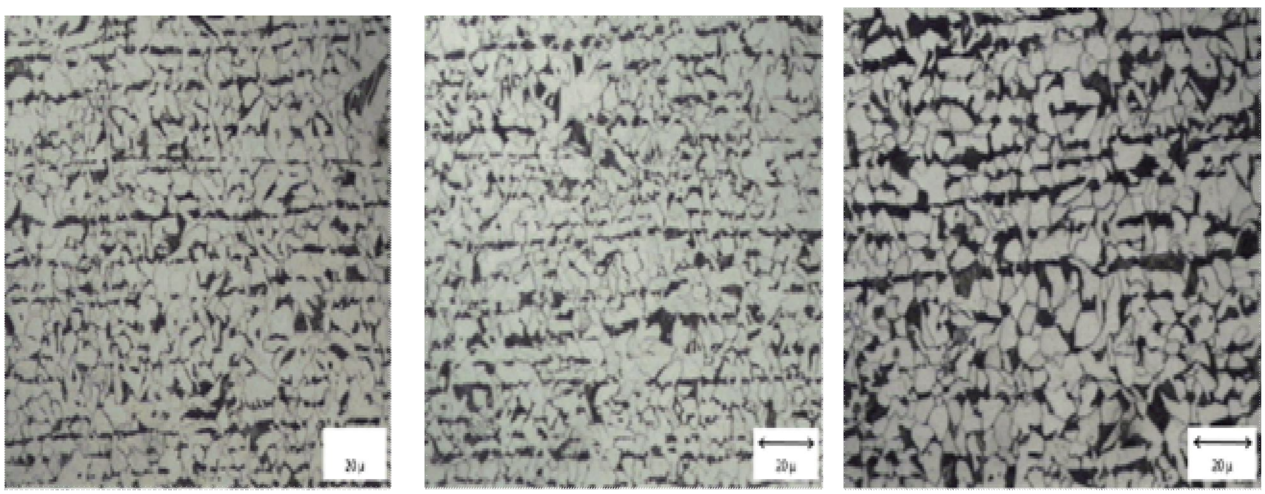


Figure 5.3: Group C (Carbon, 0.160-0.190%) Mn Vs Impact energy



(a)0.85% Mn, 15567704 (500X) (b) 1.01%Mn, 15057935 (500X) (c) 1.36%Mn, 15566738(500X)

Figure 5.3M: group C (carbon 0.130-0.190%) combination grade with (a) 0.85%Mn, (b) 1.01%Mn, (c) 1.36%Mn

In group C (Carbon kept const ant 0.16-0.19%), Mn varied from 0.85-1.36%. Increasing Mn from 0.85 to 1.36% increased perlite percentage approximately by 6%. Effect of Manganese on grain size is not observed. As Manganese increases, Impact energy decreased approximately by 20-30 Mpa irrespective of impact test temperature.

C. Effect of Carbon

To know the effect of Carbon, samples with similar Manganese and different Carbon percentage without micro alloying elements were chosen. Impact samples are grouped into three categories based on the Manganese as given below.

D. Manganese is mainly divided in to 3 groups

Group D, Mn percentage from 0.40 to 0.55%
Group E, Mn percentage from 0.75 to 0.90%
Group F, Mn percentage from 0.130 to 0.140%

All the samples were tested at different temperature mainly 20°C, 0°C, -20°C and -40°C. Samples were also prepared for metallographic observations under microscope. Results of them are shown below

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Group D - Manganese kept constant and Carbon varied from 0.077- 0.131%

Sl no	Coil No	Grade	%C	%Mn	Avg 20°c	Avg 0°c	Avg-20°c	Avg-40°c	Grain size	% Ferrite	% Pearlite
1	15563494	JVHDRA7AES	0.077	0.52	130	124	120	110	10.5	91	9
2	15058204	JVDHRA8BJ0	0.089	0.45	131	122	118	110	11	89	11
3	15059019	JVHST15BSS	0.131	0.44	92	85	81.5	70	10.7	84	16

Table 5.4: Table for Impact energy avg valve at different temp

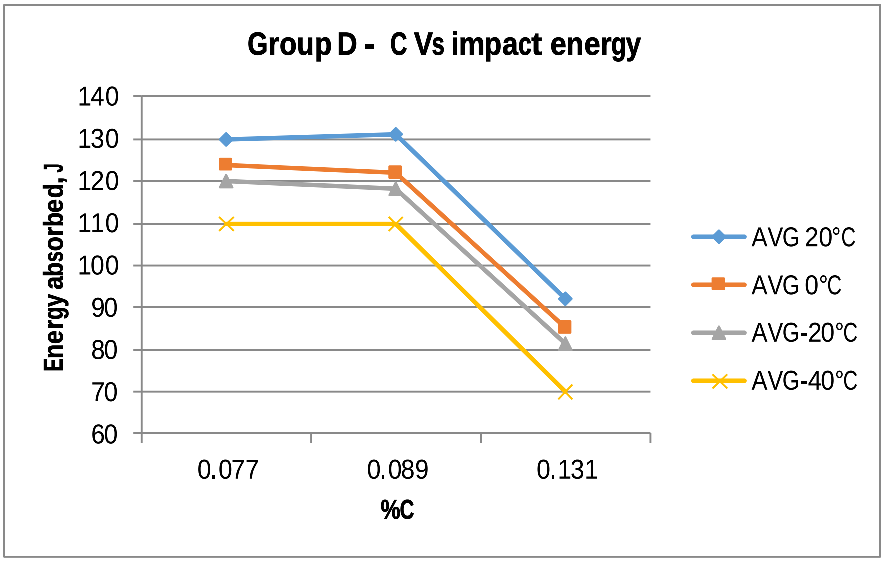
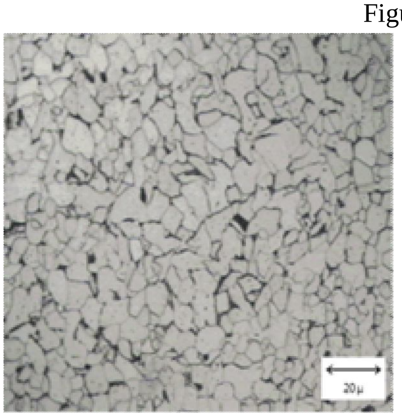
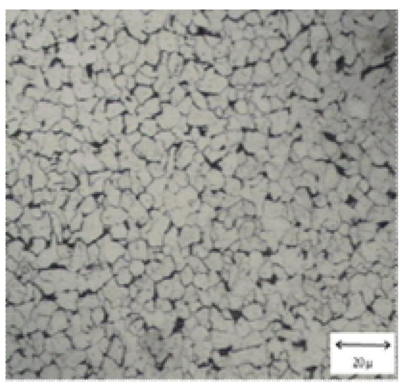


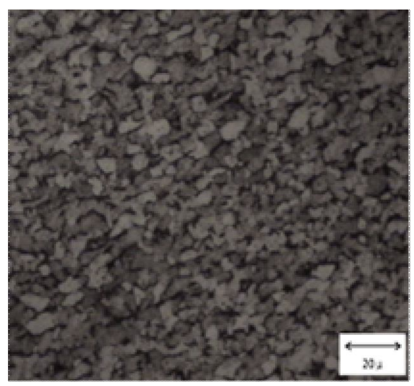
Figure5.4: Group D (Mn,0.40-0.55%) Carbon Vs Impact energy



(a) 15563494(500X)



(b) 15058204(500X)



(c) 15059019(500X)

Figure 5.4M: Mn at group A (Mn 0.40-0.55%) combination grade with (a) 0.077%C, (b) 0.089%C, (c) 0.131%C

In group D (Manganese kept constant 0.40-0.45%), Carbon varied from 0.077-0.131%. Increasing carbon from 0.77 to 1.31% increased pearlite percentage approximately by 7%. Effect of carbon on grain size is not observed. As carbon increases, Impact energy decreased approximately by 40 Mpa irrespective of impact test temperature.

Group E - Manganese kept constant and Carbon varied from 0.07 - 0.18%

Sl no	Coil NO	Grade	%C	%Mn	AVG 20°C	AVG 0°C	AVG-20°C	AVG-40°C	GRAIN SIZE	% Ferrite	% Pearlite
1	15565203	JVHDR08AES	0.07	0.79	127	131	120	108	11	91	9
3	15565150	JVHST01C00	0.142	0.78	85	72	70	65	10.6	83	17
5	15563690	JVHWT03D1S	0.18	0.89	84	79	65.5	60	10.1	74	26

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Table- 5.5 schematic table for Impact energy avg valve at different temp

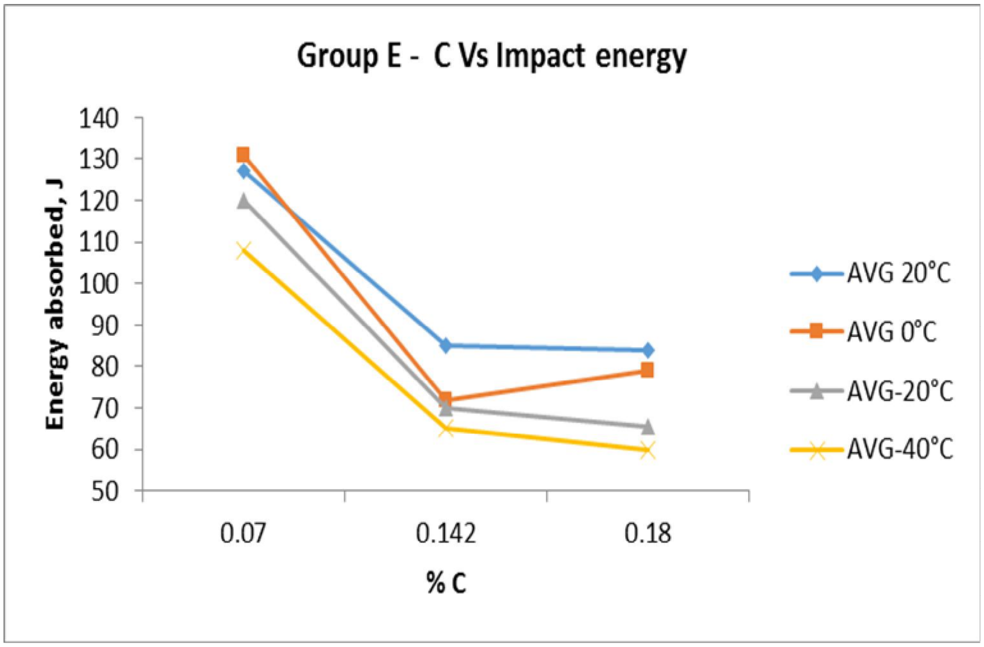
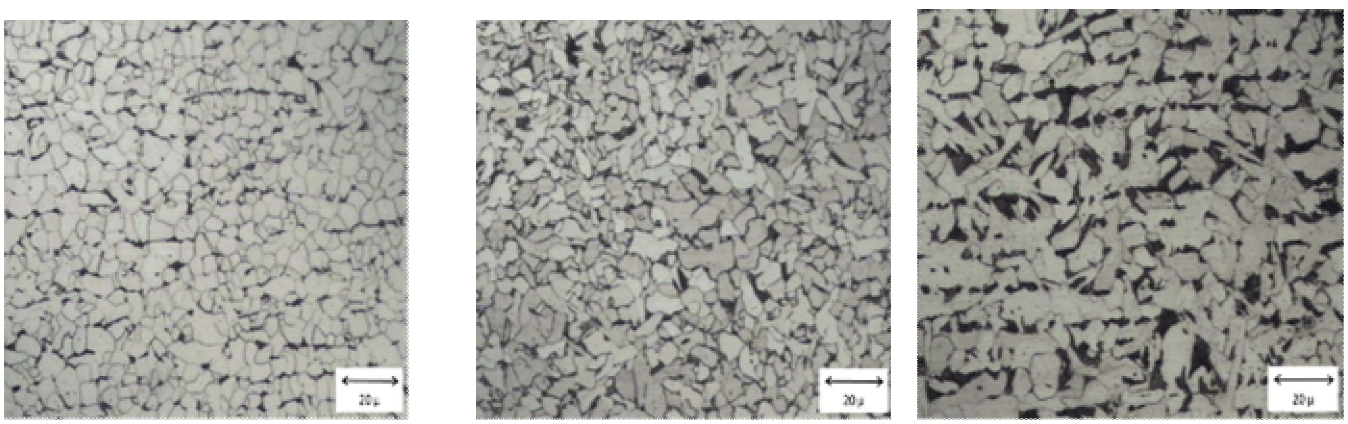


Figure-5.5 Group E (Mn,0.75-0.90%) Carbon Vs Impact energy



(a)15565203(500X) (b)15565150(500X) (c)15563690(500X)

Figure 5.5M: Mn at group A (Mn 0.75-0.90%) combination grade with (a) 0.07%C, (b) 0.142%C, (c) 0.18%C

In group E (Manganese kept constant 0.75-0.90%), Carbon varied from 0.07-0.18%. Increasing carbon from 0.07 to 0.18% increased pearlite percentage approximately by 17%. Effect of carbon on grain size is not observed. As carbon increases, Impact energy decreased approximately by 40 Mpa irrespective of impact test temperature.

Group F - Manganese kept constant and Carbon varied from 0.189 – 0.208%

Sl no	COIL NO	Grade	%C	%Mn	AVG 20°C	AVG 0°C	AVG-20°C	AVG-40°C	GRAIN SIZE	% Ferrite	% Pearlite
1	15566738	JVHHTK1BOS	0.189	1.36	84	79	65.5	60	10.7	77	23
2	15563946	JVHHTD1AES	0.208	1.37	63.5	57	58	51	10.4	72	28

Table- 5.6 schematic table for Impact energy avg valve at different temp

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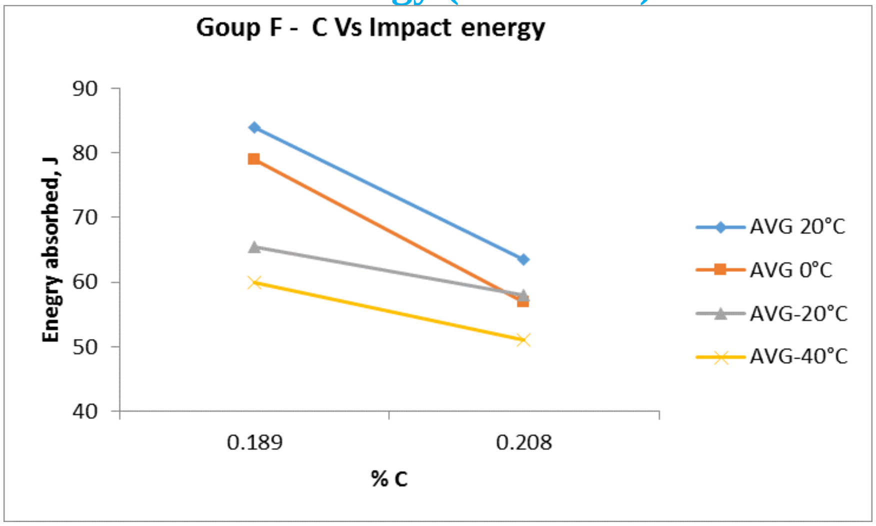
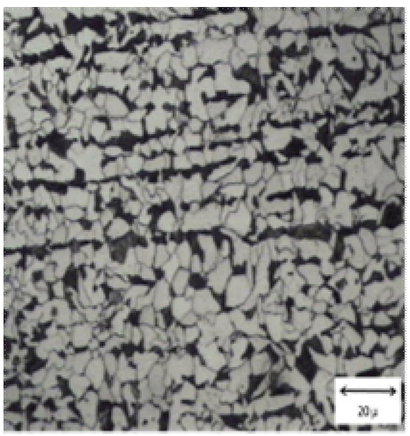
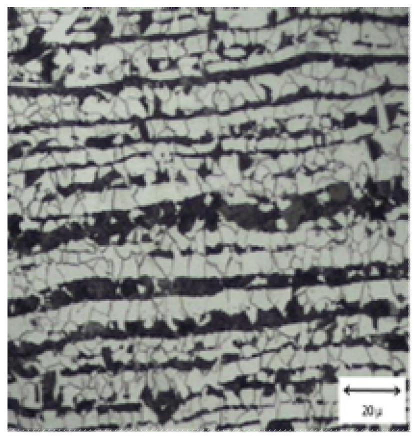


Figure 5.6: schematic diagram for Carbon Vs Impact energy



(a) 15566738(500X)



(b) 15563946(500X)

Figure 5.6M: Mn at group A (Mn 1.30-1.40%) combination grade with (a) 0.189%C, (b) 0.208%C

In group F (Manganese kept constant 1.30-1.40%), Carbon varied from 0.189-0.208%. Increasing carbon from 0.189 to 0.208% increased pearlite percentage approximately by 5%. Effect of carbon on grain size is not observed. As carbon increases, Impact energy decreased approximately by 15 Mpa irrespective of impact test temperature.

E. Effect of Vanadium

To know the affect of Vanadium, samples with similar Carbon Manganese and different vanadium percentages were chosen. Impact test results and microstructure photographs were given below.

Group G - C and Mn kept constant Vanadium varied from 0.001 -0.022%

Sl no	COIL NO	Grade	%C	%Mn	%V	AVG 20°C	AVG 0°C	AVG-20°C	AVG-40°C	GRAIN SIZE	% FERRITE	% PEARLITE
1	15565203	JVHDR08AES	0.07	0.79	0.001	127	131	120	108	11	91	9
2	15566734	JVHLNS1A00	0.073	1.05	0.022	143	140	128	125	11.5	88	12

Table- 5.7 schematic table for Impact energy avg valve at different temp

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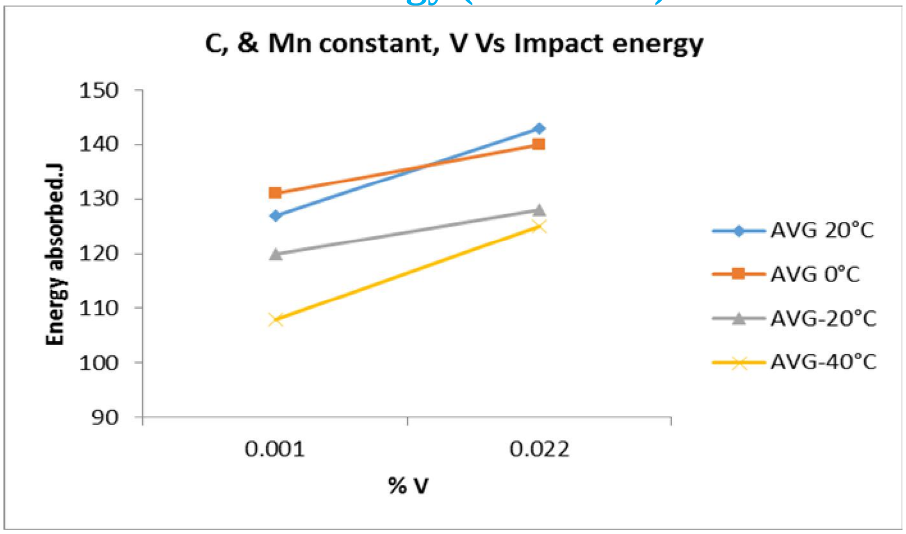
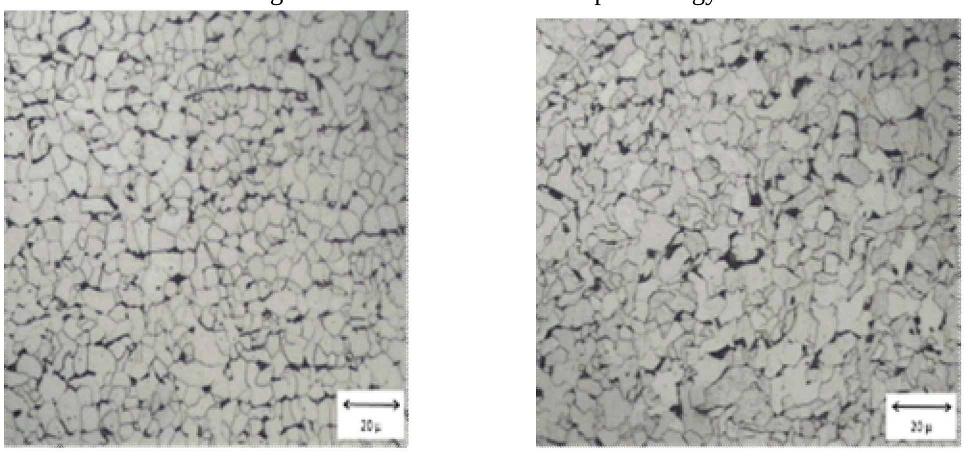


Figure-5.7 for Vanadium Vs Impact energy



(a) 515565203(500X) (b) 15566734(500X)

Figure 5.7M: (C-0.07% & Mn ,0.75-1.05%) combination grade with (a) 0.001%V, (b) 0.022%V.

To know the effect of Vanadium on impact properties of steel C, Mn are kept constant and Vanadium varied from 0.001-0.022%. Increasing Vanadium from 0.001 to 0.022% increased ASTM grain size number from 11 to 11.5; i.e resulted in fine grain structure. Even though Pearlite% increased by 3% it can be thought as the result of increased Mn in the second steel. As Vanadium increases, Impact energy increased approximately by 15 Mpa irrespective of impact test temperature.

F. Effect of Titanium:

To know the effect of Titanium, samples with similar Carbon Manganese and different Titanium percentages were chosen. Impact test results and microstructure photographs were given below.

Group H - C and Mn kept constant and Titanium varied from 0.001 -0.02%

Sl no	COIL NO	Grade	%C	%Mn	%Ti	AVG 20°C	AVG 0°C	AVG-20°C	AVG-40°C	GRAIN SIZE	% FERRITE	% PEARLITE
1	15566210	JVHDR08BES	0.072	0.8	0.001	140	139	136.5	130	10.5	91	9
2	15056741	JVHDM07B0S	0.085	0.86	0.02	148	150	147	141.5	11.5	89	13

Table- 5.8 schematic table for Impact energy avg valve at different temp

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ISSN: 2321-9653
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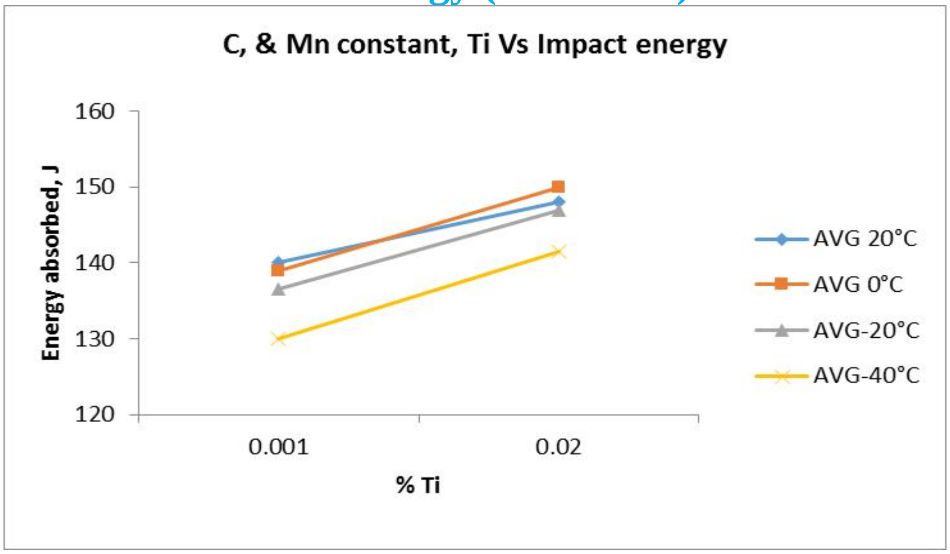
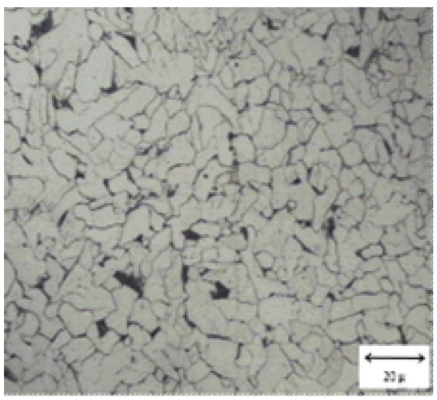
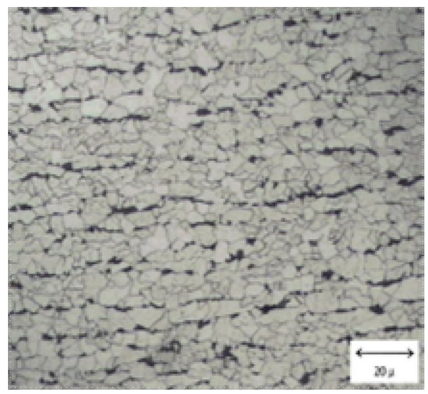


Figure-5.15C & Mn constant Titanium Vs Impact energy



(a) 15566210(500X)



(b) 15056741(500X)

At Fig 5.16 (C,0.070-0.085% & Mn ,0.80-.90%) combination grade with (a) 0.001%Ti, (b) 0.02%Ti.

To know the effect of Titanium on impact properties of steel C, Mn are kept constant and Titanium varied from 0.001-0.02%. Increasing Titanium from 0.001 to 0.02% increased ASTM grain size number from 10.5 to 11.5; i.e resulted in fine grain structure. Even though Pearlite% increased by 4% it can be thought as the result of increased C and Mn in the second steel. As Titanium increases, Impact energy increased approximately by 10 Mpa irrespective of impact test temperature.

F. Effect of Vanadium & Titanium together:

To know the effect of Vanadium and Titanium combination, samples with similar Carbon Manganese and different V+Ti percentages were chosen. Impact test results and microstructure photographs were given below.

Group I - C and Mn kept constant and V+Ti varied from 0.001+0.002 % and 0.05+0.03 %

Sl no	COIL NO	Grade	%C	%Mn	V+Ti	AVG 20°C	AVG 0°C	AVG-20°C	AVG-40°C	GRAIN SIZE	% FERRITE	% PEARLITE
1	15057935	JVHDR09CES	0.161	1.01	0.001+.002	97	85	82	80	11.1	79	21
2	15566139	JVHHTA1CES	0.165	1.43	0.05+0.03	125	110	98	92	11.6	78	27

Table- 5.9 schematic table for Impact energy avg valve at different temp

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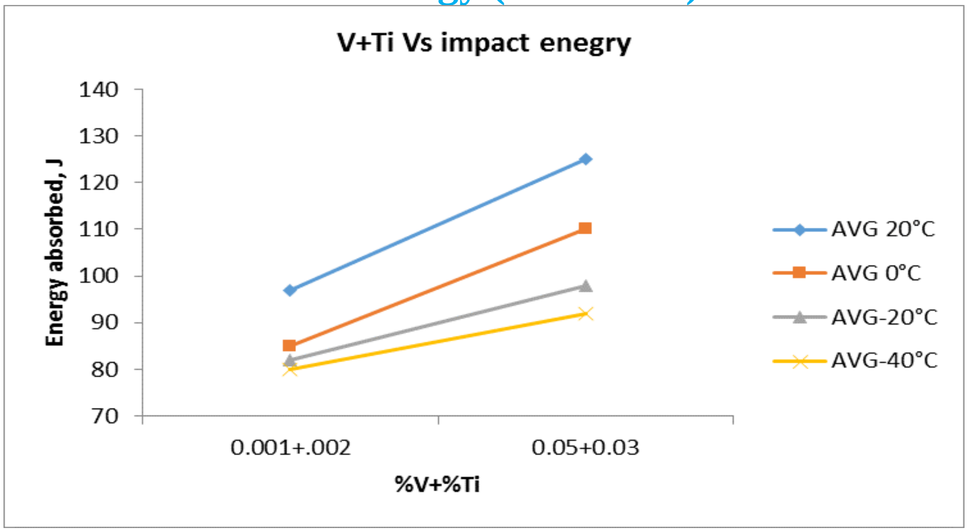
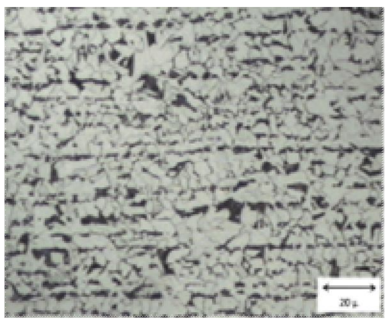
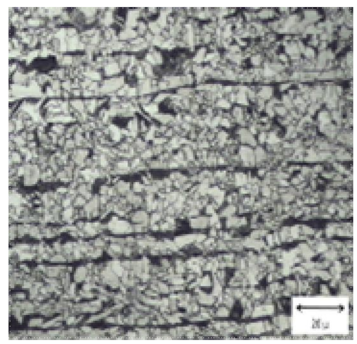


Figure-5.17C, and Mn constant, % of Vanadium and Titanium Vs Impact energy



(a)15057935(500X)



(b) 15566139(500X)

Fig-5.18(As Carbon,0.161- 0.165% & Mn1.01-1.43%) combination grade with(a)0.001%Vanadium and0.002% and (b) 0.05%V, 0.03%Ti

To know the effect of V+Ti combination on impact properties of steel, V+Ti varied from 0.001+0.002 % and 0.05+0.03 %. Increasing V+Ti, increased ASTM grain size number from 10.5 to 11.6; i.e resulted in fine grain structure. Even though Pearlite% increased by 6% it can be thought as the result of increased C and Mn in the second steel. As V+Ti increases, Impact energy increased approximately by 15 Mpa irrespective of impact test temperature

G. Effect of Vanadium & Niobium together

To know the effect of vanadium and Niobium combination, samples with similar Carbon Manganese and different V+Nb percentages were chosen. Impact test results and microstructure photographs were given below.

Group J - C and Mn kept constant and V+Nb varied from 0.001+ 0.001% and 0.039 + 0.016%

Sl no	COIL NO	Grade	%C	%Mn	V+Nb	AVG 20°C	AVG 0°C	AVG-20°C	AVG-40°C	GRAIN SIZE	% FERRITE	% PEARLITE
1	15565203	JVDHR08AES	0.07	0.85	0.001+0.001	127	131	120	108	11	91	9
1	15567873	JVHDR11AJS	0.078	1.22	0.039+0.016	145	142	132.5	124.5	11.7	88	12

Table- 5.11 schematic table for Impact energy avg valve at different temp

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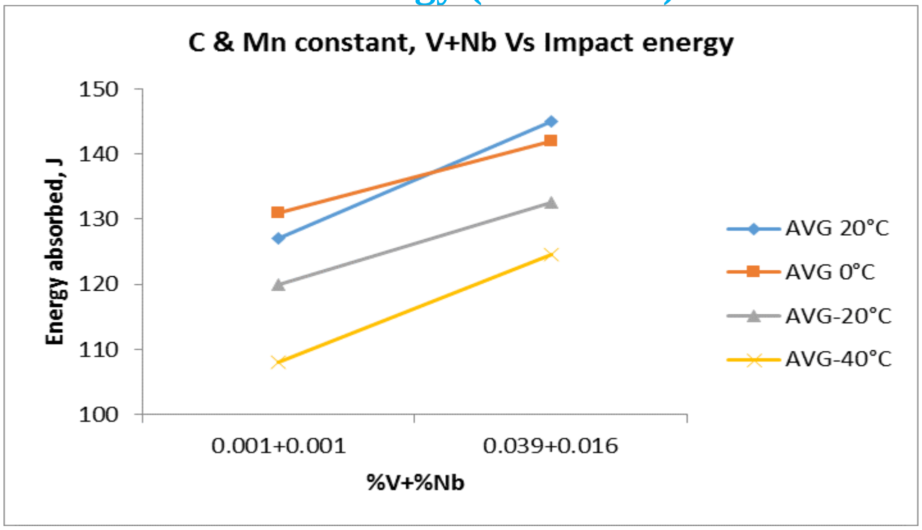
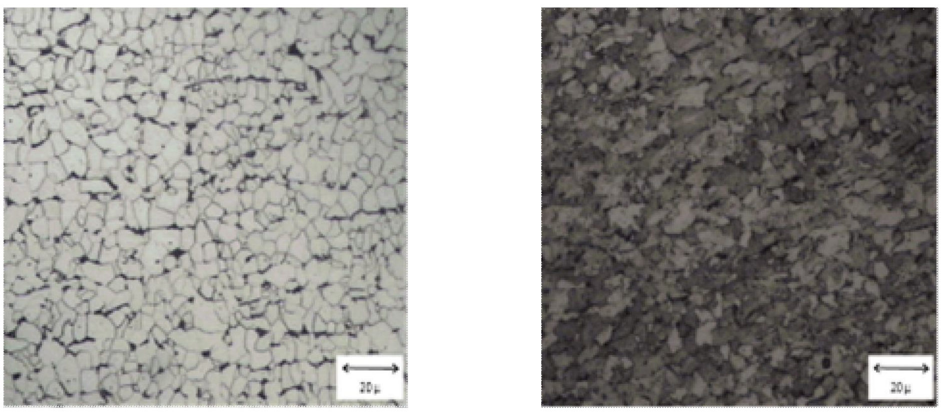


Figure-5.20 % of Vanadium and Niobium Vs Impact energy



(a) 15565203(500X) (b) 15567873(500X)

Fig 5.21 (C,0.070-0.078% & Mn ,0.85-1.25%) combination grade with (a) 0.001%V+0.001%Nb, (b) 0.039%V & 0.016%Nb.

To know the effect of V+Nb combination on impact properties of steel, V+Nb varied from 0.001+0.001% and 0.039+0.016%. Increasing V+Nb, increased ASTM grain size number from 11 to 11.7; i.e resulted in fine grain structure. Even though Pearlite% increased by 3% it can be thought as the result of increased C and Mn in the second steel. As V+Nb increases, Impact energy increased approximately by 20 Mpa irrespective of impact test temperature.

VI. CONCLUSIONS

In this project effect of chemical composition mainly Carbon, Manganese, Vanadium, Niobium and Titanium on Impact properties was found by testing impact specimens at different temperatures (20, 0, -20 and -40 C). As carbon percentage increases impact energy decreases. As Manganese percentage increases impact energy decreases. Increase in Pearlite% with carbon and manganese has resulted decrease in impact energy. Effect of Carbon and Manganese on grain size was not seen When micro alloying elements like V, Nb, and Ti were added in the steel, they resulted in finer grain microstructures. Niobium, Vanadium and Titanium are strong carbide formers. Carbides and nitrides formed in steel have restricted the grain growth and resulted in fine grain structures. Addition of Nb, V and Ti in steel increased the impact energy. V + Nb combination has better impact strength compared to V+Ti and Nb+Ti combinations. Replacing Ti with Nb will result in higher toughness.

VII. ACKNOWLEDGMENT

We express sincere gratitude to all the faculties of Department of Mechanical / I&P engineering for his able guidance, regular source

Volume 5 Issue V, May 2017
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

of encouragement and moral support rendered and facilities provided towards completion of the project work in a systematic manner. We wish to express our sincere thanks to project coordinator Dr. A Thimmana Gouda for his moral support towards completing our project work.

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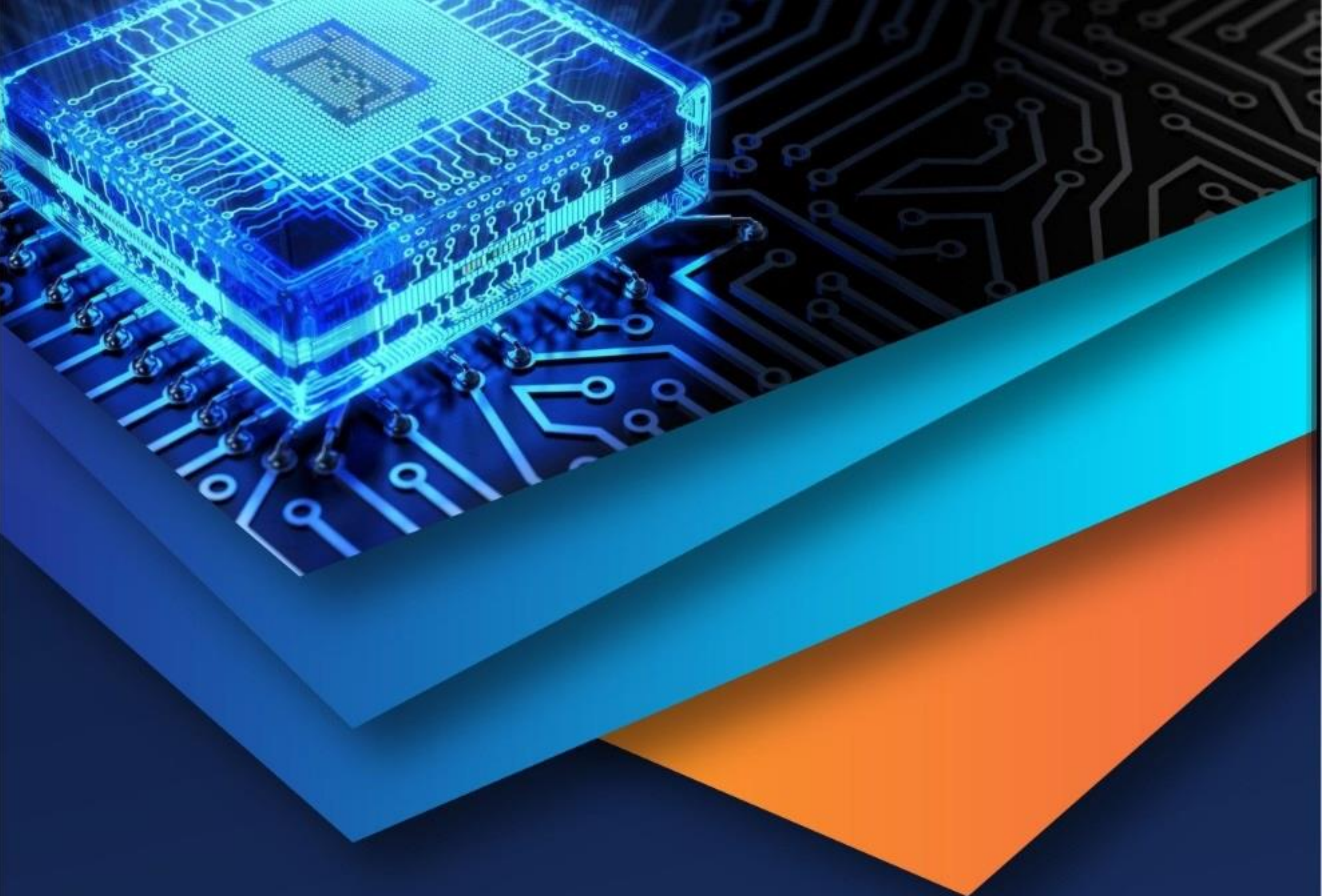

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