International Engineering Journal For Research & Development
Vol.5
Issue 5

E-ISSN NO:-2349-0721

Impact factor : 6.549

PROCESS OPTIMIZATION OF MEDIUM DENSITY FIBERBOARD

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ABSTRACT

The Medium Density Fiberboard (MDF) has been one of the most rapidly growing wood-based composite panel products to enter the world market in recent years.A large number of boards (nearly 10-15 % or about 1 lac Cbm per year) rejected in the market because of deformitiesfor example, powerless internal fiber arrangement, low Bending and elasticity, low internal bonding, sides lose, de-lamination problem and rough surface, among others.The number of paper had reviewed on properties of MDF which is affected by hot press temperature etc. So this paper completely concentrate on Optimization of Medium Density Fiberboard by using multiple response characteristics by Taguchi and Grey Relational Analysis(GRA) method.Manufacturing process parameters such as Moisture contents in fiber mat, Press cycle time of hot press, the temperature of thermo oil in hot press plate and hydraulic pressure applied by hot press plate and the influence of these variables on Internal Bonding (IB) strength of the panel and bending strength were considered for the study. By analyzing Taguchi and Grey relational analysis, the degree of influence for each controllable manufacturing process factor on to individual targets can be found. An optimal condition for the manufacturing of MDF is obtained via GRA. The optimal combination of process parameters for multiple performance optimization has been set at Moisture (8%), Press cycle time(260 sec), hydraulic pressure (165 bar) and temperature (230 ^{o}C)

Keywords: Internal Bonding, Bending, Taguchi Technique ,GRA

INTRODUCTION

MDF is a wood- predicated composite product that is manufactured by commixing different wood fibers with glue/water and then pressed to a high temperature. The main utilization of MDF is in the furniture industry and as well as for the adornment of room, offices, etc., where it is utilized as a supersession for solid wood. The density of MDF mainly depends upon the thickness of the board. And it is generally controlled in the production between 750 Kg/m^3 to 900 Kg/m^3 .Mainly the raw material used for MDF are Firewood from near forests, Ghaz wood (Tamarix aphylla), Poplar wood (Populus caspica), Eucalypts, Bagas, Keekar etc.[1]

The performance index for MDF is divided into three main categories i.e The Physical Performance, Mechanical Performance and the last which is Biological Perfromance. The Physical performance includes the Density of the Panel, the amount of water or the moisture contents in the panel, the amount of swelling the panel occurs. Second and Important performance index is Mechanical, which includes the important properties of panel i.e Internal Bonding of the panel, Modulus of Elasticity, Bending strength, Modulus of Ruputure etc.[2]

Figure 1 shows the whole manufacturing process associated with different work stations, that is , material preparation at chipping section, fiber formation at refining section, mat formation at forming and Pre-press section, and board/panel formation at hot press section ,board treatment and warehouse.[3] The logs of different

wood from the forest are first debarked in a debarking machine and then converted into the standard size of chips in the chipper section. After that, these chips are traveled through the conveyor into the vibrator screen, where oversized chips are expelled from the chipping. These wood chips are then moved to the preheater by the screw transport. The fundamental capacity of the screw transport is to move the chips to the preheater and furthermore to go about as a fitting to hold steam inside the screw transport and preheater. In the preheater, the temperature is around 100 ^{0}C. These warmed chips at that point went through the purifier, where they are changed over to strands. Paste and water are included in the blow line. These wet strands are first dried to a dampness substance of 13 percent and structure a thick tangle in the tangle's previous territory. These fiber cakes at that point go into the hot press area for a couple of moments relying on the thickness.[4]

The boards after the hot-pressed, cool down, then send it to a sending section where the rough surface is removed from the board and then the board is sent to the sorting section to sort out a different quality of boards and then the board is ready to send it to the market. There are two types of plants, one is called continuous pressing or Menda line plant and the other is called multi-opening press/single opening plant.

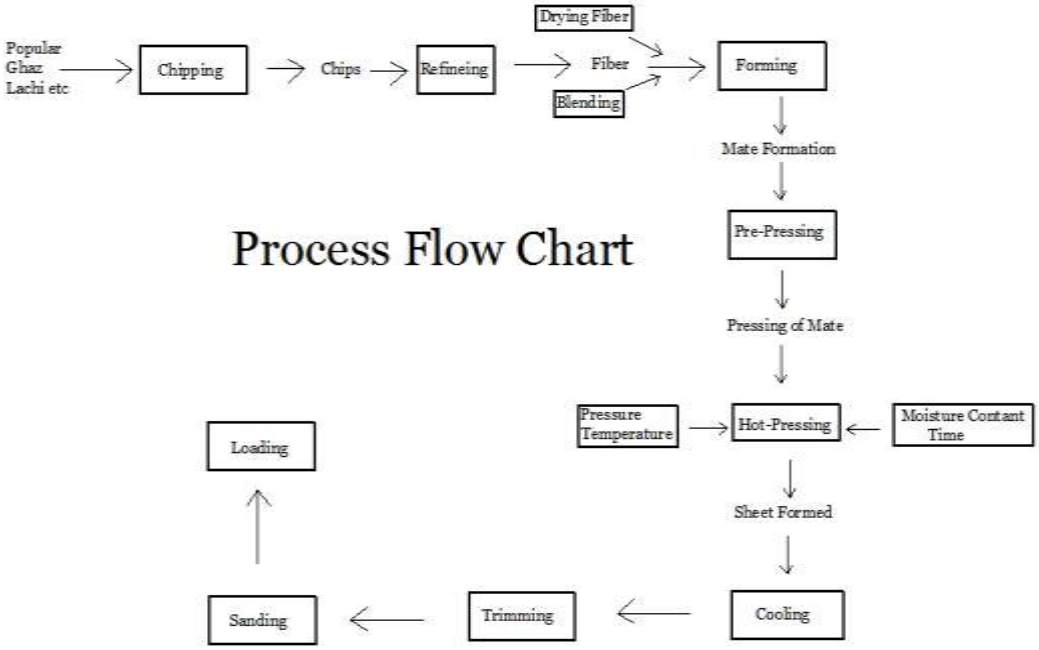

FIGURE 1; MDF Process Flow Chart

Increasing in demand for MDF in furnature industry and extensie use of these boards in building materials are factors driving the MDF market. For this pupose optimization of manufacturing process plays an important rule. This Research fouse on process optimization of MDF manufacturing parameters, that is, hot press temperature and pressure, time in which the process of mdf formation completed and the moisture content that is present in the fiber mat.

FIGURE 2: Medium Density Fiberboard

LITERATURE SURVEY

Taeho kim (2019) researched was motivated by the possibility of production cost saving and environmental protections. It is cheaper than the other wood products ,however the main problem with MDF is less resistant to moisture content and water, and emits Urea Formaldehyde in air because it include some adhesives through its production process. The effect of moisture content in the panel results in low internal bonding and bending strength.[5]

M.lakhi et al (2019) evaluate the delamination in the drilling process of mdf. During the drilling in the mdf delamination occur in the board which is not acceptable for the board. They worked on the processing parameters including the feed rate and cutting speed on the delamination of mdf board. He conculuded that the delamination value decreases with increasing cutting speed and increases with increasing feed rate. Though, there were some fluctuations in the results.[6]

W.Gul et al (2017) performed an experiment on the impact of Hot Pressing temperature and its effect on medium density fiberboard to increase its Modulus of Rupture(MOR), Internal Bonding(IB), Water Absorption and the thickness expansion, etc., by increasing/decreasing the hot press temperature and pressure. Hot pressing temperature is resolved by the exhibition of sheets, the glue used, and the generation effectiveness of hot press. They consider only two parameters i.e. Pressure and temperature[7].

A. Kargarfard et al (2014) investigate the possibility of MDF production from eucalyptus wood. Euclyptus wood have large amount of moisture contents in its so it have great effect on the board. MDF samples are prodced by using the eucalyptus generated fibers and different hot pressing temperatures and the pressing times. The press temperature had great effect on Modulus of rupture, and by increasing the press temperature, Modulus of rupture is also increased. Higher steaming time reduced the IB of boards as well as the thickness swelling and by increasing the steaming time from 7.5 min to 15 min, it decreased IB from 0.787 to 0.533 Mpa.[8]

ZhiyongCai et al(2006) carried out research on hot press parameters of fiber mat during the manufacturing process of MDF panels. He finds a relationship between vertical density profiles (VDP), fiber moisture content and pressing time of hot press. MDF boards could be created with attractive exhibitions extending from great VDPs with thick faces and less thick centers to that having a for all intents and purposes level VDP.[9]Again ZhiyongCai et al , built up a principal model to understand the heat transfer and resin reaction during the hot-pressing of the MDF board. It will help to optimize the manufacturing process of medium-density fiberboard

(MDF) which will cause to increase the MDF productivity, have to improve sheet quality, and enhance the sheet durability.[10]

S.wang et al, (2000) examined the impact of step pressing closing of Medium Density Fiberboard on vertical thickness profile. A well MDF board for cover, Gluing and completing ought to have a tolerable equality thickness profile, in which the face thickness is stunningly higher than the middle thickness. The movement ends plan through and through changed the ordinary condition of the vertical thickness profile of the Laboratory, made MDF sheets. The progression shutting plans brought about various densification tops as opposed to the customary two pinnacles related to ordinary squeezing. Most of the researcher worked on two controllable factors i.e Tmeprature and pressure and its effect on the vertical density profile. These are not only the controllable parameters ,but there are various other controllable parameters which effect the mdf properties.[11]

Large number of researcher worked on the controllable process parameters such sa pressing temperature and the moisture content in the mate and its effect on Internal bonding, Bending strength and vertical density profile. This research paper outlines the optimization of mdf manufacturing process parameters such as Pressing temperature of the hot plates, Hydraulic pressure applied by the hot plate through fiber mat, The time for the pressing/cooking of mat and the moisture or the amount of water present in mat.

METHODOLOGY

The plan of the Experiment is created to break down the impact of various peocess parameters i.e. Moisture, Hydraulic Pressure, Hotpress temperature and press cycle time and its effect on Internal bonding and bending. The important area of the research to be covered, including the flow of the process, different process parameters selection and the application and usage of the Taguchi method and Grey relational analysis on multiple response variables. The methodlogy flow chart clearify the whole research procdure in detail from literature review to final results.

E-ISSN NO:2349-0721

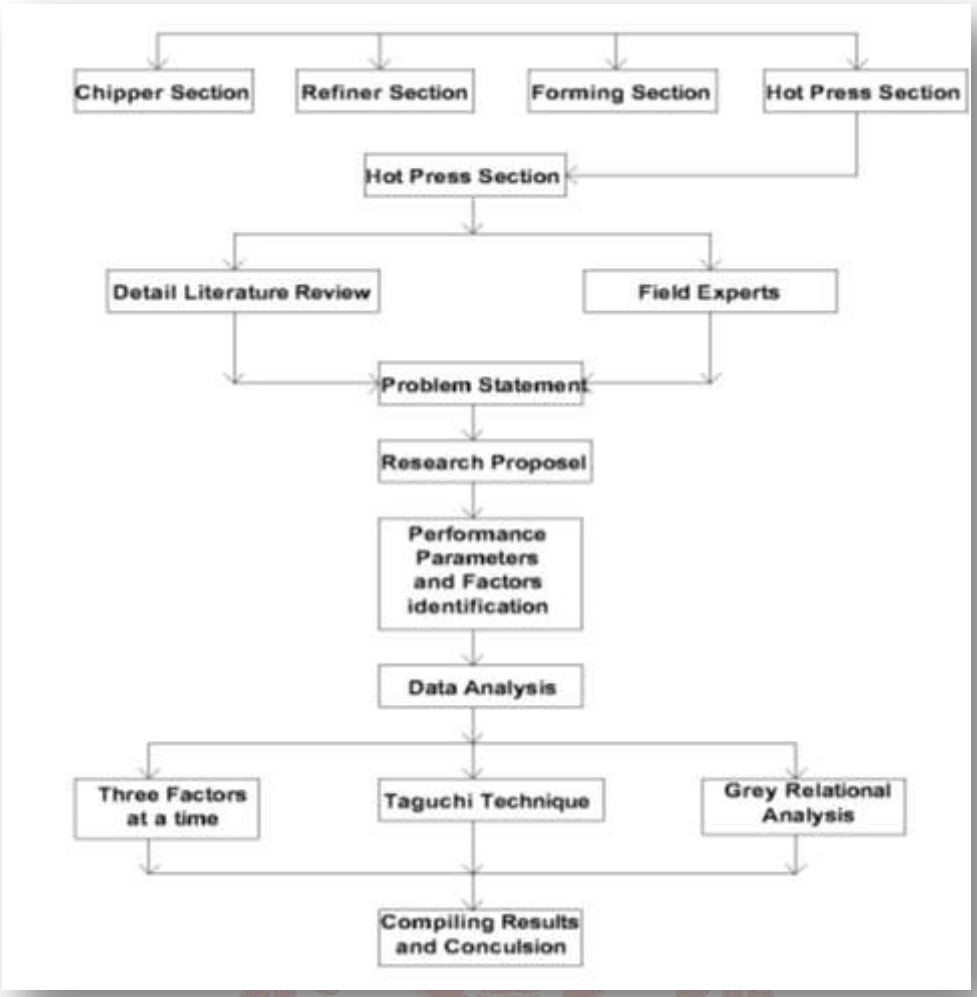

FIGURE 2: METHODLOGY FLOW CHART

DESIGN OF EXPERIMENTS

Design of experiments (DOE) is a process aims to seek out the link between different factors that are used to set a process and to see the output of that process. In other words, it can be used to control the cause and effect relation. The objective is to design such a system or job which describes the variation in information under different conditions that put forward to show the variation.

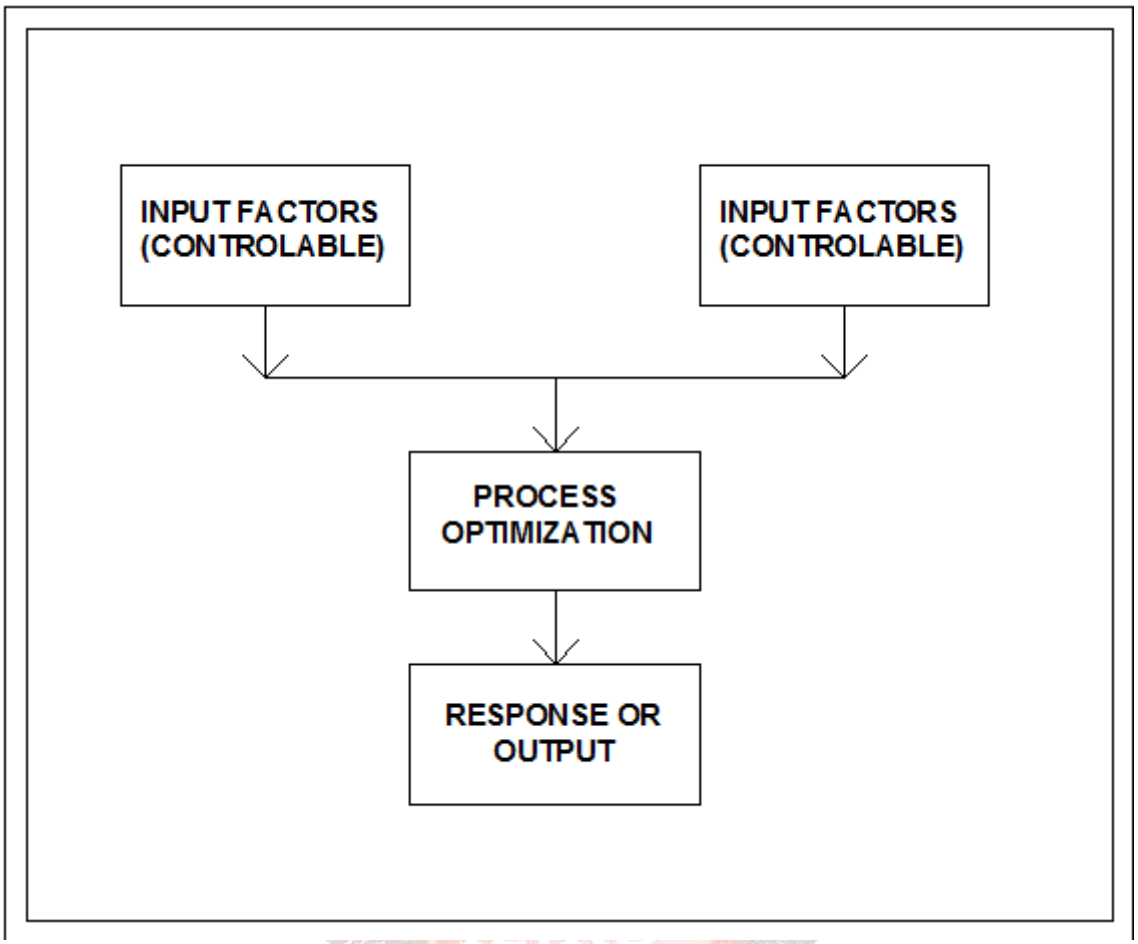

Figure 3.1: Design Of Experiments

The input factors are of two types; the one which we can control is called controllable factors while the other which we are unable to control is called uncontrollable factors or noise factors. In this research, four controllable input parameters are as follows.

1. Moisture Contents (%)
2. The temperature of the Hot Plate (^{o}C)
3. Hydraulic Pressure Appl0ied on the Hot Plate (Bar)
4. Press Cycle Time (Sec)

And the response variable or output parameters are as follows.

1. Internal Bonding
2. Bending Strength.

The objective is to control those four parameters in order to make an optimized product.

TAGUCHI TECHNIQUE

It is an improvement method presented by Dr. Taguchi. Taguchi has conceived another strategy for directing the structure of analyses that depend on well-characterized rules and to diminish the difference.The objective of the Taguchi method is to achieve the acceptable result by using the plan of examinations and enhancement of control variables. The important factor in this method is orthogonal array (OA). Taguchi method is a mechanism

that is mostly used for evaluating and implementing improvements not only at the process level but also used at the product, equipment, and facility level. The objective of improvement is to improve the required feature and at the same time the numbers of defects are reduced by analyzing the major controlling variables which control the process to give the best possible results. It is considered as a tuning of the process to give the optimum results. [12]

GREY RELATIONAL ANALYSIS

Grey Rational Analysis tells us that

- The most important is the grey relational analysis (GRA) in which gives the optimal process parameters.
- It is used when there are multiple objective process parameters which are not possible by Taguchi and ANOVA techniques.

There are international standards for internal Bonding and Bending of Medium Density Fiberboard. If the experimental value will not in the range of the standard value then the experimental results will not be accepted.[13]

Assurance of ideal manufacturing parameters is a persistent designing task whose goals are to lessen the creation costs and to achieve the perfect thing quality. In the machining procedure of MDF, Bending quality and inner bonding is one of the most significant exhibition measures. Bending quality is a generally utilized record of item quality and much of the time a specialized necessity for mechanical items. Accomplishing the ideal Bending quality is critical for the utilitarian conduct of a section. At the same time, Internal Bonding is considered as the factor that legitimately influences the creation cost and the machining hour rate. The Taguchi technique utilizes orthogonal arrays to lessen differences and streamline process Parameters. In the Taguchi technique, the Mean of the reaction variable (response variable) is utilized as a performance Characteristic to quantify process vigor and to assess deviation from wanted qualities.

Table 4.1(a) L9 Orthogonal Array

Table 4.1(a) shows Taguchi L9 orthogonal array (OA) with nine runs to conduct experiments. The two Response variables, namely, Internal Bonding represented by I.B, and Bending Strength. The two response variable variables found out with the help of a universal testing machine called wood testing machine

Exp...	Process Parameters			
	Moisture (%)	**P.S.T (Sec)**	**Hydraulic Pressure (Bar)**	**Temperature (℃)**
1	8	220	145	210
2	8	240	155	220
3	8	260	165	230
4	9	220	145	210
5	9	240	155	220
6	9	260	165	230
7	10	220	145	210
8	10	240	155	220
9	10	260	165	230

EXPERIMENTAL WORK

Determination of Optimal process parameters

So as to assess the wear performance parameter of the MDF board, four control factors, namely, Moisture content (%), Press Cycle Time (Sec) Hydraulic pressure (Kg), and Temperature of the hot plate each at three levels, were chosen as appeared in below Table.

Table 4.1(b) Result Obtain from MINITAB Software

Sr. No	Taguchi method				
1	Factors: 4		Replicates: 2		
2	Base runs: 09		Total runs: 09		
3	Number of levels:	3	3	3	3

Response Table for Bending Strength:

Taguchi Analysis: Bending Strength Vs Moisture(%), Press Cycle Time(Sec), Hydrulic Pressure(bar), Temperature(^{o}C). The response table of Bending shows the Delta value and rank for different values of moisture, press cycle time, hydraulic pressure and temperature. The positions in a response table assistance you rapidly recognize which components have the biggest impact. The factor with the biggest delta value is given position 1, the factor with the second biggest delta is given position 2, etc. It is obvious from the above table that factor D has higher delta esteem so it positions 1, etc.

Table 4.2.1(a) Response Table for Bending Strength

Factors	Level 1	Level 2	Level 3	Delta	Rank
Moisture(%)	26.33	28.33	25.33	3.00	4
Press Cycle Time(Sec)	27.00	29.00	24.00	5.00	3
Hydrulic Pressure(bar)	25.00	24.00	31.00	7.00	2
Temperature (C)	21.67	28.67	29.67	8.00	1

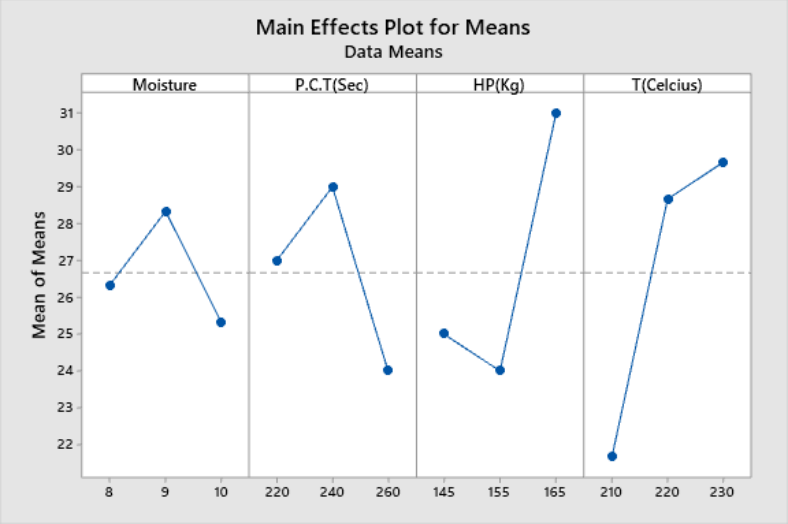

Fig. 4.2.1 Main effect plot of means of the mean for bending strength

In the above Fig. showed the main effect plot for means of the Bending against the Moisture, press cycle time, hydraulic pressure, and temperature. It could be noted that the greater the value of hydraulic pressure gives the better value of Bending.for better Bending of the MDF the above graph shows that moisture of 9%, Press cycle time is 240 sec, Hydraulic pressure 165 kg and the temperature of 230 ^{o}C.

Fig. 4.2.1(b) Pieces for Internal BondingFigure.4.2.1(c) shows the Internal Bonding Specimen

RESPONSE TABLE FOR BONDING:

Taguchi Analysis: Internal Bonding Vs Moisture(%), Press Cycle Time(Sec), Hydraulic Pressure(bar), Temperature(^{o}C)

Factors	Level 1	Level 2	Level 3	Delta	Rank
Moisture(%)	0.44	0.33	7.29	6.9	1
Press Cycle Time(Sec)	0.39	0.400	7.272	6.8	3
Hydrulic Pressure(bar)	0.33	7.28	0.45	6.9	2
Temperature (^{o}C)	7.22	0.426	0.420	6.8	4

Table 4.2.2 Typical Response table of IB from Minitab

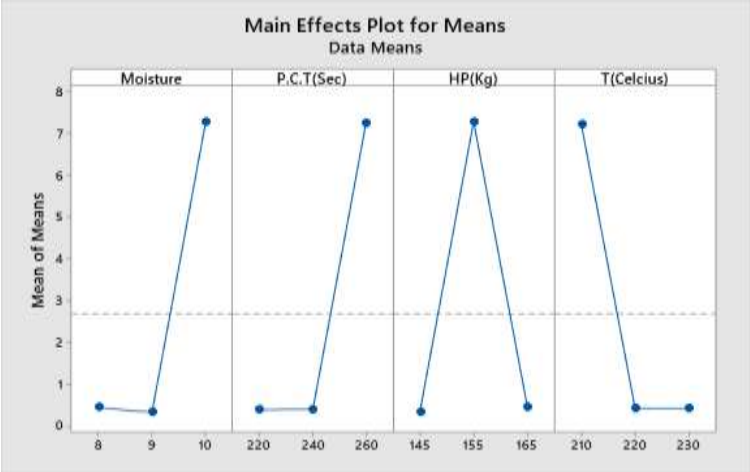

Fig. 4.2.2 Main effect plot of means for Bonding

The above graph shows the main effect plot of the mean for Bonding of MDF against the parameters Moisture, press cycle time, hydraulic pressure, and temperature. It could be observed that the optimal for the better bonding effect, is Moisture of 10 %, the press cycle time of 260 sec, the hydraulic pressure of 155 kg and temperature of 210 ^{o}C.

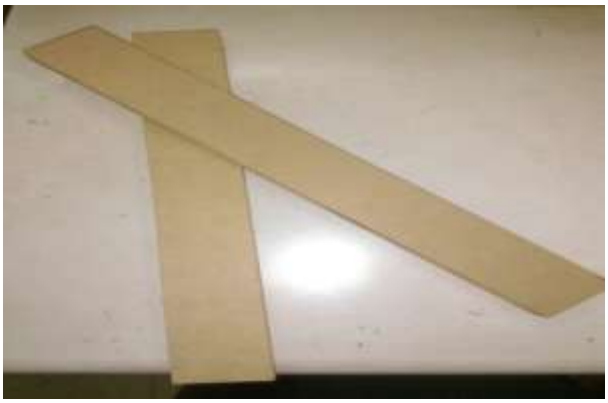

Fig. 4.2.2 (a) Pieces for Bending (b) Experimental arrangement

RESULTS AND DISCUSION

Final results of response variables are concisely summerized in Table 5(a). The comparative analysis of the wel defined MDF properties, such Internal Bonding and Bending strength can be accomplished on the basis of temperature, pressure, time and moisture contents. Internal Bonding and Bending are the mechancial properties of the formed MDF.[14] As conduction of heat between the press platens and the central layer of the mat, phase change of water from the absorbed to the vapor state and the convective heat and mass transfer through the edges of the mat.[15]. It includes conditon of heat between the press plate and the central layer of mat, phase change of water from the adsorbed to the vapor state and the convective heat and mass transfer through the edges of the mat.

Taguchi test method is acceptable to choose the perfect settings of manufacturing process parameters for single reaction qualities. By virtue of in any event two reactions, with extraordinary quality traits, multi-reaction optimization using GRA is the favored technique. Grey examination can in like manner be utilized to choose the equivalence between obviously unusual finite data. Hence, multi-response improvement of wear parameters in this assessment is performed using the going with strides in GRA.[16]

The advancement of different parameters considering various execution qualities of the MDF creating process using the GRA is shown in Table 5(a) Execution qualities including Internal Bonding and Bending are picked to survey the yield parameter[17]. Those Process parameters that are immovably related with the picked performance attitude in this assessment are the Moisture Content, Press cycle span, hydraulic pressure of hot plate and hot plate temperature. Preliminaries subject to the best possible L9 OA are coordinated first. The selection of these process parameters for obtaining optimal responses is very important to increase the product quality as well as increase production rate considerably by reducing the market complaints. In such a case multi objectives optimization are necessary to solve the problems [18].The standardized exploratory aftereffects of the presentation attributes are then acquainted with ascertain the coefficient and grades as per GRA. Optimized process parameters all the while prompting higher Internal Bonding and Bending quality will at that point be checked through an affirmation experiment.[119]

After performing the experiments as per Taguchi's experimental design, main effects plots for Internal Bonding and Bending. The main effect is a direct effect on parameters on response and dependent variables.[20] Typical main effect plots of parameters with respect to Internal Bending and bonding are shown in Fig 4.5.2-3. It is plotted by considering means of response at each level of parameters. Maximum Bending obtained for Moisture (9%), Press Cycle Time (240Sec), Hydraulic Pressure (165 bar) and Temperature (230 ^{o}C). And Maximum Internal Bonding obtained for Moisture (10%), Press Cycle Time (260Sec), Hydraulic Pressure (155 bar) and Temperature (210 ^{o}C).

GRA can successfully be prescribed as a strategy for improving the convoluted interrelationships among various performance attributes[19].In order to optimize the Moisture, Press Cycle Time, Hydraulic Pressure and temperature, Grey Relational Analysis has been Utilized for Internal Bonding and Bending. By GRA experimental method we got the result in the form of Grey Relational Grade. Higher the GRG, higher will be the value. We observed from the GRG that experiment 03 has a higher value as compared to the rest of the experiments. So the best values for Moisture (8%), Press Cycle Time (260 sec), Hydraulic Pressure (165 bar) and the Temperate (230 ^{o}C).

Table 5(a) Table shows Experimental results for Internal Bending and Bonding

Exp...	Process Parameters				Response Variable	
	Moisture (%)	P.S.T (Sec)	Hydraulic Pressure (Bar)	Temperature (℃)	Internal Bonding	Bending
1	8	220	145	210	0.32	20
2	8	240	155	220	0.48	28
3	8	260	165	230	0.52	31
4	9	220	145	210	0.38	25
5	9	240	155	220	0.55	33
6	9	260	165	230	0.47	27
7	10	220	145	210	0.48	33
8	10	240	155	220	0.42	31
9	10	260	165	230	0.15	10

Table 4.3(b) shows the experiment according to rank wise

Experiment	Rank
1	8
2	3
3	1
4	6
5	5
6	7
7	2
8	4
9	9

CONCLUSION

The quality of a product is an important factor in showing the growth of a company. Quality and productivity are two of the most important criteria in any MDF manufacturing process. Moisture (%), Press Cycle Time (Sec), Hydraulic Pressure (bar) and Temperature (^{o}C) are the most important response parameters of any MDF manufacturing process. It is very important to optimize the four process parameters simultaneously.

By Grey based Taguchi Technique following results are observed.

- By using the Taguchi Method, four process parameters have been optimized individually. It gives different values of four process parameters for both Internal Bonding and bending.
- Grey relational analysis (GRA) has been employed for the simultaneous optimization of multi-Process characteristics.

- By using GRA, the Optimization of multi-process characteristics was converted into single characteristics called grey relational grade.
- The optimal combination of the process parameters for multiple performance optimizations has been set at Moisture(8%), Press Cycle Time(260 sec), Hydraulics pressure(165 bar) and Temperature(230 ^{o}C)

During the experiments, it is observed that not only the Internal Bonding and Bending justify the quality of the panel, but nowadays the market also demands good density profile and surface roughness of the panel.

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