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Contents

Integrated Water Resources Management: A Case Study for Barind Area, Bangladesh

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A B S T R A C T

The objective of this paper is to review the state of art on integrated water resources management (IWRM) approaches for sustainable irrigation at the basin scale under semi-arid and arid climatic conditions, with main emphasis in Barind area where Surface water irrigation has not been developed satisfactorily due to its limited availability and undulated topography. As IWRM is an interdisciplinary approach and used for different objectives, the main emphasis is given to IWRM approaches for sustainable irrigation and their environmental aspects. In general integrated approaches in Bangladesh are scarce. Groundwater is the main source of irrigation as well as for domestic and industrial purposes in Barind area. In recent years, lowering of groundwater table is observed in some areas of the region. Lowering of groundwater table during dry months creates problems in the operation of STWs and hand tubewells. In some places of Tanore Upazila, declining trend of groundwater level also observed. In the next 25 years, food demand of the country is expected to increase by 29% which will require increased cropping intensity. In absence of major surface water diversion, added pressure on groundwater will lead to further depletion of the sources. Rivers being recharged from groundwater causing a major natural loss of groundwater through Mahananda and the Ganges river. Reduction of surface water flows and lowering of groundwater table combined with climate change will aggravate the existing water scarcity problem. All these have compounded the sustainable management of water in this area. To overcome this complexity, an integrated water resources management (IWRM) is necessary. Upazila wise potential resource as well as usable resource, present and future demand for expanded irrigation coverage, number of DTW, surface water availability, impact of conserving surface water on kharies have been assessed for the study area which is very important for IWRM.

Keywords: IWRM, Drought, Climate Change, Declining trend of Groundwater, Sustainable Irrigation, otential Recharge

I. Introduction

Integrated water resources management (IWRM) was defined by the Global Water Partnership (GWP, 2000) as ―a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.‖

Currently, one-third of the world’s population is living in countries and regions of water resources limitation (Bates, et al., 2008). Because of limited water availability imposing strong restrictions on natural and human systems, the management of water resources has become an urgent issue in semiarid and arid regions. Generally, when the demand of water has reached the limits that the natural system can provide, water shortage can become a major obstacle to social and economic development for one region (Bronster et al., 2000; Li et al., 2006). Therefore, these issues have forced planners to contemplate and propose ever more comprehensive, complex, and ambitious plans for water resources systems in the semiarid and arid regions (Li et al., 2008).

Different studies have documented that groundwater level declined substantially during the last decade causing threat to the sustainability of water use for irrigation in this region and impacting upon other sectors too (Jahan et al. 2010). Due to lack of proper knowledge, indiscriminate installation of pumps and non-availability of modern technologies, farmers inappropriately lift water without caring ground sources. These impacts upon interlinked sources of water table which is declining alarmingly in many areas of Bangladesh. Although the groundwater dominates the total irrigated area, its sustainability is at risk in terms of quantity in the northwest region (Simonovic 1997; Shahid 2011). Frequent shortage of water in the region has had impacts that can be ranged as economical, social and environmental (Takara and Ikebuchi, 1997; Sajjan et al. 2002; Dey et al. 2011).

A recent study shows that groundwater level in some areas falls between 5-10 m in dry season and most of the tubewells fail to lift sufficient water (Dey and Ali 2010). Researchers and policymakers are advocating sustainable development as the best approach to today's and future water problems (Loucks2000; Cai X et al. 2001). With groundwater development, fluctuations will amplify; but as long as rainfall is managed to recharge aquifers, and proactive water saving strategies are put in place, a steady and sustainable state can be achieved (IWMI 2010). In mainstream irrigation thinking, groundwater recharge is considered as a by-product of flow irrigation, but in today's world, groundwater recharge needs to be understood on its first emergency for making groundwater sustainable integrating all possible options (IWMI 2010).

Hydrologic model was a useful tool for water resources management (Sahoo et al., 2006). Previously, many lumped hydrologic models were developed to investigate watershed hydrology. With a low data requirement, these lumped catchment models could reflect runoff dynamics and water balance in water resource management systems. However, the lumped models assumed the study watershed as a spatially homogeneous region, and the spatial heterogeneity of the climate variable and land surface was not considered (Bronster et al., 2000).

Consequently, several distributed and semi-distributed hydrological models were developed in response to the aforementioned challenges (Apul et al., 2005). For example, Refsgaard (1997) integrated MIKE SHE, MIKE 11, MIKE 21, and DAISY to study the environmental assessment in connection with the Gabcikovo hydropower scheme. Sahoo et al. (2006) used the physically distributed hydrological modeling system (MIKE SHE) to study the watershed response to storm events within the Manoa-Palolo stream system on the island of Oahu, Hawaii. IWM (2005, 2006 and 2009) used the physically distributed hydrological modeling system (MIKE SHE & MIKE 11) for the assessment of potential groundwater and surface water resources. The primary advantage of the distributed hydrological models was enabled to reflect the spatial variations for characteristics of watershed (e.g., rainfall, topography, soil type, and land use) (Refsgaard, 1997). However, higher data requirement became a main obstacle on extensively applying these models to practical problems.Both the Poverty Reduction Strategy (PRS) and Millennium Development Goal (MDG) of the Government of Bangladesh attached priority to increase agricultural production. In this backdrop, Barind Multipurpose Development Authority (BMDA) undertook a programme entitled ―Groundwater Resources Study and Decision Support System Development of Rajshahi, Naogaon, Chapai Nawabganj, Pabna, and Natore Districts and also Remaining Districts (Except Thakurgaon, Panchagarh, Dinajpur & Joypurhat Districts) of Rajshahi Division Through Mathematical Model Study for Barind Integrated Area

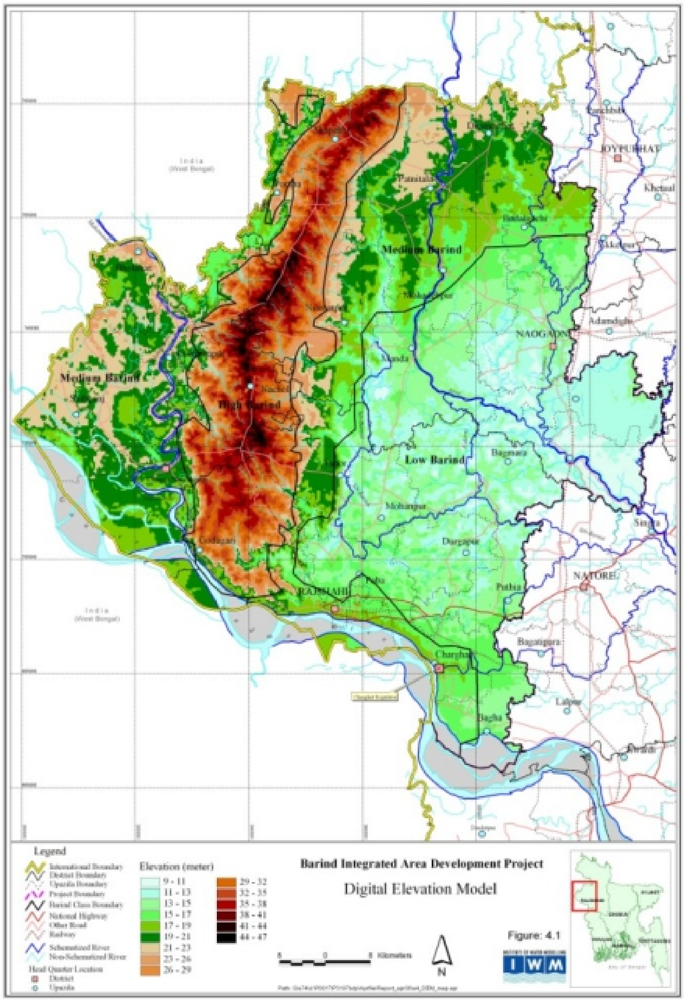

Figure 1: Study Area

Development Project, Phase-III‖. Under this project, IWM (2012) carried out the study. The study area comprised of 25 Upazilas of Rajshahi, Chapai Nawabganj and Naogaon District (Figure 1) of Bangladesh and situated in the Ganges Basin. The gross area of the project is about 7,50,000 ha and net cultivable area is 595760 ha. The annual rainfall varies from 1250 mm to 2000 mm (IWM, 2006). During dry season, most of the ponds and tanks have become derelict creating shortage of water for both domestic and livestock population. Groundwater is the main source of irrigation and other uses using a large number of deep tube well (DTW) and shallow tube well (STW) both by public and private initiatives. Operation of a few thousand DTWs by BMDA and STWs by private owners for irrigation during dry period creates problem for operation of hand tubewells and dug wells. Deficit of rainfall is one of the main reasons for occurring drought in Barind area. Drought is pivoting factor for crop production in this area. Due to drought, frequent damage ofcrops area occurred in this area.

Climate change is the largest mechanism of global change. It will have pronounced impact on dry season water availability and short period of intensive rain in the wet season causing devastating floods. In recent year, it has been observed that climate is becoming more variable with greater occurrence of extreme events in this area. This will encourage the upstream countries to divert more surface water leaving a gloomy picture of prolonged drought with dry wells at many places of the region. Reduction of surface water and lowering of groundwater table combined with climate change will aggravate the existing water scarcity problem.

1.1 Rational for Groundwater Use

Though surface water is available at the outfall of the Mohananda river into the Ganges and in the Ganges River, large pumping plants are required for pumping water from the river. Moreover the water levels of the rivers in some reaches go down beyond the suction limit of low lift pumps becoming the problems of pumping from river. Moreover, the undulated topography of the area is not suitable for gravity irrigation. However, pumping from the rivers and conserving water by small water control structures are being practiced for limited surface water irrigation. Main dependence for irrigation is on ground water. Groundwater is being extracted for irrigation mainly by DTW and STW. There are about 8,955 DTW and 97,669 STW in Barind area (BADC, 2010).

After development of groundwater, irrigation coverage and agricultural yield in the area has significantly been increased as well as the cropping pattern has also been changed. Now a days Rabi cultivation season is also known as main irrigation season. However, impact of groundwater use has not been well monitored.

1.2 Policy Statement for Groundwater Use

The government policies that have direct relevance with use of groundwater are mainly the National Water Policy (NWPo) and National Agricultural Policy (NAP). In the context of water use, the objectives of the NWPo are to promote agricultural growth through development of groundwater along with surface water. The main elements of Government policy for use of water are to (i) encourage and promote continued development of minor irrigation without affecting drinking water supplies, (ii) encourage future groundwater development for irrigation by both the public and the private sectors, (iii) improve resource utilization through conjunctive use ofall forms of surface water and groundwater for irrigation, (iv) strengthen systems for monitoring water use, water quality and groundwater recharge. (v) strengthen crop diversification programmes for efficient water utilisation, (vi) develop and promote water management techniques to prevent wastage and generate efficiency of water and energy use and (vii) produce skilled professionals for water management.

Recently Government has approved the Poverty Reduction Strategic Paper (PRSP) that provides the guideline to achieve the Millennium Development Goals (MDG). In the PRSP, among others, due emphasis has also been given on the rational and productive utilization of the water resources. The main elements of the PRSP as stated in Policy Matrix which have relevance with the efficient and productive use of water includes, among others (i) create additional irrigation facilities utilizing surface water resource where justified, (ii) ensure conjunctive use of surface and groundwater in existing Command Area Development Projects, (iii) monitor quality and quantity of groundwater on regular basis, (iv) augment surface water in rivers, creeks and khals by constructing barrage, rubber dam and water control structures and (v) promote community participation in multipurpose use of water.

II. Approach and Methodology

For sustainable management of scarce water resources and to mitigate the impact of drought, integrated water resources management (IWRM) is needed applying technically based procedures to assess the hydrologic and environmental consequences of different water resource management strategies. An attempt has been made in this paper to evaluate the existing condition of groundwater and to assess the possible effects and impacts of drought on groundwater in Barind area with focus on appropriate technologies for assessing hydrologic and environmental consequences of IWRM. Effective management strategy for sustainable use of groundwater resources under complex situation also has been tried to illuminate in this paper.The MIKE SHE model is a physical distributed hydrological modeling system covering the entire land phase of the hydrological cycle (Abbott et al., 1986). The model consists of five modules: overland flow, evapotranspiration, unsaturated flow, saturated flow and channel flow modules (DHI, 1999).

The saturated flow that is allowed for a fully three-dimensional (3D) way is described by the Darcy equation and solved by the iterative implicit finite difference technique. 3D finite difference method is used to simulate the 3D saturated flow in saturated porous media.

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)-Q=S\frac{\partial h}{\partial t}$$

where Kxx, Kyy, and Kzz are the hydraulic conductivity along the x, y, and z directions. The h is the hydraulic head, Q represents the source=sink terms, and S is the specific storage coefficient. The channel flow is calculated by the one-dimensional simulation using the full dynamic Saint-Venant equations. The coupling between MIKE SHE and MIKE 11 is made via river links.

In order to achieve the study objectives, IWM (2012) developed an integrated gw-sw model for the study area. The models developed under this study are based on MIKE-11 (DHI, 1999) for the simulation of flows in rivers, irrigation systems, channels and other water bodies and MIKE-SHE (DHI, 1999) for groundwater model. All the major river systems were included in surface water model while updated topographic features, hydro-geological setting, aquifer properties, DEM, land use pattern, irrigation abstractions were incorporated in groundwater model. Both the models were coupled through MIKE SHE and calibration as well as validation was done. The validated model was used to simulate various options and to assess the resources.

III. Results and Discussions

Considering lithological variations and groundwater flow capacity, hydro-stratigraphic units of the study area (upto 80 m depth) have been defined as Clay Top, Upper Aquifer, Clay Middle, Lower Aquifer and Clay Bottom (Figure 2). It reveals from the analysis that within the studied depth upper aquifer and lower aquifer is interconnected and the clay middle is not continuous. In fact there is only one aquifer in the study area. The main aquifer, in most of the area is either semi-confined or leaky. Recharge to the aquifer is predominantly derived from deep percolation of rain and flood water. Lateral contributions from rivers comprise only a small percentage 0.04% (MPO, 1987) of total potential recharge.

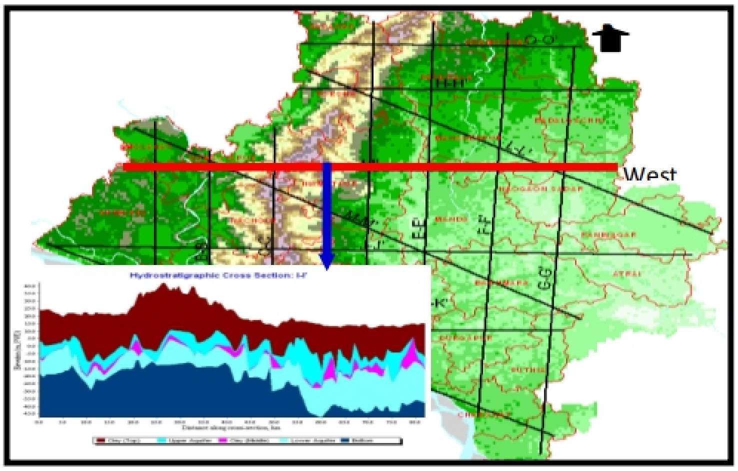

Figure 2: *Sample Plot of Hydro-Stratigraphic Cross*

Analysis reveals that in high barind area, specific yield varies from 0.01 to 0.06, while in low barind area, it varies from 0.06 to 0.30. Low specific yield will cause excessive drawdown in tubewell for high abstraction rates. In high Barind area, hydraulic conductivity varies from 10 m/day and 20 m/day whereas in low barind area it varies from 40 m/day to 70 m/day. In high barind area, transmissivity is lower than 1000 m2/day whereas in low barind area it is higher than 1000 m2/day. Highly transmissivity aquifer material indicates excellent opportunity for sustainable groundwater development in the area.

Hydrographs of observed groundwater tables show that the maximum and minimum depth to groundwater table occurs at the end of April and end of October respectively. In some places, depth to groundwater table goes below 7.0 to 25.0 m. Suction mode tubewells do not operate in the areas. However, during the peak time of recharge, groundwater table almost regains to its original positions except some places of Tanore. It can be seen from Figure 3 that groundwater is declining at some places of Tanore. In these areas, recharge is less compared to the total abstractions. Decline of groundwater table is mainly occurred due to higher abstraction round the year. In order to avoid this alarming situation groundwater abstraction should be controlled in that area.

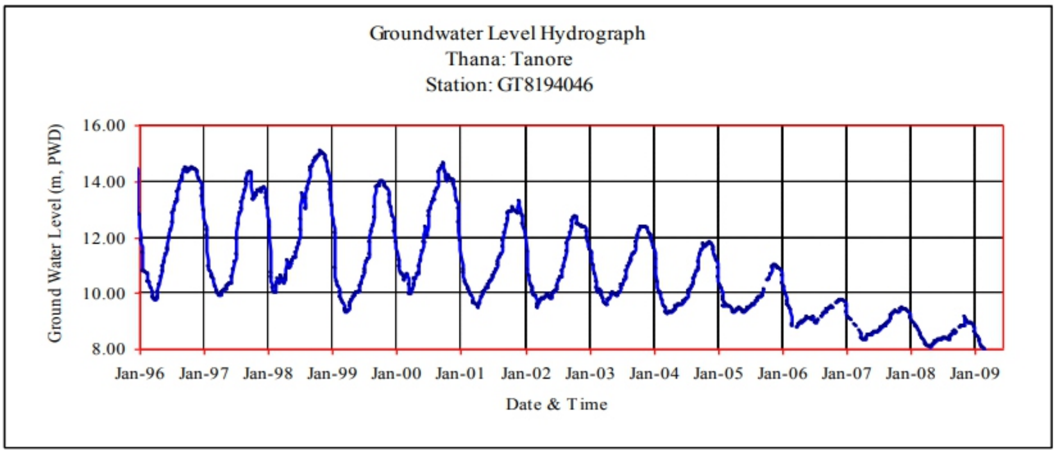

Figure 3: *Declining Groundwater Trend in Tanore*

The current water management plans are mostly based on existing knowledge and sparsely aims at optimum use of precious resources. An improved understanding of the hydrologic processes that determine the resource and movement of water in this region is critical to the development of effective strategies for sustainable development water management. The management strategy of groundwater resources depends on the following aspects:

Assessment of availability and requirements of water resources;
Understanding the recharge mechanism;
Identification of scope for future irrigation expansion based on water availability;
Development of Groundwater Monitoring System;
Estimation required number of Deep Tubewell;

IWM (2012) carried out the groundwater model study for optimum utilization of available water resources. For the study area, the Upazila wise estimated potential recharge, usable recharge which is 75% of potential recharge, abstraction and remaining water is given in Table 1 (IWM, 2012).

Table 1: *Upazilawise Groundwater Resources*

SL No.	District	Upazila	Potential Recharge (mm)	Usable Recharge (mm)	Requirement (mm) in 2010	Remaining Water (mm) in 2010
1	Naogaon	Atrai	611	458	407	51
2		Badalgachi	640	480	348	132
3		Dhamoirhat	599	449	535	-86
4		Mahadebpur	486	365	335	30
5		Manda	619	464	263	201
6		Patnitala	435	326	294	30
7		Porsha	396	297	152	145
8		Naogaon	635	476	394	82
9		Niamatpur	449	337	296	41
10		Raninagar	623	467	400	67
11		Sapahar	431	323	200	123
12	Rajshahi	Bagha	452	339	181	158
13		Bagmara	486	365	351	14
14		Charghat	498	374	352	22
15		Durgapur	570	428	401	27
16		Godagari	414	311	302	9
17		Mohonpur	415	311	281	30
18		Paba	547	410	289	121
19		Puthia	533	400	390	10
20		Tanore	330	248	294	-46
21	Chapai Nawabganj	Bholahat	664	498	386	112
22		Gomastapur	438	329	256	73
23		Nachole	467	350	212	138
24		Nawabganj	590	443	158	285
25		Shibganj	498	374	294	80

It was estimated for the future scope of irrigation expansion based on water availability and recommended optimum number of tubewell to be installed in future. The study (IWM, 2006) reveals that although the area has groundwater potential, major part of the area, the groundwater table goes below the suction limit which would be more vulnerable due to climate change. The area is suffering from surface water shortage. The study (IWM, 2006) shows that, the area is loosing groundwater to the nearby river Ganges about 13Mm3
in each year. Some part of the area has already been found as groundwater resource constrained zone. So, it is anticipated that situation might become worse in that area with the longer dry season due to the climate change. However, in other areas of Bangladesh, effective management strategy for sustainable use of groundwater resources needs to be developed considering the above aspects. Careful management can avoid problems in over exploitation of resources and environmental degradation of this area.

3.1 Surface Water Availability

For the purpose of assessing surface water resources, discharge data were analyzed to estimate the flow event for different return periods. Monthly available resources in the above rivers were also analyzed. Conservation of these resources was considered by construction of rubber dam. For sustainability of river, usable resource was taken as 70% of the available resources and remaining 30% as ―in-stream flow requirement‖ in the river. Based on monthly crop water requirement (Boro-Aman) the scopes for surface water based scheme were also estimated. Table 2 shows the scope of surface water development. It is observed that some water resources are available in Atrai and Mohananda while very limited resource is available in SibBarnai river.

Table 2: Scope of Surface Water Development

Location of Rubber Dam	Month					
	Nov	Dec	Jan	Feb	Mar	Apr
Atrai River, Ch 60.34 km, Atrai R.B						
Monthly Available Water (million m^3)	50.83	31.12	20.4	13.66	11.54	11.46
Monthly Water Requirement (m^3)	0.127	0.065	0.258	0.21	0.251	0.18
SW development Area (km^2) based on resources	400	478	79	65	46	64
Mohananda River, Ch 44.90 km, Nawabganj						
Monthly Available Water (million m^3)	313.16	235	193	136.66	99.69	70.4
Monthly Water Requirement (m^3)	0.127	0.039	0.254	0.21	0.254	0.181
SW development Area (km^2) based on resources	2466	6025	762	651	392	388
Sib-Barnai River, Ch 54.75 km, Pearpur						
Monthly Available Water (million m^3)	8.48	0.78	0.7	-	-	-
Monthly Water Requirement (m^3)	0.131	0.039	0.258	0.21	0.258	0.18
SW development Area (km^2) based on resources	65	20	3	-	-	-

3.2 Impact of Environmental Change on Groundwater Environmental change compounds the challenges of sustainable groundwater management of this area as it has significant impact on groundwater levels and recharge capacity as well as water demand. Following issues related to global environmental change and its impact on groundwater resources have been discussed below;

Climate Change

Climate change is strongly affecting many aspects of physical and biological systems, particularly rainfall distributions and increases of temperature. In Bangladesh, recent studies indicate that there is an increasing trend of temperature of about 10 C in May and 0.50 C in November during the 14 year period from 1985 to 1998 (Mirza, 2002). The temperature projection for the 21st century based on climatic models indicate that in South Asia annual mean warming would be about 2.5 0 C (IPCC, 2007). The combination of shorter duration but more intense rainfall (meaning more runoff and less infiltration) combined with increased evapotranspiration and increased groundwater abstraction will lead to further groundwater depletion in this area.

Land use change

Land use and land cover change due to increasing population and urbanization is one of the largest mechanisms of global change. In northwest region of Bangladesh, growth of cities and rural settlement has been increased rapidly due to development of infrastructures. Consequently land available for forest and agriculture has been reduced. It is expected that further development of infrastructures will reduce the area of land available for forest and agriculture by some 17 % (NWMP, 2001) over the next 25 years. This land use change will reduce groundwater recharge area leading to groundwater depletion.

3.3 Exploration for Deeper Aquifer

After investigation of potential deeper aquifer, a DTW of 248 m depth was installed at a place where a severe scare of drinking water was observed. Model result was also analyzed (Figure 6) for additional DTW in deeper aquifer in this area. The simulation results of first trial which is for addition 4 DTWs, shows that groundwater level at Saidpur is goes further 24.3m from existing conditions. Though groundwater level almost regains its original position but production cost would be higher considerably due to additional draw down. So it would not be feasible to install four additional DTW. Model was simulated for another trial considering 2 additional DTWs in place of 4 with a spacing 2000m and observed that it will create additional 6.0m drawdown and groundwater

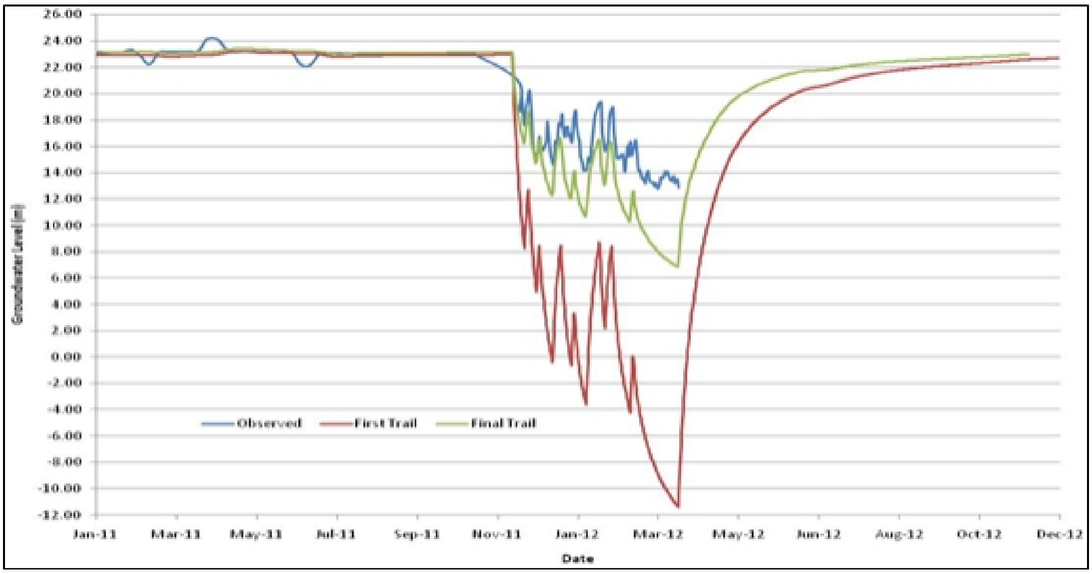

Figure 3:Groundwater leve comparison for adition DTW

level regain its original position. This option is quite feasible. But still it would be needed further detail investigation to know the exact number of additional DTWs as well as resources in deeper aquifer.

3.4 Necessary Steps for Future Action

Indiscriminate use of groundwater has already caused some local water scarcity problems in this area. Occurring of drought and environment change will aggravate the water scarcity problems in future. There should have a balance between groundwater recharge and withdrawal. Accordingly, judicious use of surface and groundwater in an integrated water resources management approach is equally important to mitigate the impact of drought. It has been observed from a model study (IWM, 2006) that sufficient rainwater in kharies can be conserved by retention structures. Supplementary irrigation is possible using this water. In addition, groundwater recharge also increases by conserving rainwater in kharies. In view of that, Sarmongla khal (Figure 5) is being used for conserving rain and surface water. However, it is suggested to utilize all kharies in Barind area for conserving rainwater.

Figure 5: Use of Surface and Rain Water for Irrigation

IV. Conclusion

Earlier Barind area was a drought prone area and was being desertification due to shortage of surface water and less rainfall. But in recent years, this has been turned into a green due to development of groundwater and surface water for irrigation in an integrated approach. Crops are grown almost everywhere and farming practices have strongly influenced the present vegetation. However, impact of groundwater use should be monitored and it should be used judicially without creating environmental hazards. In Barind area, the problems that are being faced related to water availability, use, control and management are not new. In this regard, conjunctive use of surface and groundwater, development of a monitoring system and finally regional cooperation is essential. For sustainable development of Barind area and to mitigate the impact of drought, a number of mitigations have been worked out among which some of them are already being practiced. Those are: i) rainwater harvesting through construction of cross dam on different Kharies in Barind area, ii) introduce less water consuming crops through crop diversification, iii) introduce of alternate wet and dry (AWD) method for irrigation to reduce water consumption, iv) promote surface water irrigation where and when possible, v) introduce artificial recharge by installation of recharge well, vi) implementation of North-Rajshahi irrigation project and vii) implementation of Ganges Barrage for maintaining a required pond level in different rivers like Ganges, Baral and Mahanda etc.

Acknowledgements

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Study on Nugget Development in RSW Process with Flat Tip Cylindrical Electrode

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A B S T R A C T

The objective of this work is to develop a numerical model of the resistance spot welding process with a flat cylindricallower electrode, enabling to predict accurately the spot weld geometry development. A 2D axisymmetric electro-thermo-mechanical finite element (FE) model is developed to study the effect of spot welding parameters on nugget size using ANSYS commercial software package. The nugget formation processes at the various welding conditions were investigated by both experimental measurement and FEM simulation.In order to improve the accuracy, temperature dependent properties of material are taken into account during the simulation. Experiments were carried out to verify the preciseness of simulation. Two different thicknesses of austenitic stainless steel sheets were used in the study. The FE predicted weld nugget sizes agreed well with the experimental results. Overall, the present work indicated that finite element analysis can be very useful as an off-line observation tool to estimate the influence of welding parameters on the welding quality and to predict or improve the welding quality.

Key words:Resistance spot welding, Austenitic stainless steel, Finite element method, Nugget.

I. Introduction

Resistance spot welding was inventedin 1877 by Elihu Thomson and has beenwidely used since then as a manufacturingprocess for joining sheet metal. It is still the dominant process for sheet metal joining in the automotive industry. Its main advantage is thatit easily enables further automation and robotic enhancements leading to an increased production rate. The main goal of the RSW process is to generate heat quickly at the contact point between the sheet metals andto minimize the amount of heat dissipated by driving it from the metal plates to the electrodes as well as for theregions in the periphery of the Heat Affected Zone (HAZ).The high thermal conductivity of the electrodes provides a method to control the nugget formation and cool-down by conducting heat from the workpiece.In this study a larger diameter flat tipped cylindrical bottom electrode is used to provide more mechanical support, larger surface area for heat dissipation,which helps to improve the weld quality and restricts the formation of dimples to only one side of the spot welded joint.The change of electrode shape induces some new characteristicsabout nugget formation during resistance spot welding,

whichshould be investigated. The nugget formation of resistancespot welding with cylindrical electrodes was simulated by ANSYS commercial software. Resistance spot welding is a complicated process, which involves interactions of electrical, thermal, mechanical and metallurgical phenomena. The materials to be joined are brought together under pressure by a pair of electrodes. A high electric current passes through the workpieces between the electrodes. Due to contact resistance and Joule heating, a molten weld nugget is formed in the workpieces. The workpieces are joined as solidification of the weld pool occurs. Force is applied before, during and after the application of welding current, to maintain the electric current continuity and to provide the pressure necessary to prevent expulsion.Some works have already been carried out on the modeling of spot welding process and study the effect of parameters on nugget size.Nied-1984[1] introduced an electrically, thermally, and structurally coupled axisymmetric model considering temperature-dependent properties and Joule heating. The displacements and stress distributions of the electrode and workpiece were illustrated. However, temperature dependency of contact resistance was not considered. Gould-1987 [2] measured the nugget growth using a metallographic technique.

A one-dimensional thermal model, which accounted for heat of fusion, contact resistance, and convection by qualitatively increasing the effective thermal conductivity in the liquid, was developed for comparisons. The differences between the predicted and measured nugget thicknesses and the nugget growths were suggested to be due to radial heat losses and under estimation of the heat generation at the faying surface.Cho and Cho-1989 [3] presented a theoretical basis for thermal behaviour of resistance spot welding. Finite difference models were developed to predict the temperature and voltage distributions during nugget

formation, incorporating the thermal–electrical interaction at the faying surfaces. Tsai-1991, 1992 [4-5] created a two-dimensional axisymmetric model using ANSYS to perform some parametric studies on the spot welding process.

In the finite element analysis procedure, the temperature-dependent contact resistance and material properties were taken into account. Nugget growth was presented under various welding conditions. Feulvarch E-2004, 2006 [6-7] presented a finite element formulation to measure the interface contact properties. It was shown that the calculated nugget appears earlier. It was also noticed that the nugget grows faster across the thickness. Hou-2007 [8] developed a 2D axisymmetric thermo-elastic–plastic FEM model using ANSYS software package. The objective of this study was to investigate the behaviour of the mechanical features during the RSW process. They studied the distribution and change history of the contact pressure at both the faying surface and the electrode–workpiece during spot welding. The deformation of the weldment and the electrode displacement due to the thermal expansion and contraction were also calculated. They observed that the electrode displacement has a direct correlation with the nugget formation, and suggested utilizing this parameter for quality monitoring and process control in RSW. Rogeon-2008 [9] determined the contact conditions at the interfaces electrode–sheet and sheet–sheet. They measured electrical contact resistances depending to the temperature and under pressure in their work.

Shamsul and Hisyam-2007 [10] studied the RSW of austenitic stainless steel type 304. They found that the nugget size does not influence the hardness distribution. In addition, increasing welding current does not increase the hardness distribution. Lately, Eisazadeh-2010 [11] developed an incremental finite element model for parametric study of nugget size in resistance spot welding process. They used published experimental data to verify their model, and investigated effects of contact resistance and electrode force on nugget size and shape.

They found that with increasing electrode force, nugget size reduces due to decreasing contact resistance. It is well known that nugget size is the key factor that influences the welding quality. American Welding society (AWS), American National Standards Institute (ANSI) and Society of Automotive Engineers (SAE) [12-14] jointly recommended the size of the spot weld nugget diameter for steel according to the following equation $d = 4\,t$.Where „d" and „t" are the nugget diameter and sheet thickness in „mm" respectively.

However to ensure an acceptable weld quality and confidence, understanding the mechanism of heat distribution, and weld formation are one of the key issues to develop an appropriate welding conditions. Due to a large number of pertinent parameters; such as the geometry and materials of sheet products, electrodes, and dynamic characteristics of process and welding machines, it is therefore a difficult task to manage the time-to market of new products, especially when joining complex geometries and new metal combinations. The development of sheet combinations and optimization of process parameters setting in the industry are strongly dependent on the personal experience of welding engineers, which is often based on a trial-and-error method. This involves a great number of running-in experiments with real welding, destructive tests, and metallographic studies. The advantage of applying numerical modelling for resistance welding processes is obvious, especially for joining complex geometries and novel metal combinations. Recent advanced numerical modelling can be therefore an approach to disclose the internal physical phenomena and a promising predictive tool for an innovative resistance welding process. In this study, a two-dimensional axisymmetric finite element model with contact elements has been developed to investigate the distribution of temperature and nugget formation during resistance spot welding as well as to study the effects of welding parameters such as applied welding current,electrode force and welding time on the nugget size. The results of finite element analyses are compared with the experimental measurements. The contribution of this work contains following three parts:

[1] The entire welding process was viewed as a coupled electrical-thermal-mechanical process.

[2] Development of an effective finite element model to describe the resistance spot welding.

[3] Conduct extensive experiments and result data analysis to verify the effectiveness of this finite element model.

II. Experimental Procedure

The material used in this study is SS 304 austenitic stainless steels are themost common and familiar types of stainlesssteel. They are most easily recognized as nonmagnetic.They are extremely formable and spot weldable, and they can be successfully usedfrom cryogenic temperatures to the red-hot temperaturesof furnaces and jet engines. Austeniticstainless steel metal sheets of thickness of0.8 mm and 1.0 mmand the length of the coupons is 80 mm and width of the coupons is 40 mmfor both the lap sheet thicknesses. The experiments involved joining of two layer of sheet metal of 0.8 mm and 1.0 mm thickness were chosen as the base metal for this study.The chemical composition of the investigated steels is given in Table 1. Spot welding was performed using a calibrated 15 kVA, AC pedestal type resistance spot welding machine operating at 415 V, 50 Hz, controlled by a Programmable Logic Controller (PLC). Spot Welding was conducted using an upper electrode of45° truncated cone with a 10 mm face diameter and lower electrode of flat tipped cylindrical in shape with a face diameter of 30 mm.To investigate the effect of Electrode force, welding time and welding current on

nugget size, series of test-specimens of the same material wasspot welded, by varying spot weld parameters for two lap sheets as per the details in table 2.The arrangements of spot weld coupons before and after spot welding of both two lap sheets of different thicknesses are shown in figure1 and 2.

Designation	Maximum percentage of alloying elements							
	C	Cr	Ni	Mn	Si	P	S	N
SS 304	≤ 0.07	17.0 to 19.5	8.0 to 10.5	≤ 2.0	≤ 0.045	≤ 0.045	≤ 0.015	≤ 0.11

Table 1: Chemical composition SS 304 Austenitic stainless steel

S. No.	Thickness of the sheets in mm	Spot Welding Parameters		
		Welding Current in kA	Electrode Force kN	Welding time in cycles
1.	0.8 mm (80mm×40mm)	3.0	1.6	75
2.		3.5	1.8	100
3.		4.0	2.0	125
4.		4.5	2.2	150
5.	1.0 mm (80mm×40mm)	3.0	1.6	75
6.		3.5	1.8	100
7.		4.0	2.0	125
8.		4.5	2.2	150

Table 2:RSW Parameters used for investigating their effect on Nugget size for two lap sheets

Fig.1

Fig.2

III. Simulation of SS 304 Austenitic Stainless Steel-RSW Via FEM

The objective of this study is to develop a multi-coupled method to analyse the thermal and mechanical behaviours of RSW process, reduce the computing time with the minimum loss of accuracy and get more adequate information of the process, improve the quality monitoring and process control of RSW. Apractical model of Resistance spot welding process for two lap sheetsis used.Welding current (I) and Welding force (F) applied to the electrodes are electrical load and mechanical load, respectively. The thermal boundary condition, electrical boundary condition (current boundary and potential) and displacement boundary conditions are also shown in these figures 3 & 4. As simply described in the above sections, the spot welding process couples electrical field, thermal field and mechanical field including the contact states at the interfaces between worksheets and electrodes.

IV. Governing Equations

The RSW process can be simulated as axisymmetric problem. The governing equation for as axisymmetric transient thermal analysis is given by:

$$\frac{\partial}{\partial r}\left(k\frac{\partial T}{\partial r}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+\frac{k}{r}\frac{\partial T}{\partial r}+q_V = \rho C\frac{\partial T}{\partial t}(1)$$

It is convenient to introduce cylindrical coordinates to solve the problem. Assumingsymmetry of the processes with respect to the electrode axis it is possible to reduce thenumber of dimensions to two without loss of generality.Where „r' and „z' are radial and axial coordinates and „ρ' is the density of the material; „C' is the specific heat capacity; „T" is the temperature as a function of coordinates and time; „t" is the time; „k' is the thermal conductivity;and qv is the rate of internal heat generation per unit volume.All the material properties are considered to be temperature dependent. The thermal boundary conditions can be decomposed from the nonlinear isotropic Fourier heat flux constitutive relation:

$$q = -k\nabla T(2)$$

On the boundary surface, there is

$$\mathbf{q} = -\mathbf{k}\frac{\partial \mathbf{T}}{\partial \mathbf{n}} \quad (3)$$

Where „q" is the heat flux through the boundary surface; „n" is the outward normal to the surface. The governing equation of the electrical analysis is

$$\frac{\partial}{\partial \mathbf{r}}\left(\mathbf{C_e}\frac{\partial \emptyset}{\partial \mathbf{r}}\right) + \frac{\mathbf{C_e}}{\mathbf{r}}\frac{\partial \emptyset}{\partial \mathbf{r}} + \frac{\partial}{\partial \mathbf{z}}\left(\mathbf{C_e}\frac{\partial \emptyset}{\partial \mathbf{z}}\right) = \mathbf{0} \quad (4)$$

Where, Ce′ is the electrical conductivity; „ф" is the electrical potential.The coupled thermal electrical problem is solved by the following matrix equation:

$$\begin{bmatrix} [\mathbf{C^t}] & [\mathbf{0}] \\ [\mathbf{0}] & [\mathbf{0}] \end{bmatrix} \begin{Bmatrix} \{\dot{\mathbf{T}}\} \\ \{\dot{\mathbf{V}}\} \end{Bmatrix} = \begin{bmatrix} [\mathbf{K^t}] & [\mathbf{0}] \\ [\mathbf{0}] & [\mathbf{K^v}] \end{bmatrix} \begin{Bmatrix} \{\mathbf{T}\} \\ \{\mathbf{V}\} \end{Bmatrix} = \begin{Bmatrix} \{\mathbf{Q}\} \\ \{\mathbf{I}\} \end{Bmatrix} \quad (5)$$

Where Ct is the thermal specific heat matrix; Kt the thermal conductivity matrix; Kv the electric coefficient matrix; T temperature vector; V the electric potential vector; {Q} the heat flow vector; and {I} is the current vector.

For the structural analysis, the stress equilibrium equation is given by

$$\nabla \boldsymbol{\sigma}\{\mathbf{r}, \mathbf{t}\} + \bar{\mathbf{b}}(\mathbf{r}, \mathbf{t}) = \bar{\mathbf{0}} \quad (6)$$

Where „σ' is the stress; „b' is the body force, „r' is the coordinate vector.

The constructive equation of the material based on the thermo-elastic-plastic theory is given by

$$\mathbf{d}\{\boldsymbol{\sigma}\} = [\mathbf{D}]\mathbf{d}\{\boldsymbol{\varepsilon}\} - \{\mathbf{C}\}\mathbf{dT} \quad (7)$$

$$\{\mathbf{C}\} = -[\mathbf{D^e}]\left(\{\boldsymbol{\alpha}\} + \frac{\partial [\mathbf{D^e}]^{-1}}{\partial \mathbf{T}}\{\boldsymbol{\sigma}\}\right) \quad (8)$$

Where {σ} is the stress vector; [D] is the elastic-plastic matrix; {ε} is the strain vector; [De] is the elastic matrix; and {α} is the coefficient of thermal expansion.

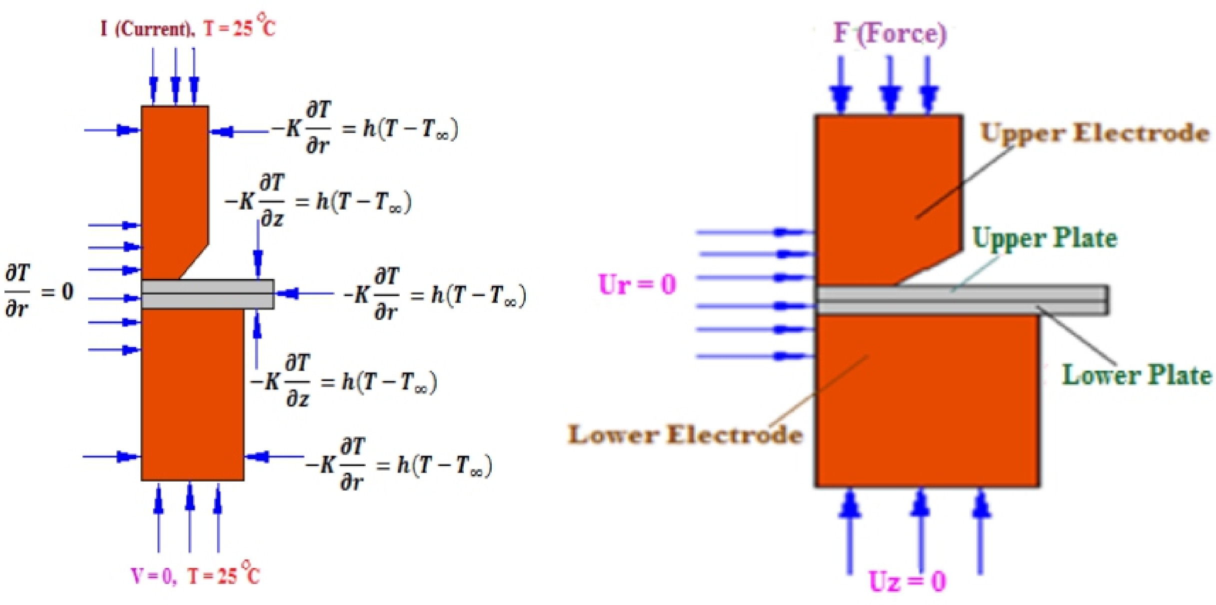
V. Modeling and Parameters

Figure 3 & 4 illustrates the 2-dimensional axisymmetric FEA model of RSW process built in program, where X and Y represent the faying surface and the axisymmetric axis respectively.Its corresponding dimensions for 0.8 mm and 1.0 mm thickness sheets are tabulated in Table 4.2-D axisymmetric model of twolap sheets joining with the application of flat cylindrical lower electrode is constructed. Both electrical-thermal and mechanical contact elements are specially treated at the electrode-to-sheet and sheet-to-sheet interface. The imposed boundary conditions and representative mesh model can be found in Fig.4. It is worth noting that in the mechanical analysis, elements of type "Plane 42" and in the electro-thermal model, elements of type "Plane 67", having capabilities of thermal, electrical and thermal electrical analyses were used. There were three contact areas in the model, two contact areas representing the electrode–sheet interface and one representing the sheet–sheet interface. The contact pair elements "Targe169" and "Conta171" were employed to simulate the contact areas. Contact occurs when the element surface penetrates one of the target segment elements (TARGE169) on a specified target surface. Any translational or rotational displacement, forces, moments, temperature, voltage and magnetic potential can be imposed on the target segment element.In the finite element analysis 2507 elements and 8051 nodes for 0.8mm thickness plate and 2635 elements and 8439 nodes for 1.0mm thickness plate have been employed.

In each analysis, the model is meshed using contact elements as shown in fig.4 the solid element is employed to simulate the coupled interaction between the sheets and electrodes. In order to correctly couple and transfer the data the model must have identical mesh both in the electrical –thermal analysis and in the thermoelastic and plastic analysis. Whereas the element types are different or have different degree of freedom options as shown in Table 5.

Dimensions	US=LS	AC=BD	UA	UH	UF	ED	LL	UB
Value(mm)	0.8 or 1.0	15	12	30	8	3	16	45º

Table 4

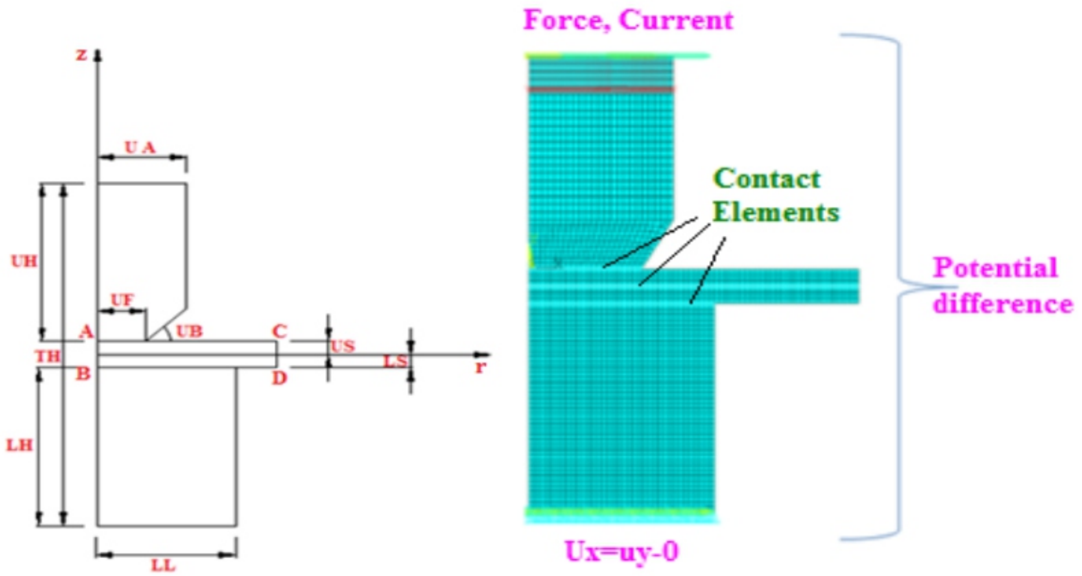


(3a) **(3b)**

Fig. 3 a, b, c: The Computational Domain and Boundary Conditions

VI. Interface Elements

The contact between an electrode and a sheet or between two sheets was modeled by the interface elements Ma and Murakawa, 2009 [15] as shown in Fig. 5. If the strain 'εn' of the interface element in the normal direction 'n' of the contact interface is larger than −1.0, the state of the interface is the non-contact state. In the initial state and non-contact state, the electrical conductivity 'Ce'thermal conductivity 'k' and Young‟s modulus 'E' will be zero. This means that current flow through the interface element and heat generation will be zero at the inter-face element. If the strain 'εn' of the interface element in the normal direction n of the contact interface is equal to or less than −1.0, the state of the interface is the in-contact state. In the contact state, the electrical conductivity Cethermal conductivity k and Young‟s modulus E will be a given value, respectively. This means that current flows through the interface element and heat is generated at the interface element. In the state, the interface element has a strong stiffness. The material properties of interface contact elements used for the analysis of the electrical field, thermal field and mechanical field are independent from worksheets and electrodes. Therefore, the contact resistance can also be considered if it is known. The formulation of the interface element has no much difference from the ordinary element except the material properties and their changes with the contact states. Therefore, it is relatively simple and reliable to deal with the electrical–thermal–mechanical contact between two faces for the spot welding process simulation.



(3c) Fig.4: The FEA model for two lap sheets

Prior to welding, the electrical initial conditions are set equal to zero, while the temperature of entire structure is maintained at temperature of 25°C. During the welding cycle, the welding current is applied at the top of the upper electrode and zero potential is imposed at the bottom surface of the lower electrode. Consequently, the current flows from the upper electrode, passes through work piece and terminates at the bottom annular section of the lower electrode. Both force and current are modelled from practical welding signals and defined as a time-dependent function.

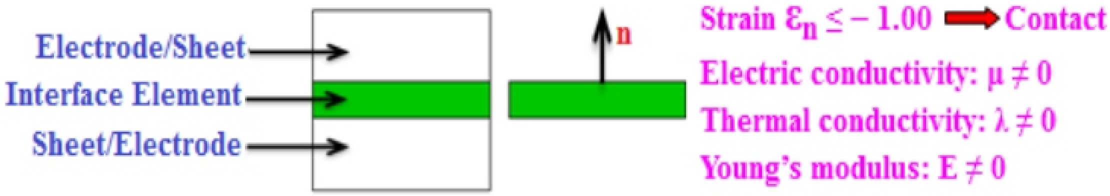


Fig.5: Contact elements

Analysis	Electrical-Thermal	Thermo-Elastic-Plastic
Solid	PLANE 67	PLANE 42
Contact element type	CONTA 171/TARGE169	CONTA 171/TARGE169
Degree of freedom (for contact element)	TEMP, VOLT	UX, UY

Table 5: Element types and degree of freedom options

VII. Mechanical Boundary Conditions

Uniform load was applied at the top of the copper electrode during welding and holding cycle. The electrode was removed at the end of the holding cycle. At the faying surface between the electrode and the workpiece, a conta 171 element was used. At the faying surface between workpiece and workpiece, the vertical displacement of the part of faying surface under electrode was set to zero, and a subroutine program was used to determine if the other part of faying surface is under contact or not. If some nodes are under contact and are under pressure stress, a zero vertical displacement was applied here.

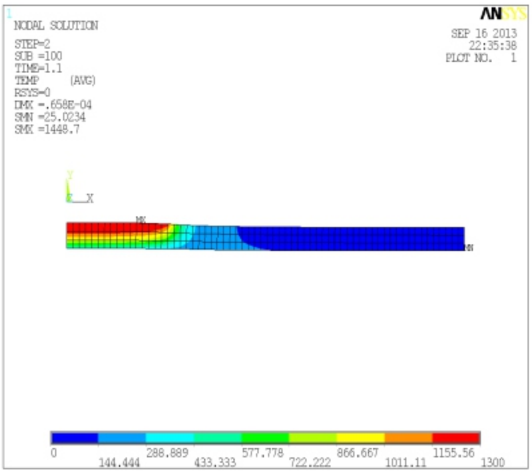


Fig. 6a

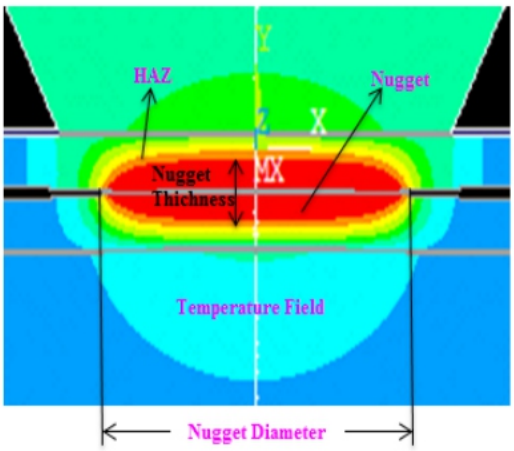


Fig. 6b

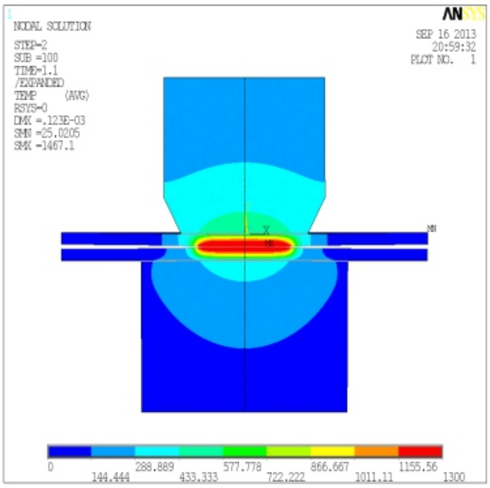


Fig. 6c

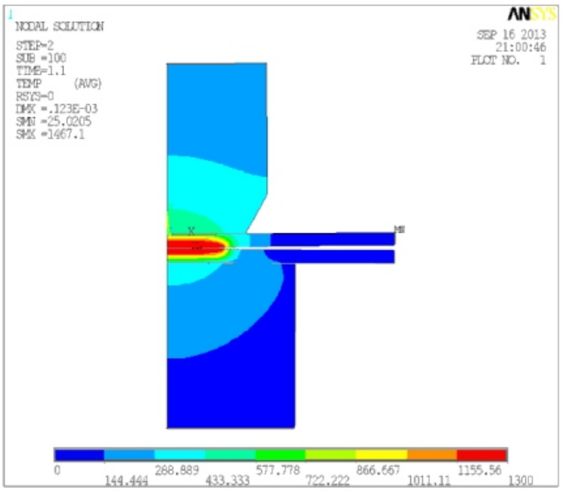


Fig. 6d

VIII. Results and Discussions

In this study, a coupled thermal-electro-mechanical finite element model is presented for predicting temperature distribution and spot nugget size in a spot welded steel joint. By providing the necessary information and boundary conditions, simulations were performed for three combined analysis during different stages of welding cycle.The thermal, electrical and mechanical properties of electrode and work piece are given in Table 6 and Table 7. Because the materials are subjected to a wide range of temperatures, most of these properties are considered as temperature dependent.To verify the simulation results, weld experiments were done under the same welding conditions. Comparisons were made between simulation and experimental results of the nugget diameter and they are shown in the Fig.8. There is generally good agreement between simulation and experimental results for most of the experiments for two lap sheets spot weld.Fig. 3 shows the geometry used for the modeling purpose.

It is observedthat the highest temperature is always at the center of faying surfaceduring the whole RSW process. In addition, the temperatureof the faying surface is higher than that of the electrode–sheetinterface.The region which experiences the melting temperature during welding process is determined as weld nugget. Fig.7 shows temperature distribution of the weldment at the end of welding cycles and the nugget size determined for parameters of sample 1and Fig. 6 shows nugget geometry details.

Temperature °C	Thermal conductivity J/m.°C		Electrical resistivity μΩ.m		Contact resistivity $\Omega.m^2 \times 10^{-7}$	Specific Heat J /(kg.°C)	
	Stainless Steel	Copper Electrode	Stainless Steel	Copper Electrode	Faying surface	Stainless Steel	Copper Electrode
20	14.6	390.3	0.604	26.4	2.38	462	397
93		380.6		30.0	2.31		402
100	15.1		0.702		2.25	496	
200	16.1	370.1	0.774	40.0	2.12	512	419
300	17.9		0.858		1.93	525	
316		355.1		50.5	1.79		431
400	18.0		0.922		1.31	540	
427		345.4		61.9			440
538		334.9		69.9	0.567		465
600	20.8		1.001			577	
649		320		80.0			477
760		315.5		89.8	0.492		
800	32.2		1.120		0.417	604	
871		310.3		94.8	0.342		
982		305		99.8			502
1200			1.210			676	
1300	33.7		1.280			692	
1480	120					700	

Table 6: Thermal and electrical properties of the employed SS304 andcopper electrodes.

Temp-erature °C	Young's Modulus G P_a		Yield stress M P_a		Poisson's ratio		Coefficient of thermal expansion (C-1 x 10^{-5})		Density Kg/m^3	
	Stainless Steel	Copper Electrode	Stainless Steel	Copper Electrode	Stainless Steel	Copper Electrode	Stainless Steel	Copper Electrode	Stainless Steel	Copper Electrode
	198.5	124	319		0.294		1.70	1.65	7900	8900
93		105						1.67		
100	193		279		0.295		1.74		7880	
200	185	93	238		0.301		1.80	1.71	7830	
300	176		217	83	0.310	0.32	1.86		7790	
316		82						1.75		
400	167		198		0.318		1.91		7750	
427		55						1.78		
538		38						1.84		
600	159		177		0.326		1.96		7660	
649		25						1.85		
760		16						1.89		
800	151		112		0.333		2.02		7560	
871		14						1.93		
982		7								
1200	60		32		0.339		2.07		7370	
1300	20		19		0.342		2.11		7320	
1480	10		8		0.388		2.16		7320	

Table 7: Mechanical properties of the employed SS304 andcopper electrodes

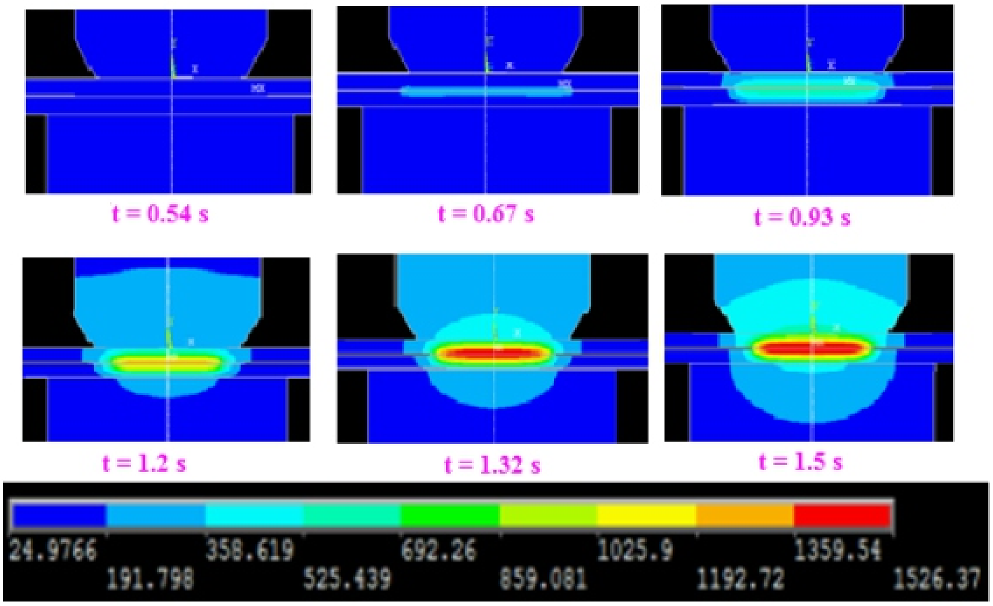


Fig.7

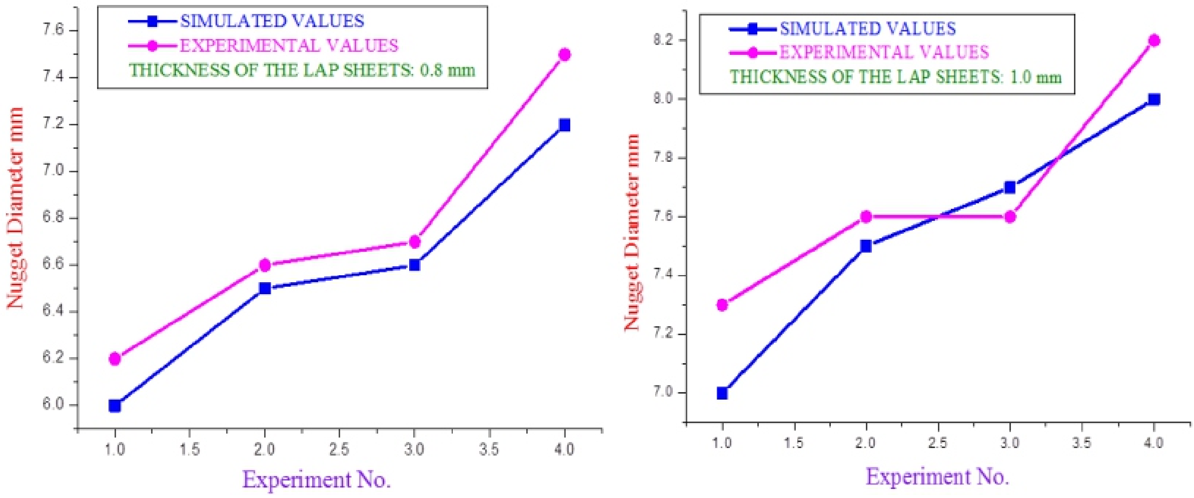


Fig. 8

IX. Conclusions

A comprehensive simulation model using FEM for the analysis of resistance spot welding process has been developed. It has been observed that the finite element modeling of the resistance spot welding process can provide good simulation, if the model includes the electro-thermal-mechanical interaction and good temperature dependent material properties. This finite element model so developed can calculate most of the resistance spot welding responses in terms of nugget diameter, depth of penetration, the extent of heat affected zone, electrode face heating etc. Finally this FEM model will certainly help in optimizing process parameters combinations in any industrial application of resistance spot welding process.

A multi coupled electro-thermal and thermo-elastic-plastic analysis is developed and carried out on the transient thermal and mechanical behaviors of the RSW process. The results provide informationon the development of the weld nugget and thus predictthe welding quality prior to the actual welding process.Based on the ANSYS software, this multi coupled method can efficiently provide sufficient details of the RSW and benefit to the quality monitoring and process control of RSW. Finite element analysis can be very useful as an off-line observation tool to estimate the influence of welding parameters on the welding quality and to predict/improve the weld geometry.

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Performance Enhancement of Sugar Mill by Alternate Cooling System for Condenser

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A B S T R A C T

Agro industry plays a crucial role in the industrialization process of developing countries. Sugar industry is second largest agro industry in the world. In sugar manufacturing plants there are various processes for production of sugar i.e. extraction of juice, clarification, evaporation, concentration of juice, forming and separating crystals etc. These processes consumed energies in the form of mechanical energy, electrical energy and heat energy. So there are various sources of waste heat in sugar factory i.e. waste heat from hot flue gasses, hot water from evaporative body and boiler blow down. The large amount of waste heat passes from various devices of sugar factory causes decrease in the efficiency of sugar plants, and also increase the "Global Warming" which is very dangerous for our environment. The present cooling system for condenser is inappropriate & hence decrease vacuum in evaporators and pans. This will increase the boiling point temperature of juice. The proposed cooling system gives solution of both problems. The most important source of waste heat i.e. hot flue gases are use to run absorption chiller. The absorption chiller gives better cooling system for condenser. There will be improvement in condensation of vapour in condenser which will cause increase vacuum in evaporators and pans thereby reducing boiling point temperature of juice. This reduced boiling point temperature of juice requires less amount of steam for boiling, ultimately saving of bagasse and fuel economy can be attained. Thus this arrangement can be treated as the efficient method of utilization of waste heat for cooling condenser water in sugar factory thus saving further depletion of natural resources like coal, petroleum or else increasing its availability to other important processes and one can hope that the "waste heat recovery" may play an even greater role in the industrial development in this new millennium.

Key word: Boiling of juice, bagasse yields, crushing, scrubbing system, vacuum measurement, gur.

I. Introduction

The sugar industry processes sugar cane and sugar beet to manufacture edible sugar. More than 60% of the world‟s sugar production is from sugar cane, the balance is from sugar beet. Sugar manufacturing is a highly seasonal industry, with season lengths of about 6 to 18 weeks for beets and 20 to 32 weeks for cane. Approximately 10% of the sugar cane can be processed to commercial sugar, using approximately 20 cubic meters of water per metric ton (m3/t) of cane processed. Sugar cane contains 70% water; 14% fiber; 13.3% saccharose (about 10 to 15% sucrose), and 2.7% soluble impurities. Sugar canes are generally washed, after which juice is extracted from them. The juice is clarified to remove mud, evaporated to prepare syrup, crystallized to separate out the liquor, and centrifuged to separate molasses from the crystals. Sugar crystals are then dried and may be further refined before bagging for shipment. In some places juice is extracted by a diffusion process that can give higher rates of extraction with lower energy consumption and reduced operating and maintenance costs. For processing sugar beet (water, 75%; sugar, 17%), only the washing, preparation, and extraction processes are different. After washing, the beet is sliced, and the slices are drawn into a slowly rotating diffuser where a countercurrent flow of water is used to remove sugar from the beet slices. Approximately 15 cubic meters (m3) of water and 28 kilowatt-hours (kWh) of energy are consumed per metric ton of beet processed. Sugar refining involves removal of impurities and decolonization. The followed include, affixation, melting, clarification, decolonization, evaporation, crystallization, and finishing. Decolonization methods use granular activated carbon, powdered activated carbon, ion exchange resins, and other materials.

II. Methodology

1.1 Raw Sugar Milling with Present Cooling System:

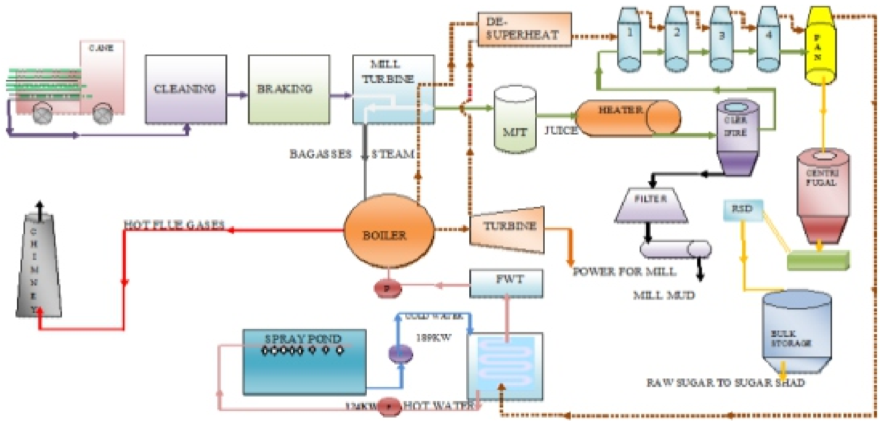

Fig.1.1 Raw Sugar Milling with Present Cooling System

Cane Unloading: Mature canes are gathered by a combination of manual and mechanical methods. Cane is then placed into large piles and picked up, tied, and transported to a sugar factory by means of tractor, truck, or bull car etc.

Cleaning: Canes are cut at ground level, its leaves are removed and the top is trimmed off by cutting off the last mature joint. This process is known as “primary cleaning”.

Cane Braking: Stalks are thoroughly washed and cut when reaching the sugar mill. After the cleaning process, a machine led by a series of rotating knives, shreds the cane into pieces. This is known as “grinding.”

Mill Turbine: After grinding, hot water is sprayed on to the sugarcane then crushed in mill turbine for extract the juice. The crushing process must break up the hard nodes of the cane and flatten the stems. The juice is collected, filtered and sometimes treated and then boiled to drive off the excess water. The dried cane residue (bagasse) is often used as fuel for this process.

Clarifiers: Juice should be filtered through a cloth before boiling in order to remove any solids such as dirt or particles of cane. Large-scale sugar processors add lime to the juice in order to coagulate impurities which then settle out. The juice is then neutralized with sulphur dioxide. Small-scale producers add a variety of clarificants to the juice including wood ash. All of these have the effect of settling out impurities.

Evaporation (Juice Boiling): The clear juice which results from the clarifying process is put under a vacuum, where the juice boils at a low temperature and begins to evaporate. It is heated until it forms into thick, brown syrup. This is done in large pans over open fires or simple furnaces. The essential requirement is for clean pans and tools. Sediment settles to the bottom of the pan during boiling and is dredged out. Scum rises to the top and is skimmed off both of these wastes can be fed to cattle. A large pan such as that pictured in figure 3.1 would hold about 100 kg of juice reducing to around 20kg of gur. The pans are usually made from galvanized mild steel sheets.The boiling point temperature of juice about 105°C.The end point of the boiling process is judged from

experience; from the sight and sound of the boiling juice. After boiling of juice vapour passes from vacuum pans and then passing through condenser for phase change process and feed hot water to boiler.

Centrifugal:

By evaporating what little water is left in the sugar syrup, crystallization takes place. Inside a sterilized vacuum pan, pulverized sugar is fed into the pan as the liquid evaporates, causing the formation of crystals. The remaining mixture is a thick mass of large crystals, which is sent to a centrifuge to spin and dry the crystals. The dried product is raw sugar, still inedible.

Bulk Storage: After screening, the finished, refined granulated sugar is sent to conditioning bins, and then to storage bins prior to packaging or bulk load out. Almost all packaged sugar uses multiwall paper containers, cardboard cartons, or polyethylene bags; bulk load out is the load out of the sugar to specially designed bulk hopper cars or tank trucks.1.2 Steam Condenser:A steam condenser is a device or an application in which steam condenser and heat released by steam is absorbed by water. The hot water feed into boiler by means of feed pump. It serves the following purposes:o It maintains a very back pressure on pans and evaporators side in sugar manufacturing plant. The thermal efficiency of a condensing unit therefore is higher than that of non condensing unit for the same available steam.

1.2.1Condenser Efficiency:

It is defined as the ratio of the difference between the outlet and inlet temperatures of cooling water to the difference between the temperature corresponding to the vacuum in the condenser and inlet temperature of cooling water.

$$\text{Condensre efficiency} = \frac{\text{Rise in tempratuer of cooling water}}{\text{Temp. corresponding to vacuum in condenser - Inlet temp. of cooling water}}$$

$$= \frac{(tw_2 - tw_1)}{(ts - tw_1)}$$

Where: - tw1 = temp. of incoming water to cond.

tw2 = temp. of outgoing water from cond.

ts = saturation temp. of steam

o Its main function in sugar manufacturing plant is to condense the exhausts steam from the vacuum pans and thus recover the high quality feed water for reuse in the plant.

o A more useful function is to create a vacuum pressure (in case of using enclosed box for heat exchange) and thus maintain back pressure for evaporators and pans.

1.2.2Vacuum Measurement:The term vacuum in case of a condenser pressure below atmospheric pressure. It is generally expressed in mm of mercury. The vacuum is measured by means of a vacuum gauge. Usually for calculation purpose the vacuum gauge reading is corrected to standard barometric reading 760 mm as follows.

Corrected vacuum in mm of Hg = (760 - absolute pressure in mm of Hg)

= 760 – (actual barometric height – actual vacuum).

o By increasing the back pressure:

- Reduces the boiling temperature of juice.
- Increases the plant efficiency.
- Reduces the steam flow rate.

1.3 Determining the Waste Heat Quantity:

In any heat recovery situation it is essential to know the amount of heat recoverable and also its usage. The total heat that could be recovered can be calculated using this formula.

$$Q = V \times \rho \times C_p \times \Delta T$$

Where, Q = the heat content in kcal.

V = the flow rate of the substance in m3/hr.

P = the density of the flue gas in kg/m

Cp = the sp. heat of substance in kCal/kgoC.

ΔT = temperature difference in oC3.

1.4 Identifying Waste Heat Sources in Sugar Factory:

1.4.1 Boiler Flue Gases:

• Boiler flue gases are major sources of waste heat in sugar factory.

• The essential quality of heat is not the amount but rather its “value”. The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved.

• Large quantity of hot flue gases is generated from boilers, kilns, ovens and furnaces. If some of this wastes heat could be recovered. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and loss minimized by adopting following measures as outlined in this chapter.

1.5 Limitations of Present System:

The power consumption for pumps -313 kW. For pumping hot water from condenser to spray pound –2pumps of 124kW.For pumping cold water from spray pound to condenser – 3pumps of 189kW.

Steam to Bagasse ratio – Approximately 1.8 to 2, that is1.8-2 kg of steam required 1 kg of bagasse.

Increase in temperature of incoming water affects condensation of vapours in condenser and in turn affects vacuum in evaporator body.

Increase in boiling point of juice in the evaporative body increases the steam and bagasse consumption.

Large quantity of cooling water is needed for cooling the condenser.Proposed cooling system for condenser which shown in fig.3.4 is efficient cooling system for condenser. The basic aim of this system is reduction in the inlet temp of cooling water by incorporating a vapour absorption unit `which runs on waste heat in boiler flue gases.

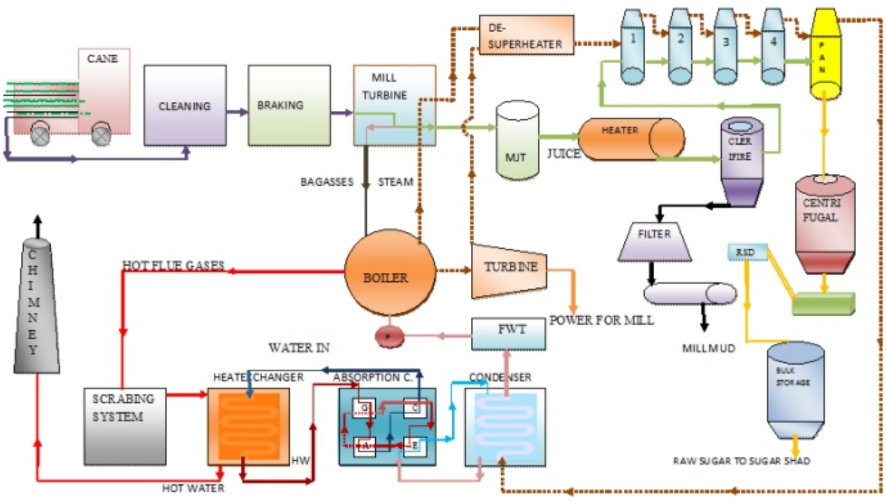

Fig.1.2 Raw Sugar Milling with Proposed Cooling System

Components-

Scrubbing system to remove suspended matter from hot flue gases.

A heat exchanger between flue gas and water.

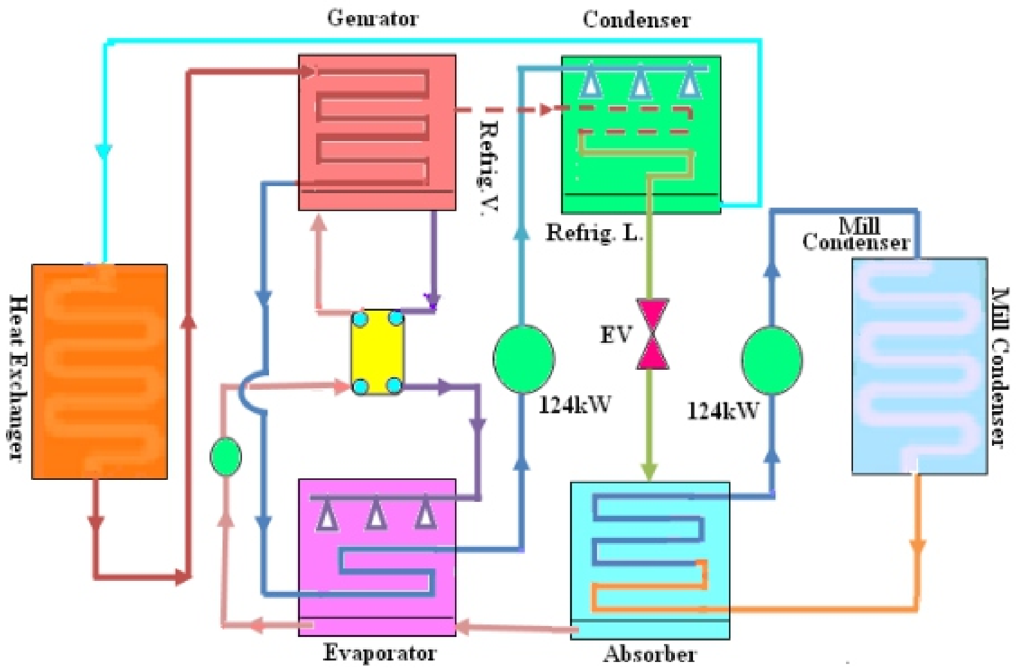

Fig. 1.3 Absorption Chillier with Proposed Cooling System

1.6 Benefits from Proposed System:

Flue gases from boiler will be passed through a scrubbing system where the suspended matter and unborn particles will be removed.

Then this gas will be passed through a heat exchanger where the water will be heated by flue gases.

This hot water will be then used as heat source for the absorption refrigeration system. The hot water from the condenser will be passed through the absorption refrigeration machine where its temperature will be decreased.

This cold water will be then passed to the condenser for cooling purpose. Proposed system will be able to cool the condenser cooling water to lower temperature.

The power required for spraying the water will be saved. The power will be required for pumping the condenser water through the absorption chillier and heat exchanger. It is proposed to estimate the saving in power by this arrangement.

It also expected because of low temperature of cooling water rate of condensation of cooling water will be more and it will create more vacuum in the evaporator and pans. This will lower down the boiling point in the evaporator and it will reduce steam consumption and ultimately result in bagasse saving.

As the particulate matter in gases is reduced due to scrubbing system, it will reduce the pollution at the factory site.

As the temperature of cooling water is less the quantity of water required for condensing vapours will also is less. This will result in saving of water when there is scarcity of water. Low boiling temperature will improve the quality of sugar.

III. Result & Discussion:

2.1Calculation of Waste Heat Sources in Sugar Mill:

There are number of waste heat sources in sugar factory i.e. boiler flue gases, boiler blow down water, and hot water over flow. The amount of waste heat can be calculated below.

2.1.1 Boiler Flue Gases:

The major source of waste heat is boiler flue gases and the value of waste heat can calculated below.

Waste heat content of flue gases [10];

Q = 4.187K ((1-W) (1.4M-0.13) +0. 5) * t

Where:-

Q Amount of waste heat in flue gases kJ/kg.

K = K1*K2

K1 = % of bagasse in cane (28 % factory data)

K2 = Quantity of cane required to get unit quantity of sugar.=11(data of factory).

W = Moisture content in bagasse average

= 50 % (from data of factory).

M = Ratio of actual air to theoretical air. = 1.4

t = Temp of fine gases going to chimney.

= 180°C (from data of factory).

Thus waste heat content in flue gases can be calculated as

Q = (4.187) (0.28) (11) (1-0.5) (1.4*1.4-0.13) +0.5)*180

Q = 3285 kJ/kg of sugar.

2.1.2 Boiler Blow down Water:

The second largest waste heat source in sugar factory is boiler blow down water. The amount of heat content of blow down can be calculated as.Blow down to control the amount of Total Dissolved Solid (TDS) in the boiler water for smooth operation.Blow down amount varies from 2 to 3 % of evaporative capacity or steam generation rate.

Q = Mb. Cb. Tb

Where: Q = Heat carried in KJ/kg of sugar

Mb = Average quantity of blow down in kg/kg of sugar

= 2.5 % of evaporative capacity of boiler (from data of factory)

= 0.025 * (50% of cane crushed)

= 0.025 * (0.5 * 11) per kg of sugar

Cb = Sp. Heat of water = 4.187 kJ/kg K

Tb = temp of blow down = 340 °C (from data of factory)

Q = 0. 025 (0.5 *11) * 4.187*340

Q = 195.7 kJ/kg of sugar

2.1.3 Hot Water Overflow:

Other source of waste heat is hot water overflow in sugar factory. Condensate from 1 and 2 evaporators body is used as feed hot water for 3 and 4 evaporators body and pans for the process. Normally the condensate produced is more than that required for the process. By measuring the excess quantity of hot water, heat carried by excess water can be calculated.

Q = Mc.Cc.Tc

Where: - Mc = quantity of surplus condensate

= 7.5% of cane crushed (data factory)

= 0.075 * 11

Cc= 4.187 kJ/ kg K

Tc = temp of hot water = 65°C

Q = (0.075) (11) (4.187) (65)

Q = 224.5 kJ/kg of sugar

2.2 Results of Present Cooling System:

• Vapours from evaporators and vacuum pans enter in condensers at about 60-65°C. The heat from vapour is absorbed by cold water introduced in the condenser. The temperature of this cold water is around 30-35°C. The heat exchange between vapours and water is affected by

o Contact time of vapours with cold water.

o Contact surface offered by cold water to vapours.• The temperature of outgoing water (45-50°C) from condenser, after cooling the incoming vapour from evaporators and pans. The temperature of incoming and outgoing water changes according to ambient conditions.tw2=44°C (from company data)

• Warm water leaving the condenser flows in spray pond by gravity channel, and cooling with the help of spray nozzles. The cooling water temperature around 35-40°C returns through gravity channel and it is pumped to the condenser. Thus it is a closed system. tw1 = 37°C (from company data)

This temperature of cooling water at inlet to condenser (tw1 = 37°C). So the present cooling system for condenser is inappropriate and hence decrease vacuum in evaporators and pans. This decreased vacuum in evaporators causes increases the boiling point temperature of juice from 102°C to 106°C.

2.2.1 Vacuum Measurement:

Corrected vacuum in mm of

Hg = (760 - absolute pressure in mm of Hg)

=760–(actual barometric height – actual vacuum)

Absolute pre. = 680 mm of Hg company data)

= 760 – 680 in mm of Hg

= 84× 0.001333bar

= 0.11196bar

Saturation temperature of steam corresponding to the condenser vacuum ts = 48°C (steam table).

2.2.2 Condenser Efficiency:

$$\text{Condenser efficiency} = \frac{(tw_2 - tw_1)}{(ts - tw_1)}$$

$$= \frac{(44^\circ - 37^\circ)}{(48^\circ - 37^\circ)}$$

= 61.54%

2.2.3 Power Consumption:

In present cooling system there are five pumps use for cooling the condenser water. The total power consumption for pumps 313kWh. (From data of factory)o For pumping hot water from condenser to spray pound – 2pumps of 124kWh.o For pumping cold water from spray pound to condenser – 3pumps of 189kWh.

2.2.4 Bagasse Consumption:

Bagasse calculation are: bagasse in cane 28%, bagasse generated 32.2 tones/h, bagacilo 0.47tones/h, bagasse losses 0.1tones/h, so net bagasse 31.63 tones/h, 1 tones produce 2.2 tons steam at 87 atm, fuel required 31.3 tonnes/h, surplus bagasse 0.33 tones/h. Increase in boiling point of juice increases the steam and bagasse consumption.

2.2.5 Quality of Sugar:

This temperature of cooling water at inlet to condenser (tw1 = 37°C) is inappropriate and hence decrease vacuum in evaporators and pans. This decreased vacuum in evaporator causes increases the boiling temperature of juice from 102°C to 106°C and decrease the quality of sugar.

2.3 Results of Proposed Cooling System:

The temperature of outgoing water (45-50°C) from condenser, after cooling the incoming vapour from evaporators and pans. The temperature of incoming and outgoing water changes according to ambient conditions. tw2 = 44°C (from company data)

Warm water leaving the condenser flows to the absorption chillier and it is cooled at 30°C. The cooled water around 30°C pumped to the condenser. Thus it is a closed system.Temperature of incoming water to condenser = tw1 = 30°C .This temperature of cooling water at inlet to condenser (tw1 = 30°C) provide appropriate cooling for condenser and hence increases vacuum in evaporator and pans, ultimately results in bagasse saving.

2.3.1 Vacuum Measurement:

Vacuum in mm of Hg = (760 - absolute pressure in mm of Hg)

(Absolute pressure = 667 mm of Hg)

= 760 – 667 in mm of Hg

= 93× 0.001333bar

= 0.123969bar

Saturation temperature of steam corresponding to the condenser vacuum ts = 50.5°C (steam table).

2.3.2 Condenser Efficiency:

$$\text{Condenser efficiency} = \frac{(tw_2 - tw_1)}{(ts - tw_1)}$$

$$\text{Condenser efficiency} = \frac{(44° - 30°)}{(50.5° - 30°)}$$

=68.23%

So by the use of proposed cooling increases the efficiency of condenser.

2.3.3 Bagasse Saving Calculation[from company data]:

o Factory Capacity=2500 TCD

o Temperature of the water=85-90°C

o Qty. of the raw juice=150 m^3 /h

o Temperature of the juice=30° C

o Calorific value of bagasse with 50% moisture 2200 Kcal/Kg

o Working of sugar mill=24 hours 200 Days

o Boiler efficiency=70%

2.3.4 The Possible Heat Recovery and the Saving of Bagasse:

Heat Recovery = Mass x Sp.heat x Temp.diff.

= 20000 x 1 x 30°C

= 6, 00,000 kcal /hr

Saving of Bagasse = 6, 00,000 ÷ 2200 kg/hr

= 272.7273 kg /hr

Saving w.r.t efficiency of boiler = 272.7273 ÷ 0.70 = 389.61 kg /hr

Yearly saving = 389.61 x 24 x 200(company data) = 1870128 kg = 1870 tons/year

The proposed cooling system increase the efficiency of condenser (approximate 07%) and increase vacuum in evaporators and pans. These vacuums decrease the boiling point of juice. (Approximate 6°C).

So by the use of proposed system, fuel (bagasse) saving 1870 tons per year.

2.3.5 The Cost Saving on the basis of the Indian Conditions:

The cost of saving by sale of bagasse

Total bagasse saved per year =1870 tons /yr

Cost of the bagasse per ton =2300Rs/tones

So total saving by sale of bagasse =1870*2300Rs/year.

Additional revenue generated=4301000 Rs/year.

2.3.6 Power Saving:

Present cooling system for condenser required 313kWh power for pumping water from condenser to spray pound and spray pound to condenser. While proposed cooling system required 265kWh power for pumping water for cooling the condenser. So by the use proposed cooling system, power saving around 48kWh

1kWh = 1unit in one hour.

48kWh = 48units/h

There for power saving per day (24 hour) in sugar mill are as:

48*24=1152 units per day

So total power saving per day in Rs, if the cost of one unit

8 Rs 1152*8 = 9216 Rs /day.

Total power saving by proposed cooling system in one year, if 200 days of working in sugar industry:

9216*200 = 18,43,200Rs/year

Total additional revenue generated by sugar mill by use of proposed cooling system.

Saving from bagasse = 43,01,000 Rs/year

Power saving = 18,43,200 Rs/year

Total add. Revenue = 61,44,200 Rs/year

IV. Conclusion

• Energy audit is an important tool to identify the areas of energy conservation in sugar factory.• Waste heat sources in sugar factory are:-

o Boiler flue gases

o Boiler blow down

o Hot condensate

• Most important waste heat source - Boiler flue gasBoiler flue gas heat can be utilized to run absorption chiller.

• The chiller will cool condenser water.

• The proposed alternate cooling system with absorption chiller reduces the power required in spray pond, improvement in condensation of vapours in condenser thereby increasing of condenser efficiency, low boiling point of juice in evaporator thereby saving of steam and bagasse.

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Establishing Relationship between Cbr Value and Physical Properties of Soil

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A B S T R A C T

Subgrade strength is mostly affected by thickness of pavement, in Highway design. California Bearing Ratio (CBR) is the one of the method to determine the sub grade strength.CBR test is laborious and time consuming, hence a method is proposed for correlating CBR value with the LL, PL, SL, PI, OMC and MDD. In the present study, different soils samples (having 20<LL<70) were collected from different locations. Various laboratory tests including Atterberg limit, Specific Gravity, Gradation Analysis, CBR and compaction were performed on the samples. Various linear relationships between index properties and CBR of the samples were investigated using simple and multiple linear regression analysis and also predictive equation estimating CBR from the experimental index values were developed.

Keywords: Coefficient of correlation ® 2, MLRA, Regression, Soaked CBR value, SLRA.

I. Introduction

All civil engineering works such as the construction of highway, building structure, dam and other structure have a strong relationship with soil. All those structures need a strong layer of soil to make sure the structure are strong and stable. The weakness and failure of soil may capable make the structure which builds above of it become weak and collapse or fail. Therefore, the proper analysis of soil is necessary to ensure that these structures remain safe and free endue settling and collapse. Soil conditions vary from one location to another location. Hence it is difficult to predict the behavior of soil. As a result, soil conditions at every site must be thoroughly investigated for proper design.Most of the Indian highways system consists of flexible pavement. There are different methods ofdesign of flexible pavement. The California Bearing Ratio (CBR) test is an empirical method of design of flexible pavement. Sub grade soil bearing capacity plays very important role for the design of highway structure. It determines the thickness of the pavement. In other words, sub grade that has lower CBR value will have thicker pavement compared with the sub grade that has higher CBR value. CBR values can be measured directly in the laboratory test in accordance with IS 2720 part-XVI on soil sample obtained from the site.

However, to conduct a CBR test, representative soil sample has to be collected from the location selected, from which a remoulded specimen has to be prepared at predetermined Optimum moisture content and maximum dry density with standard proctor compaction, for the test to be conducted. To obtain soaked CBR value of a soil sample, it takes about a week, making CBR test expensive, time consuming and laborious. As a result, only a limited number of CBR test could be performed per kilometer length of the proposed road to be constructed. Such limited number of CBR test results may not generally reveal the variation in the CBR values over the length of the road to enable rational, economic and safe construction.

This could be avoided only if a large number of soil sample are taken. But such a procedure will increase the project cost and time. . To overcome these difficulties, an attempt has been made in this study to correlate CBR value statistically with the liquid limit (LL), Plastic limit (PL), Plasticity index (PI), maximum dry density (MDD) and optimum moisture content (OMC) of soil, because these tests are simple and can be completed with less period of time.

II. Experimental Work

Twenty numbers of disturbed soil samples were collected (having different liquid limit) from different locations from in and around the city o Bagalkot district of Karnataka, India. The selected soil samples were tested for CBR value, optimum moisture content, maximum dry density, particle size distribution, liquid limit, plastic limit, shrinkage limit, plasticity index. All these tests were performed according to IS code specification. In this study, regression models, both simple linear regression analysis (SLRA) and multiple linear regression analysis (MLRA), were developed for estimating soaked CBR value using physical properties of soils.

Table.1 Results of Laboratory Test for Soil Samples

Sl .No	Fines (%)	S (%)	G (%)	LL (%)	PL (%)	SL (%)	PI (%)	Soil type	Compaction Characteristics		Soaked CBR value (%)
									OMC	MDD	
1	10	87	3	23	NP	8.7	NP	SC	12	1.9	4.84
2	71	28	1	61	26	9.6	35	CH	23.1	1.45	1.06
3	72	25	3	64	39	14.3	25	CH	26	1.45	2.03
4	31	64	5	34	24	14.6	10	SC	12.12	1.98	4.18
5	77	22	1	57	30	22	27	CH	22	1.59	2.79
6	63	37	0	45	25	17.7	20	MI	21.05	1.6	3.2
7	64	35	1	52	28	9	24	CH	23.2	1.6	1.56
8	72	26	2	58	30	23	28	CH	19.8	1.63	2.54
9	71	28	1	66	40	10.8	26	CH	22.1	1.61	2.05
10	42	53	5	39	22.5	10.7	10.7	SC	15.82	1.8	3.45
11	57	26	1	41.5	25.6	14.3	16	CI	17	1.78	3.94
12	60	36	4	35.5	17	11	18.5	CI	16.2	1.89	3.28
13	61	38	1	37	13	8.6	24	CI	17.2	1.74	2.95
14	4	89	7	22	NP	14.7	NP	SW	10.5	2.3	5.25
15	46	45	9	49	27	9.2	22	SC	17.4	2.1	4.92
16	64	35	1	49.4	27	13.2	22.4	CI	18.2	1.74	3.28
17	10	86	4	24	NP	15.1	NP	SM	11	2.12	4.92
18	64	34	2	48	26	14	22	CI	15.7	1.78	3.12
19	74	25	1	66	35	8.4	31	CH	22.3	1.55	1.31
20	68	23	9	52	32	9	20	CH	19	1.69	1.5

III. ResDiscussionults And

Table 1 gives the results of various soil properties from the experimental conducted in the laboratory for twenty samples taken for present investigation. The properties include index properties of soils such as liquid limit, plastic limit and specific gravity, compaction characteristics such as maximum dry density and optimum moisture content, grain size distribution analysis such as gravel(G%), sand(S%), silt and clay, California Bearing Ratio test is conducted at optimum moisture content. The range of soil properties studied in this investigation is: Gravel= 0-17%, Sand= 20-90%, Fines (silt & clay) = 4-75%, LL= 20-66%, PL= 20-35%, MDD= 1.45-2.3gm/cc, OMC= 10-23% and soaked CBR= 1-6%. A wide range of soil samples including fine and coarse grained soils are selected to predict soaked CBR value.

3.1 Regression Analysis

The various regression analysis between soaked CBR value with respect to different soil properties are presented in Fig.1, 2, and 3. It shows the linear trend line, which shows the effect of various soil properties with CBR value.

3.1.1 Simple Linear Regression Analysis (SLRA)

Simple Linear Regression Analysis (SLRA) was carried out by considering soaked CBR value as dependent variable and liquid limit, plastic limit, plasticity index, shrinkage limit, maximum dry density optimum moisture content are considered as independent variables. It has been carried out to develop the correlation between individual soil property and soaked CBR value.

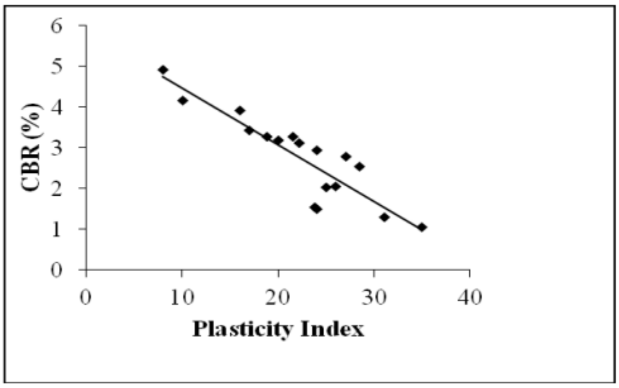

Figure 1 Correlation between plasticity index and CBR

Sample number 1, 14 and 17 are not considered for this regression analysis because these soils are non plastic (NP) in nature therefore using seventeen numbers of samples regression analyses have been made. The coefficient of correlation R2 was found to be 0.72. Effect of soil properties on CBR value can be explained as liquid limit and plastic limit has less influence on CBR value. But CBR value varies with plasticity index such that as plasticity index increases CBR value decreases. This shows that there is a fair to good relationship exists between CBR values for plastic nature of soils only.

From figure 2 it is observed that there is linear relationship exists between maximum dry density and CBR value. As maximum dry density increases CBR values also increases indicating linear relationship exists between these two parameters. From SLRA the coefficient of correlation R2for these two parameter is found to be 0.78, it represents good correlation between them.

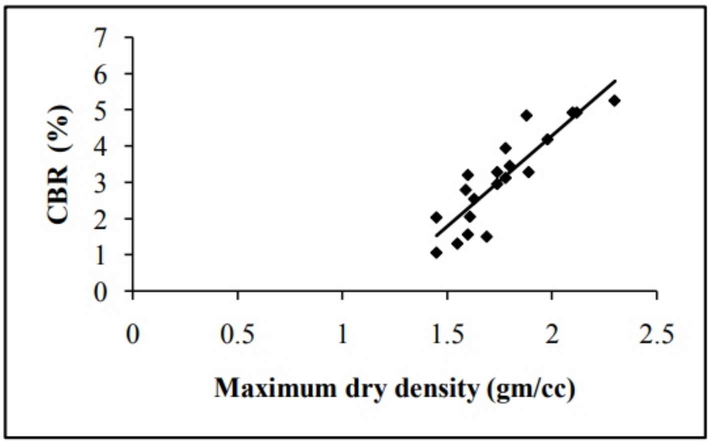

Figure 2 Correlation between maximum dry density and CBR

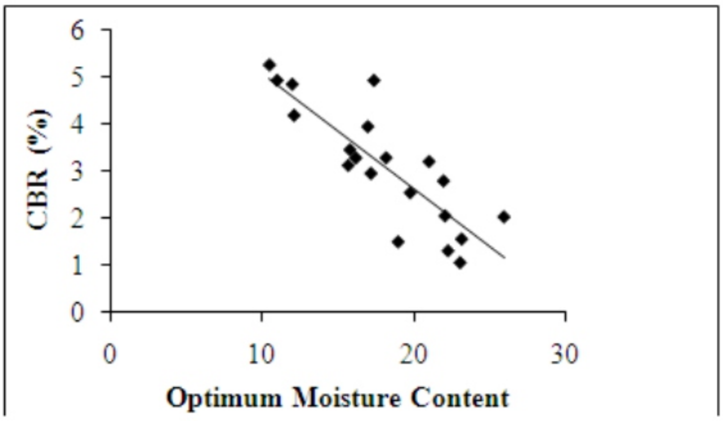

Figure 3 Correlation between Optimum moisture content and CBR

The above figure 3 indicates that as moisture content increases CBR value decreases. The model developed for soaked CBR value has correlation coefficient R2=0.70, indicating a reasonable fit to the data and also it indicates that as optimum moisture content increases CBR value increases.

3.1.2 Multiple Linear Regression Analysis (MLRA)

It has been carried out by considering soaked CBR value as the dependent variable and remaining soil properties as independent variable. It can be expressed as given below:Soaked CBR = (LL, PL, PI, MDD, OMC)Equations

1. CBR = 5.09477 - 0.09323 (LL) + 0.10939 (SL) + 0.022566 (SI)
2. CBR = 5.813 – 0.007826 (LL) + 0.12097 (PL)
3. CBR = -4.8353 – 1.56856 (OMC) + 4.6351 (MDD)
4. CBR= -3.2353-0.06939 (PI) + 2.8 (MDD)
5. CBR= 6.5452 – 0.07703(OMC) - 0.10395 (PI)

Where, CBR= California Bearing Ratio, LL=Liquid Limit, PL= Plastic Limit, SL= Shrinkage Limit, PI= Plasticity Index, OMC= Optimum Moisture Content, MDD= Maximum Dry Density. Equation 1,2,3,4 and 5 shows the multiple variable regression analysis. These equations include the correlation of all the parameters with CBR value. The three parameters plasticity index, maximum dry density and optimum moisture content directly affects the CBR value.

Equation 3 shows the correlation between CBR and optimum moisture content and maximum dry density. It is observed from figure 4 that the experimental soaked CBR values are close to predicted values. The model developed for CBR value has correlation coefficient (R2) =0.82 indicating a reasonable fit to all types of soil.

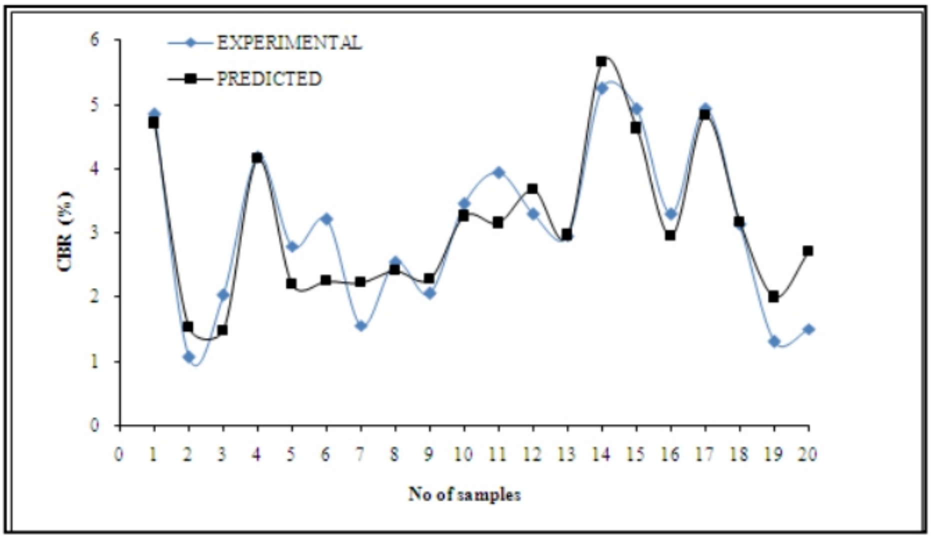

Figure 4. Comparison between experimental and predicted CBR value obtained from equation 3

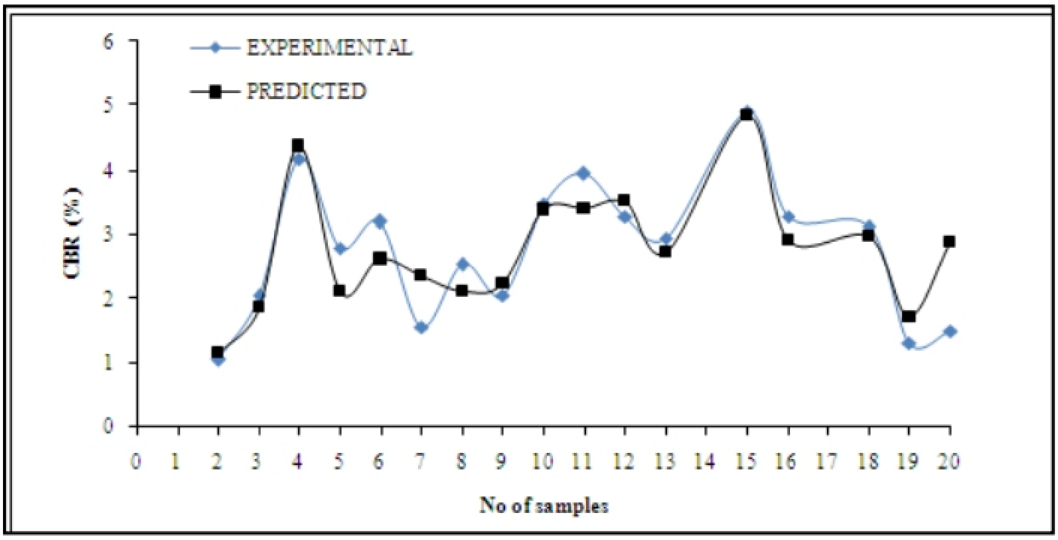

Figure 5 . Comparison between experimental and predicted CBR value obtained from equation 4

It is known from simple linear regression analysis (SLRA) that CBR value decreases with increase in plasticity index and also increases with increase in maximum dry density. From SLRA coefficient of correlation R2for plasticity index and maximum dry density are 0.72 and 0.78 respectively. Hence an attempt is made to correlate CBR from plasticity index and maximum dry density. From the correlation coefficient R2=0.76, it is concluded from figure 5 that CBR value prediction model based on MLRA are quite near to experimental values.

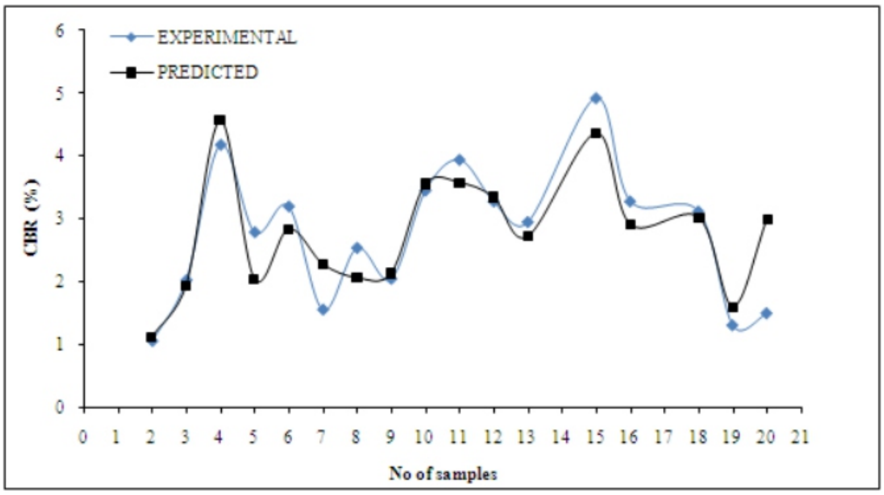

Figure 6 . Comparison between experimental and predicted CBR value obtained from equation 5

The above Figure 6 shows that the effect of moisture content and plasticity index on CBR value of soil samples collected for investigation. It is known from simple linear regression analysis (SLRA) that CBR value decreases with increase in plasticity index and CBR decreases with increase in moisture content. Also coefficient of correlation R2for optimum moisture content and plasticity index are 0.71 and 0.72 respectively. An attempt is made to correlate CBR value with these two variables using multiple linear regression analysis as shown in equation-5 and R2value found to be 0.75. Therefore it is concluded that MLRA holds good for these two parameters.

IV. Conclusion

[1] Based on experimental results and SLRA, there is no significant relation exists to predict CBR value from liquid limit and plastic limit.

[2] Linear relation exists between plasticity index and CBR value with a coefficient of correlation of R2=0.72.

[3] It is found that good empirical relations y=4.99MDD- 5.711 (R2 =0.78) and y=-0.2443OMC+7.5264 (R2=0.71) obtained by SLRA to predict CBR value from MDD and OMC.

[4] The empirical relation CBR= -4.8353–1.56856(OMC) +4.6351(MDD) (R2=0.82) obtained from

multiple linear regression analysis (MLRA) shows good relation to predict CBR value from MDD and OMC.

[5] From the correlation analysis it is clear that, large variation can be observed between experimental and predicted CBR value particularly in case of high compressible clays (CH).

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A New Design and Analysis of BUS Body Structure

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ABSTRACT

Optimization of mechanical response of automotive and body designs are increasingly relies on new models. Generally in international market for passenger's buses design processes can rely on supercomputing facilities. Nowadays for the passenger buses have many local producers which construct vehicles based on local needs. In the competitive to stay these producers comply with the same requirements and weight reduction of their international counterparts without access to latest computation facilities. This paper proposes a new method for designing a bus body structure is designed and modelled in 3D modelling software Pro/Engineer. The original body is redesigned by changing the thickness and reducing the number of elements so that the total weight of the bus is reduced. The present used material for structure is steel. It is replaced with composite materials Kevlar and S 2 Glass Epoxy. The density of steel is more than that of composite materials, so by replacing with composites, the weight of the structure is reduced. Structural and Dynamic analysis is done on both the structures using three materials to determine the strength of the structure. Analysis is done in Ansys.

Index terms: Bus body structure, Redesign, Structural finite element Analysis.

I. Introduction

A bus in any country is a kind of industries which is connected directly to the prosperity and maintains the stability of this state. After two years of completion of the security and sociality stability of the welfare states, bit it stopped immediately in case of any defects in the stability. The design of the internal bus skeleton structure is the basis of various bus developments in the bus industries. It contains the framework of tubes with various cross sections are arranged within specified shapes based on the design philosophy. The bus body can be divided into three parts; the chassis and engine, structural body, interior and exterior parts. They must pass the standard test by domestic and international organization. In this study, the chassis and engine are bought from the well known automotive brand such as MAN, BENZ, VOLVO, ISUZU, DAEWOO, HINO and so on. The chassis consists of two main types; the single piece and the three joint combination parts. The single piece chassis is used for the medium bus size with one floor, whereas the three combination parts are used for the long bus size or two floor bus. The second part is the bus body structure. The comprises of bus body have six main components the left and right frame side, the front and back frame side, the top and bottom frame side. In that the top frame side is sometime called roof frame side. The bottom frame side is also called floor frame side. The left and right side are similar but the left side is normally composed of two passenger doors. On the other hand, the right side has two doors the driver door and emergency door. In addition, the both frame sides are installed by mirrors and welded with sheet metal. They are concerned to be critical parts. They must be strong. The parts need to be analytical tests by at least simulation or physical test.

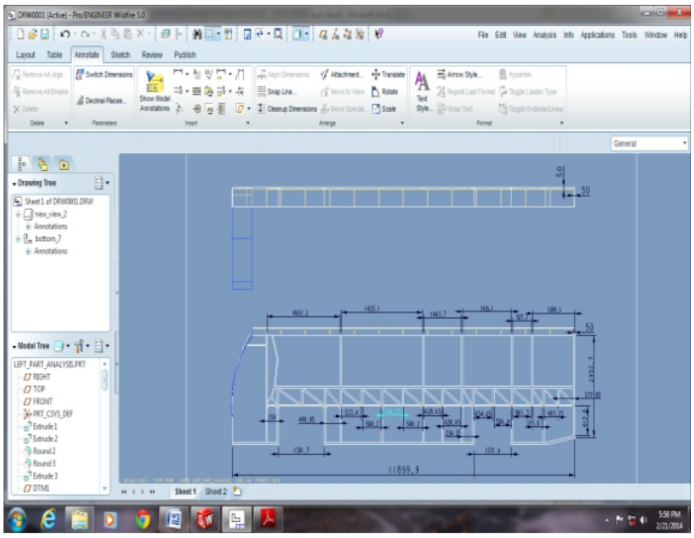
Torsion and bending tests are widely simulated by FE analysis. However, the strength of this design is affected by the manufacturing. For example the special type of welding such as MIG, TIG, and spot welding arc much better than the normal arc welding process. However, such manufacturing process is not concerned in this study. The third part, the top frame or the roof frame is considered as the critical part that is needed to be a strength part in order to be ensured safety for the passengers. This part must be sufficiently strong. It must be supported by the total weight from different loads such as interior components, air conditioners passenger carrying loads even the aero dynamic load. Then, the back frame and the front frame are mostly supported and joined with the left and right sides as well as the roof frame and the floor frame. These two parts need to be both strong and beauty style. Therefore the shape is quite become curvature, slop and good aero dynamic. The existing part is further combined by a lot of pieces which is here called trusts. The trusts are can be typed such as straight trusts, angle trusts, diagonal trusts and so on.

II. Related Work

Bus body manufacturing process consists of several steps. The first step is to design the body which is matched with a selected chassis. The critical dimensions are the length, the width, the height. They must be balanced in order to keep the vehicle stability. The second step is to check the chassis details. They are mirrors; turn left and right lights, control panel, mileage panel, fuel vessel, battery, spare tire, etc. The third step is to start manufacturing process. The chassis frame is drilled at the supporting point which has 16 points. The angle plates are extended all of 16 points and tightened by bolts and nuts. The next step is to put the beam bar which is used to support the whole mass of bus body. They are 8 beams. However, such beams are adjusted to be flat. The next step is to install the 13 major columns which are used to fix with the mirrors. Then, the door columns are jointed together. Next, the front columns of the left and right sides are welded. Then the top beams are joined. The trust bars for the front frame is then welded. The front and back console fibers are attracted. The next step is to build left and right frame structure. This step takes a long processes and long times to finish. After that, it is an assembly process. The roof and floor frames are assembled with the left and right frame structure. Next step, it is to construct the seats and walking path. Then, the front and back frames are constructed together with mirrors followings with covering the whole bus body by sheet metals. Then, the interior floor and the whole inside passenger space of the bus are installed.

III. Research Objective

The main goal of this project is to integrated software in buses industry called as BUSCAD. The BUSCAD program is to rectify all the problems related to the different types of buses in the bus industry. Bus could be classified into different types these are minibus, city bus, Intercity Bus, High Dick, Supper high Deck, School bus, ect as shown in figure1, which shows the proposed program.



Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provide the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize industrybased software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixilated) environments. The bus body redesign is developed from the existing work based on the knowledge obtained from the expert working division of the bus body manufacturing. The redesign part is analysed by FE process and the result is compared to the accepted standard values and the previous analysis results from the existing design. The existing model design is not available for the analysis of 2D sketched drawing is currently used systems. In this paper we need the CAD model for the bus body design. Then analysed by the beam method on FEA, it gives effective design has to be modelled by wireframe. The selected loads are either point loads or distribution loads, come from the weights of bus components such as seats, air conditioners, lights and sound systems, doors, windows, liquid or gas tank, etc.This research have analysis each part separately. Finally the loads from one part to be another correctly transferred before the analysis can be preceded.

1.1. Proposal of weight reduction method

In this project, a bus body structure is designed and modelled in 3D modelling software Pro/Engineer. The dimension of the body structure is taken from the journal specified in literature survey. The original body is redesigned by changing the thickness and reducing the number of elements so that the total weight of the bus is reduced. The present used material for structure is steel. It is replaced with composite materials Kevlar and S 2 Glass Epoxy. The density of steel is more than that of composite materials, so by replacing with composites, the weight of the structure is reduced.

Structural and Dynamic analysis is done on both the structures using three materials to determine the strength of the structure. Analysis is done in Ansys.

1.2. Pro/Engineer:

Pro/ENGINEER is a feature based, parametric solid modelling program. As such, it's use is significantly different from conventional drafting programs. In conventional drafting (either manual or computer assisted), various views of a part are created in an attempt to describe the geometry. Each view incorporates aspects of various features (surfaces, cuts, radii, holes, protrusions) but the features are not individually defined. In feature based modelling, each feature is individually described then integrated into the part. The other significant aspect of conventional drafting is that the part geometry is defined by the drawing. If it is desired to change the size, shape, or location of a feature, the physical lines on the drawing must be changed (in each affected view) then associated dimensions are updated. When using parametric modelling, the features are driven by the dimensions (parameters). To modify the diameter of a hole, the hole diameter parameter value is changed. This automatically modifies the feature wherever it occurs - drawing views, assemblies, etc. Another unique attribute of Pro/ENGINEER is that it is a solid modelling program.

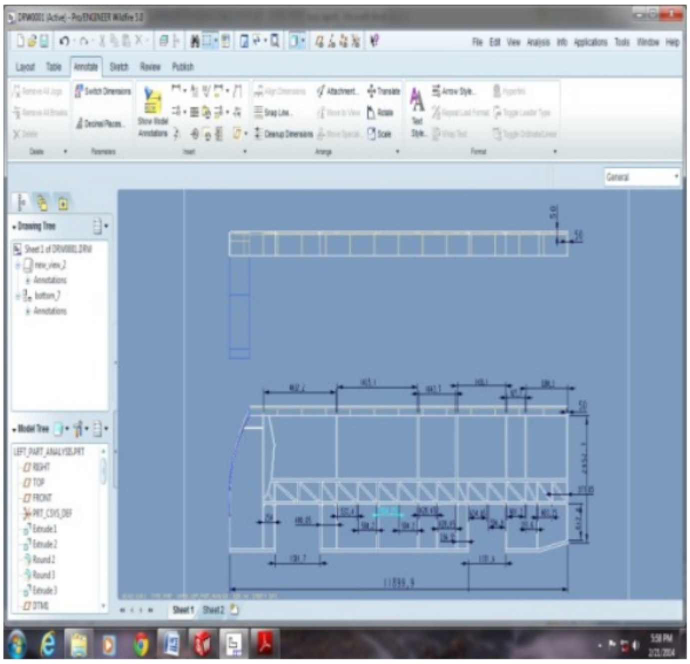
1.3. Engineering Design

Pro/Engineer offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development. A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive freeform surface tools.

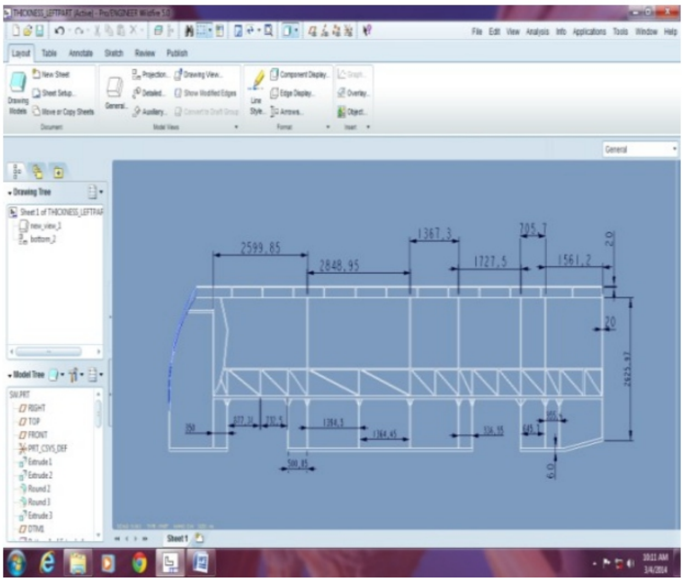
1.4. Manufacturing

By using the fundamental abilities of the software with regards to the single data source principle, it provides a rich set of tools in the manufacturing environment in the form of tooling design and simulated CNC machining and output. Tooling options cover specialty tools for molding, die-casting and progressive tooling design.

Original Model:



Modified Model:



IV. Result Of Fitness Analysis

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested. In practice, a finite element analysis usually consists of three principal steps:

a) Pre-processing:

The user constructs a model of the part to be analyzed in which the geometry is divided into a number of discrete sub regions, or elements," connected at discrete points called nodes." Certain of these nodes will have fixed displacements, and others will have prescribed loads. These models can be extremely time consuming to prepare, and commercial codes vie with one another to have the most user-friendly graphical “preprocessor" to assist in this rather tedious chore. Some of these pre-processors can overlay a mesh on a preexisting CAD file, so that finite element analysis can be done conveniently as part of the computerized draftingand-design process.

b) Analysis:

The dataset prepared by the preprocessor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations Kijuj = fi

Where u and f are the displacements and externally applied forces at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

c) Postprocessing:

In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. A typical postprocessor display overlays colored contours representing stress levels on the model, showing a full field picture similar to that of photo elastic or moiré experimental results.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

Build Geometry

Construct a two or three dimensional representation of the object to be modeled and tested using the work plane coordinate system within ANSYS.

Define Material Properties

Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

Generate Mesh

At this point ANSYS understands the makeup of the part. Now define how the modeled system should be broken down into finite pieces.

Apply Loads

Once the system is fully designed, the last task is to burden the system with constraints, such as physicalloadings or boundary conditions.

Obtain Solution

This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

Present the Results

After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

KEVLAR

V. Material Properties

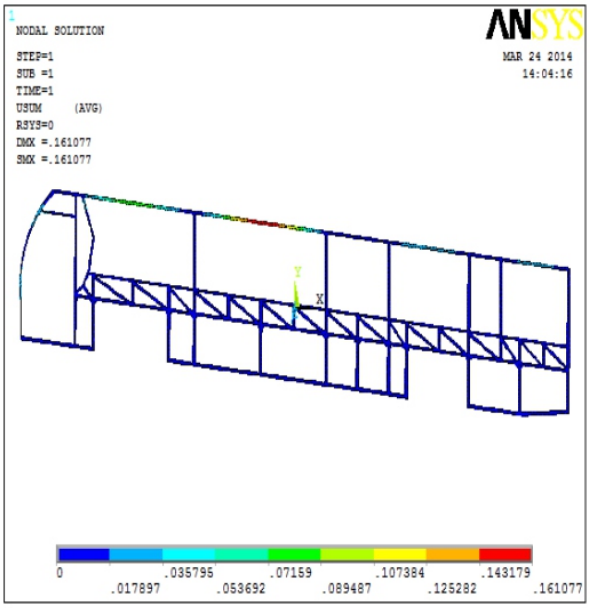
Youngs Modulus (EX) : 112000N/mm2

Poissons Ratio (PRXY) : 0.36

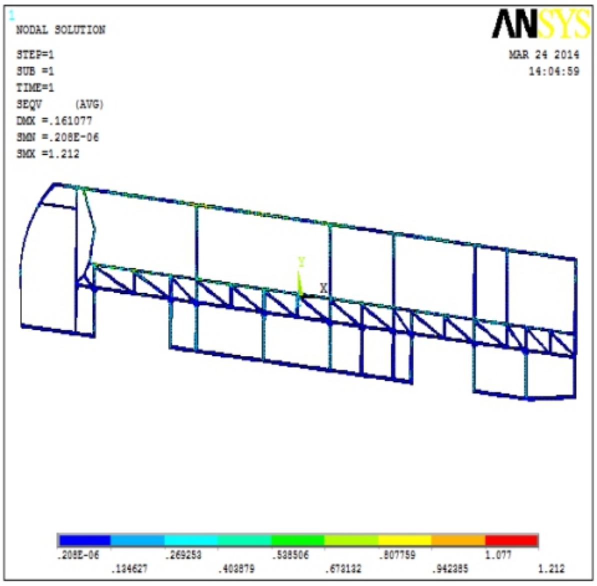
Density :0.00000144 kg/mm3

DISPLACEMENT

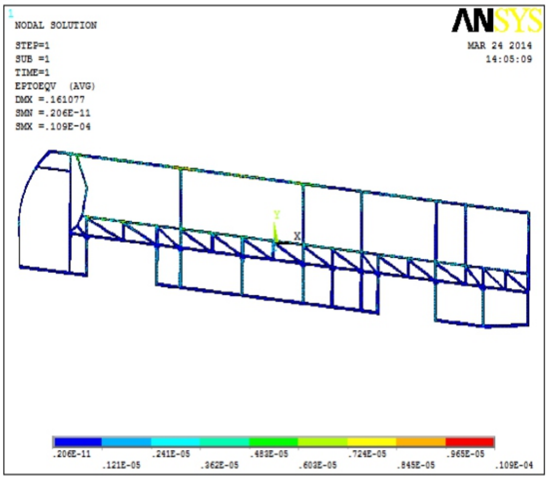
ORIGINAL MODEL



Stress



Strain:



VI. Results Table

	STELL	KEVLAR	S2_GLASS
Displacement (mm)	0.8795	0.161077	0.207357
VONMISES STRESS (N/mm^2)	1.213	1.212	1.214
STRAIN	$0.594*10^{-5}$	$0.109*10^{-4}$	$0.140*10^{-4}$

Modified:

MATERIAL PROPERTIES

Young's Modulus (EX) : 112000N/mm2

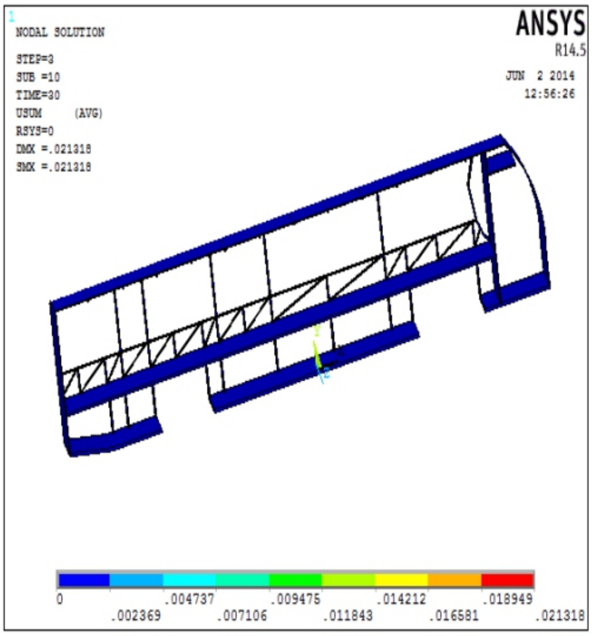
Poissons Ratio (PRXY) : 0.36

Density : 0.00000144 kg/mm3

Post Processor:

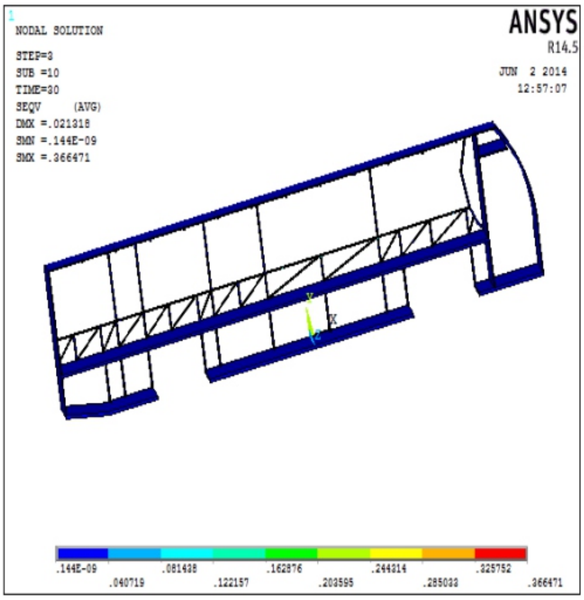
DISPLACEMENT

General Post Processor – Plot Results – Contour Plot - Nodal Solution – DOF Solution – Displacement Vector Sum



STRESS

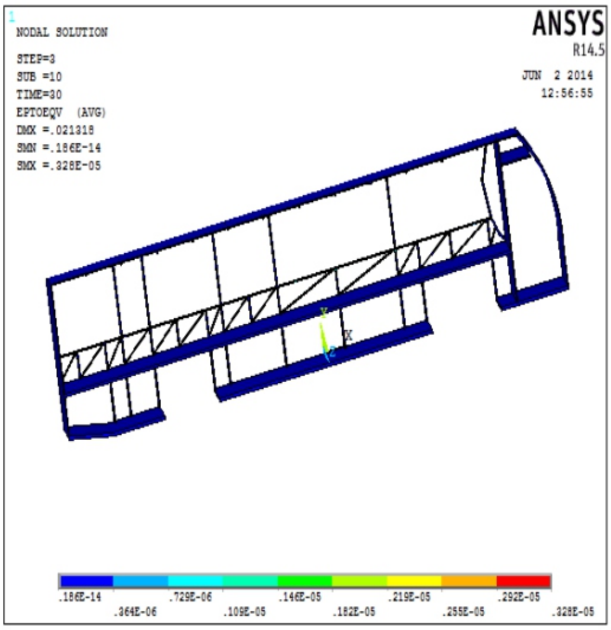
General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – Von Mises Stres



STRAIN

General Post Processor – Plot Results – Contour Plot – Nodal Solution – Stress – total mechanical

Von Mises Strain



MODIFIED MODEL

	STELL	KEVLAR	S2_GLASS
Displaceme nt (mm)	0.363507	0.665631	0.8572
Vonmises stress (n/mm^2)	3.572	3.571	3.57
Strain	$0.175*10^{-4}$	$0.319*10^{-4}$	$0.412*10^{-4}$

VII. Conclusion

In this project, a bus body structure is designed and modeled in 3D modeling software Pro/Engineer. The dimensions of the body structure are taken from the journal specified in literature survey. The original body is redesigned by changing the thickness and reducing the number of elements so that the total weight of the bus is reduced. The present used material for structure is steel. It is replaced with composite materials Kevlar and S 2 Glass Epoxy. The density of steel is more than that of composite materials, so by replacing with composites, the weight of the structure is reduced.Structural and Dynamic analysis is done on both the structures using three materials to determine the strength of the structure. Analysis is done in Ansys. By observing the analysis results, the displacement and stress values obtained are within the limits for the modified model. By using composite materials also, the stress values are within the limits, and strength of the composite materials is more. So it can be concluded that by reducing the thickness and also using composite materials yields better results than original model and conventional steel.

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