

Analysis of Pipeline Coated with Polyethylene (Pet) and Acrylonitrile Butadiene Styrene (ABS) to Determine Temperature Distribution and Mechanical Stresses During the Welding of Coated Pipeline by using Finite Element Method

Jitendra Kumar Tamiya¹, Ruchika Saini²

ME Scholar¹, Asst. Professor²

Department of Mechanical Engineering^{1,2}

Jabalpur Engineering College, Jabalpur (M.P.), India

Abstract

It was carried out on considering Acrylonitrile Butadiene Styrene (ABS) and polyethylene (PET) material layer with steel pipe. The study was conducted by using the Finite element method. Young's modulus and thermal conductivity with specific heat, has been analyzed by ANSYS 15.0. A simplified and idealized finite element model by using symmetry assumption and a non-simplified finite element model of process have been used in the analyses. The major study was done on temperature distribution on organic coating steel pipe with thermo plastic layer on welding process by using different thermo plastic layer thickness.

In our analysis, ANSYS is used and the model is developed on UNIGRAPHICS 8.0 and also analysed for Steady state thermal and static structural domain (coupled field) 15.0. The analysis results show that 4mm of layer thickness of Acrylonitrile Butadiene Styrene (ABS) and polyethylene (PET) thickness gives absolute convergence on thermal conductivity, young's modulus and temperature. Validation and optimization is done to determine the effect of temperature distribution and specific heat during welding process. The thermal stresses is analysed in organic coating steel pipe with thermo plastic layer for enhancement of better workability of system.

Keywords— *Specific heat, Temperature, steel pipe, thermal stresses, Acrylonitrile Butadiene Styrene (ABS), polyethylene (PET), thermal conductivity, welding process, thermo plastic.*

I INTRODUCTION

One of the most crucial areas in the mechanics is the mechanical behavior of materials when subjected to thermal results. Meeting the need for substances, which can characteristic usefully at exclusive temperature tiers, is one of the maximum difficult problems dealing with our generation. Some examples are the dilation results like the strengthening of bridges on a warm day or the bursting of water pipes in freezing climate and distortions set up in systems by way of thermal gradients. Sometimes-drastic changes inside the homes of materials, along with tensile electricity fatigue and ductility may also end result via the change in fabric temperature. With growing temperature the elements of pipe body extend. Such diffusion normally can't proceed freely in a non-stop medium, and stresses due to the heating are set-up. The problem is that operating conditions now not only at extended temperature stages, but regularly also at intense temperature gradients. Such temperature differentials might also produce thermal stresses considerably excessive sufficient to limit the cloth lifestyles. Fatigue failure may also occur due to temperature fluctuations. Thick-walled pipes subjected to inner heat glide are used in many programs. When a thick-walled cylindrical frame is subjected to a temperature gradient, non-uniform deformation is prompted and thermal stresses are developed. The resulting thermal stresses upload to the stresses as a consequence of internal and external pressures inside the pipe material. One of the reasons of thermal stresses in pipes is the non-uniform heating or cooling; any such scenario that exists whilst as an example pipes are welded, causing residual stresses. Two sorts of go with the flow in particular exist in pipes particularly, laminar and turbulent flows.

II BENEFITS OF CORROSION RESISTANT METAL COATINGS

All of our corrosion resistant coatings shape an impermeable barrier among the bottom metallic and the outdoor elements with a purpose to provide the quality overall performance and longest life-span to your components. The

coatings also can provide performance attributes apart from corrosion resistance, inclusive of fighting friction, minimizing wear and supporting additives keep particular tolerances. Electro much less nickel on its own has tremendous corrosion resistance, and while well applied, the coating is sort of absolutely resistant to alkalies, salt answers/brines, chemical or petroleum environments, and all forms of hydrocarbons, solvents, amonia solutions, and acids..

III LITERATURE REVIEW

L. Belec and Y. Joliff [1] - the investigation protection of pipeline networks is a concern, specifically whilst these networks grow old. The protection in opposition to corrosion is found out by coupling a passive coating with an lively cathodic safety. It is widely known that the presence of internal stresses in natural coatings is a cutting-edge phenomenon which could result in the lack of adhesion. This phenomenon is vital for the durability of pipelines. The welding manner and its outcomes on the pressure generated inside the pipeline are investigated on this paper. Using a finite detail technique, the welding manner is simulated, and the thermal and mechanical evolutions are analyzed. From those outcomes, the pressure is largely concentrated inside the metal cylinder. Indeed, the cutback found out on the coating allows its safety at some stage in the welding.

Riyadh Salha and Florin V. Tosa [2]-this research to after centuries of environmental pollutants, many research have illustrated the effect of oil and its products over the encompassing surroundings. Therefore, as a step toward sustainable neighbourhoods, it can an concept to search for opportunity oil-loose building materials. On the opposite hand, plastic is considered the main building fabric that derived from oil and utilized in a extensive-range as (water gadget pipes, insulation fabric, plastic fibre for reinforcement concrete, etc.). However, it's miles enough for these substances to be derived from oil to be polluting materials, however they're additionally atypical materials to nature that they take hundreds of years to decompose. Moreover, some materials like polystyrene it isn't always even popular yet to be recycled due to the monetary point of view. All above has urged us to search for alternative eco-friendly substances, accordingly the natural substances that come from the earth like clay may be that one. So those papers are going to present the opportunity of replacing plastic pipes with clay ones via test and analyze some specimens following the requirements.

Johanna Rajasarkka et al. [3] - the investigation Rehabilitation of aged consuming water pipes is an extensive protection and increasingly more topical in many European cities. Spray-on-lining of consuming water pipes is an opportunity cost-effective rehabilitation era wherein the insides of pipes are relined with natural polymer. A usually used polymer is epoxy resin along with monomer bisphenol A (BPA). Leaching of BPA from epoxy lining to drinking water has been a subject among public and government. Currently epoxy lining isn't encouraged in some international locations. BPA leaching has been proven in laboratory studies but the conduct and getting older system of epoxy lining in situ isn't widely recognized. In this have a look at 6 locations with one-of-a-kind age epoxy linings of ingesting water pipes performed the usage of wonderful technology were studied. While bisphenol F, four-nonylphenol, and four-t-octylphenol had been rarely determined and in hint concentrations, BPA changed into detected in majority of samples. Pipes covered with the older generation (LSE) leached extra BPA than people with greater current generation (DonPro): maxima in bloodless water have been 0.25 mg/L and 10 ng/L, respectively. Incubation of water in pipes 8e10 h previous to sampling elevated BPA awareness in cold water 1.1e43-fold. Hot water temperature brought about even extra BPA leaching - at most 23.Five mg/L. The have an effect on of growing old of epoxy lining on BPA leaching on might be proven in case of LSE era: places with 8e9 years vintage lining leached 4e20-fold extra BPA compared to a location with 2-yr-old lining. Analysis of metals showed that epoxy lining can reduce especially iron awareness in water. No full-size burden to water can be shown via the analyzed 72 risky organic compounds, along with epichlorhydrin, precursor utilized in epoxy resin. Estrogenicity became detected in water samples with the best BPA masses. Comparable responses of two yeast bioreporters (estrogen receptor a and BPA-targeted) indicated that bisphenol-like compounds had been the main reason of estrogenicity. Compared to the envisioned common day by day BPA publicity, additional BPA load thru cold ingesting water within the studied locations turned into low, maximum eight.7%. However, warm water have to additionally be taken into consideration as exposure source due to higher BPA concentrations. Epoxy lined locations should be monitored in future to be able to examine aging technique and manipulate increasing leaching of doubtlessly harmful chemical substances.

Andrej Stafura et al. [4] - the investigation timber pipe organs are treasured gadgets of cultural background the degradation of which has been very poorly studied. Fungal strains recovered from an organ dating lower back to the nineteenth century blanketed *Alternaria mali*, *Eurotium cristatum*, *Aspergillus amstelodami*, *Penicillium crustosum* and *Aspergillus sydowii*. These isolates had been used to artificially contaminate timber pipes dealt with with linseed oil varnish and varnish-loose. The pipes were incubated at extraordinary temperatures and relative humidity for 12 months.

The pipes, incubated at a excessive relative humidity (70e75%), collapsed due to the biodegradation of glued joints. After 12 months, inoculated strains (*Alternaria mali*, *Penicillium crustosum* and *Aspergillus sydowii*) as well as a few non-inoculated *Talaromyces rugulosus*, *Paecilomyces formosus*, *Cladosporium cladosporioides*, *Aspergillus versicolor* and *Epicoccum nigrum* have been recovered from the pipes. Few traces exhibited lignolytic hobby, even as nearly all had been capable of hydrolyze the rabbit glue used to join the timber factors of the pipes. A newly evolved portable pipe-sound controller did no longer stumble on differences of sound spectra among the uncontaminated and the few surviving infected pipes. In this examine we have proven that glue degradation became critical for pipe maintenance and it can be surprisingly accelerated above a positive relative humidity threshold. Therefore, it is important to apply a monitoring method able to check the environmental conditions, microbial infection and pipe sound alteration in an effort to keep these precious and rare cultural heritage gadgets.

Mauricio Latino et al. [5] - this research an more desirable electrochemical approach for correctly measuring cathodic safety (CP) currents thru defensive coatings has been evolved as a way of quantifying the permeability and 'cathodic shielding' characteristics of nominally intact coating movies. This method takes gain of the fact that cathodic currents should substantially affect the alkalinity of areas beneath disbonded coatings to self-validate the correctness of present day density measurements. In addition, the method affords a excessive stage of accuracy and control over the environment. The technique became evaluated using a series of preferably CP-defensive and non-CP-protecting substances, in addition to, commercial pipeline coatings. A robust correlation of the measured modern-day with era of hydroxyl ions and the neighborhood alkalinity was hooked up in all cases. For a few industrial area joint epoxy pipeline coatings, consequences advise that low CP ranges should permit sufficient ionic modern thru a coating to promote a high alkalinity neighborhood environment. However, this could now not be the case for fusion-bonded epoxy coatings, which shielded CP and maintained a close to-impartial pH underneath the coating.

Lorenzo Fedrizzi et al. [6] - this investigation the insulation of capillary copper tubes, used for the manufacturing of regenerative warmness exchanger, was proposed, with the aid of the application of natural coatings. The safety of copper capillary tubes become obtained the use of the same technology (coextrusion) and the identical resins (polyvinylformal or polyestherimide layer accompanied by way of a polyamideimide layer) employed for insulating copper wires for electric vehicles. The barrier properties and adhesion of the selected natural coatings were studied using coated copper samples in the as obtained conditions or after pipe bending or coating scratching, a good way to simulate actual defects which can be introduced throughout fridge assembly. EIS proved to be a completely beneficial approach for you to examine the safety homes of the chosen coatings. PVF coatings confirmed top barrier properties simplest whilst 60 mm thickness coating become carried out. Nevertheless, when artificial defects were produced in the coating, barrier houses had been remarkably faded. In truth, mechanical deformation multiplied water permeability and coating delamination without difficulty happened at scratches. PE coatings showed better barrier properties, even making use of a thinner coating (40 mm). Mechanical deformation, inside the range of 10% elongation, turned into sustained with the aid of this coating without struggling a clear decrease of its barrier properties. Moreover, this type of coating confirmed better resistance to coating delamination processes, probably due to higher adhesion to the metal substrate. Such assets might be greatly better for each kind of coatings the usage of a appropriate surface pretreatment.

J. Shrestha and J. Li [7] -This research demonstrates Reverse Osmosis (RO) filters are gaining popularity in home water deliver system to meet the growing demand for pure and stepped forward consuming water. The consciousness of this studies turned into at the corrosive impact of the permeate water at the leaching of lead steel pipes and the leaching of natural carbon from commonplace plastic plumbing materials. Three commercially to be had RO filters with various remedy stages—two, five and seven, have been chosen for the tests. As the wide variety of remedy ranges multiplied, the pH, conductivity, hardness and alkalinity of the completed water were higher balanced. The results display that the two-degree filter had the best corrosion impact the various 3 filters with a lead corrosion rate of zero.382 mpy, followed by means of the five-level filter with a corrosion rate of zero.064 mpy, and the seven-degree clear out had the least corrosion fee of zero.007 mpy. From the migration test, it changed into observed that the PEX and PVC pipes were more susceptible to natural carbon leaching as compared with the CPVC pipes. The two-stage filter out confirmed the very best extraction of organic compounds, and the seven-level clear out confirmed the least. In all of the samples, such as the manage, the preliminary TOC leaching in the course of the primary three-day length changed into better than the following leaching periods of 3 days.

K.M. Usher et al. [8] -this research demonstrates outside corrosion of buried carbon steel pipes is a trouble of worldwide proportions, affecting a extensive variety of industries and services. Many elements affect corrosion costs. Biofilms may also secrete enzymes and compounds that assault steel, regulate local acidity and create differential aeration and galvanic cells. An vital attention is that biofilm metabolisms and enzymatic reactions are continuously in flux, changing the impact of microorganisms on corrosion prices, and thermodynamic equilibrium is not reached. Recent research demonstrates that some anaerobic microorganisms catalyse the oxidation of metallic iron and at once consume the electrons, with serious effects for corrosion. This review examines relationships among soil traits,

microbiology and corrosion tactics, focussing on the impacts of microorganisms on outside corrosion of buried carbon metal pipes. Techniques for enhancing the expertise of microbially prompted corrosion are considered and critiqued, with the intention of supporting folks that paintings inside the location of corrosion mitigation.

T. Haile et al. [9] - this investigation shows the bactericidal traits of Nano-copper oxide or functionalized zeolite coated concrete pipes towards *Acidithiobacillus thiooxidans* have been studied via measuring the temporal version of bacterial dry mobile weight measurement, mobile Adenosine Triphosphate production, in addition to oxygen uptake rate of the aforementioned bacterium. Uncorroded (UC), seriously corroded (SC), and reasonably corroded (MC) concrete pipes were electrochemically covered with a nano-copper oxide, whilst another uncorroded concrete pipe turned into used to apply functionalized zeolite coating (Z2). Specimens were characterized through discipline emission- scanning electron microscopy, and optical microscopy. Oxygen uptake price of the bacterium become the highest in UC observed via the MC. Oxygen uptake charge and cell Adenosine Triphosphate decreased steadily in Z2 and SC throughout the period of the experiment due to decline in stay bacterial mobile. The minimal attention limits for the inhibition of the bacterium in the nano-copper oxide lined concrete pipes ranged from 2.3 mg to 2.6 mg Cu consistent with mg dry cell weight.

Ingun Skjevraak et al. [10] - the investigation shows the High-density polyethylene pipes (HDPE), crossbonded polyethylene pipes (PEX) and polyvinyl chloride (PVC) pipes for ingesting water had been tested with respect to migration of unstable organic components (VOC) to water. The odour of water in contact with plastic pipes was assessed in line with the quantitative threshold odour range (TON) concept. A main migrating issue from HDPE pipes changed into 2, 4-di-tert-butyl-phenol (2,4-DTBP) that's a acknowledged degradation product from antioxidants along with Irgafos 168. In addition, a range of esters, aldehydes, ketones, aromatic hydrocarbons and terpenoids have been identified as migration products from HDPE pipes. Water in touch with HDPE pipes turned into assessed with respect to TON, and values X4 had been determined for 5 out of seven manufacturers of HDPE pipes. The overall amount of VOC launched to water for the duration of three successive check periods turned into fairly steady for the HDPE pipes. Corresponding migration tests accomplished for PEX pipes showed that VOC migrated in massive quantities into the take a look at water, and TON X5 of the check water have been observed in all assessments. Several of the migrated VOC had been not recognized. Oxygenates predominated the identified VOC within the take a look at water from PEX pipes. Migration assessments of PVC pipes discovered few unstable migrants within the test samples and no big odour of the check water.

IV MODELING AND ANALYSIS

Design procedure of Flywheel

The procedure for solving the problem is

- Modeling of the geometry.
- Meshing of the domain.
- Defining the input parameters.
- Simulation of domain.

Finite volume analysis of Absorber plate

Analysis Type - Fluent

Preprocessing

Preprocessing include CAD model, meshing and defining boundary conditions.

Table 4.1 Dimension of steel pipe with organic layer coating

Diameter of steel pipe	30 mm (internal dia.) 35 mm (outer diameter)
Length of steel pipe	250 mm
Thickness of Polyethylene (PET) Layer	2mm, 4mm, 5mm, 6mm
Thickness of Acrylonitrile Butadiene Styrene (ABS) Layer	2mm, 4mm, 5mm, 6mm

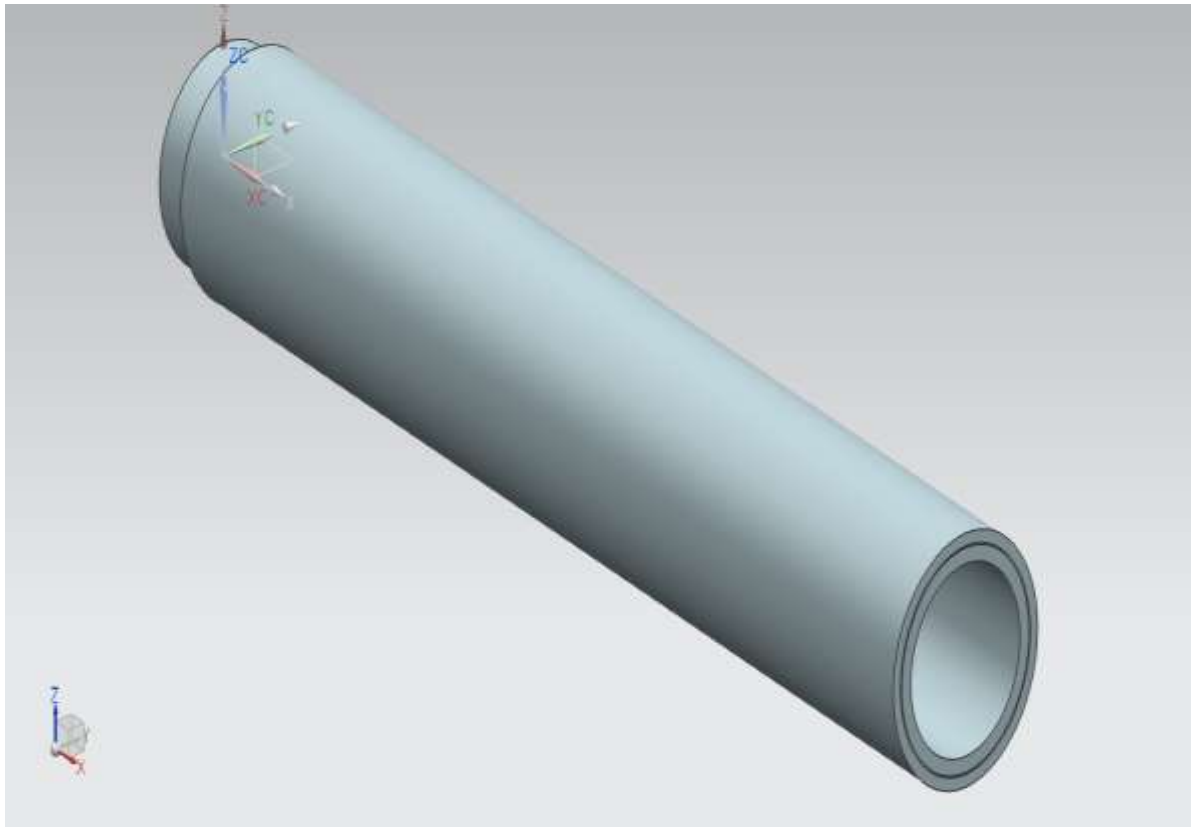


Figure: 4.1 CAD Model of organic coatings on steel pipe

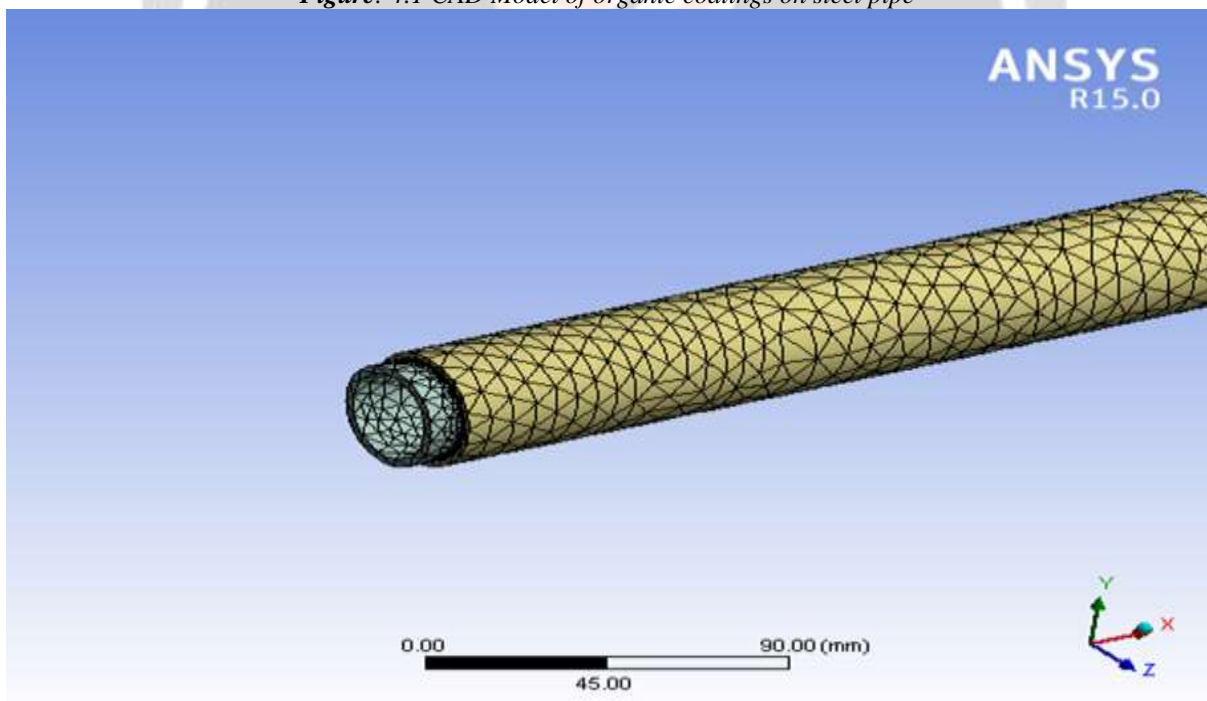


Figure4.2 Mesh domain of organic coatings on steel pipe

V RESULT AND DISCUSSION

The effects of welding temperature on steel pipe coated with organic coating and poly plastics is proceeded for present analysis the Thermal stresses and temperature distribution were also determined for enhancement of mechanical stresses and high temperature conductance of a steel pipe coated with thermo plastic material (Polyethylene and Acrylonitrile Butadiene Styrene). The results have been compared with Numerical values of same parameter and also compare with present base paper model with different layer thickness of thermo plastic materials on steel pipe for operating under similar operating conditions to discuss the enhancement in thermal stresses, thermal conductivity, specific heat, temperature on account of organic coatings on steel pipe.

5.1 Heat transfer characteristics

Table 5.1 shows the values of temperature distribution with different thickness w.r.t. length

Temperature of ABS				
2mm (ABS)	4mm (ABS)	5mm (ABS)	6mm (ABS)	Length
2000	1800	2130	2200	20
1700	1550	1760	1830	40
1500	1400	1580	1650	60
1200	1100	1300	1400	80
1060	930	1190	1250	100
800	650	910	1080	120
400	350	480	560	140
300	260	370	430	160

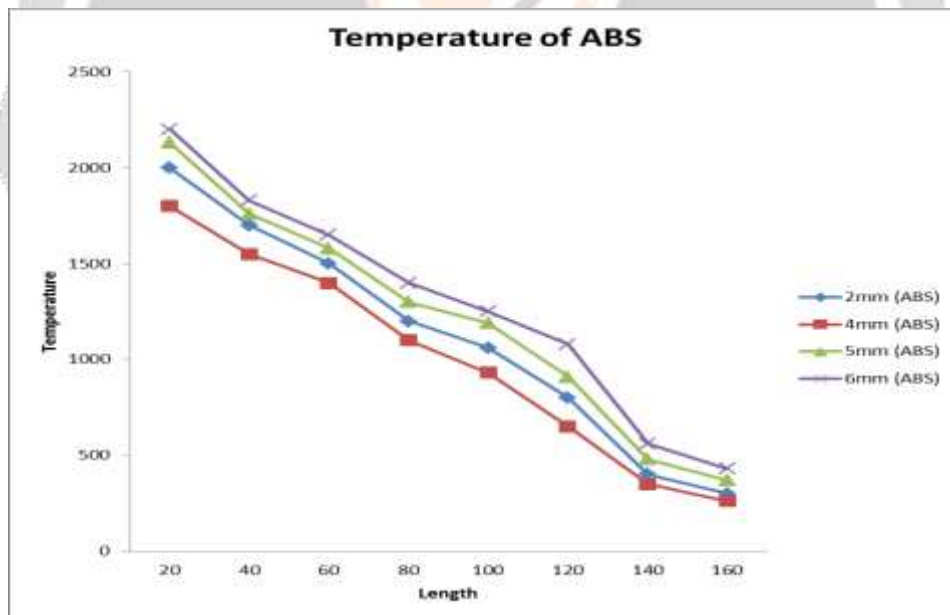


Figure: 5.1 Comparison of temperature distribution with different thickness w.r.t. length

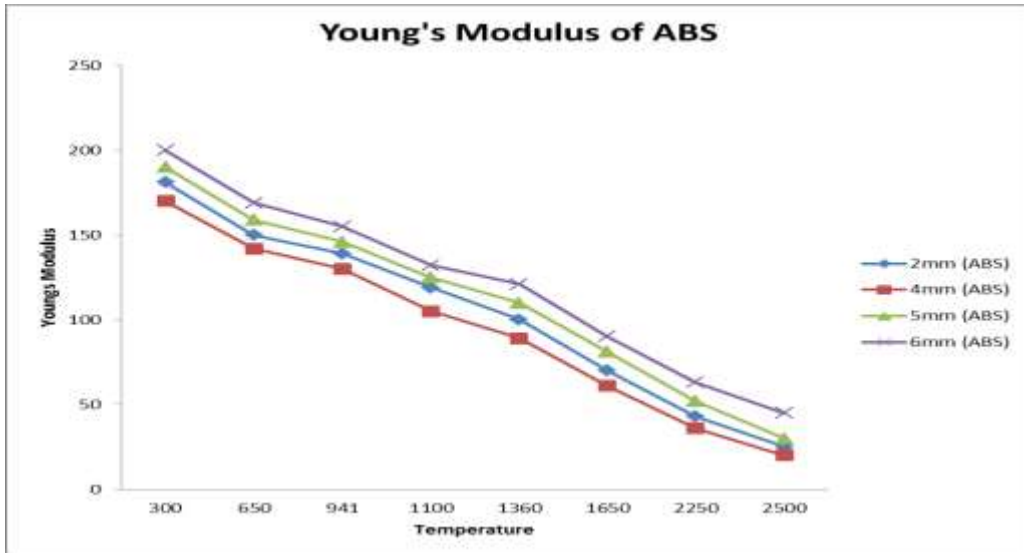


Figure 5.2 Comparison of Young's modulus of different thickness with different welding temperature of Acrylonitrile Butadiene Styrene (ABS) layer on steel pipe

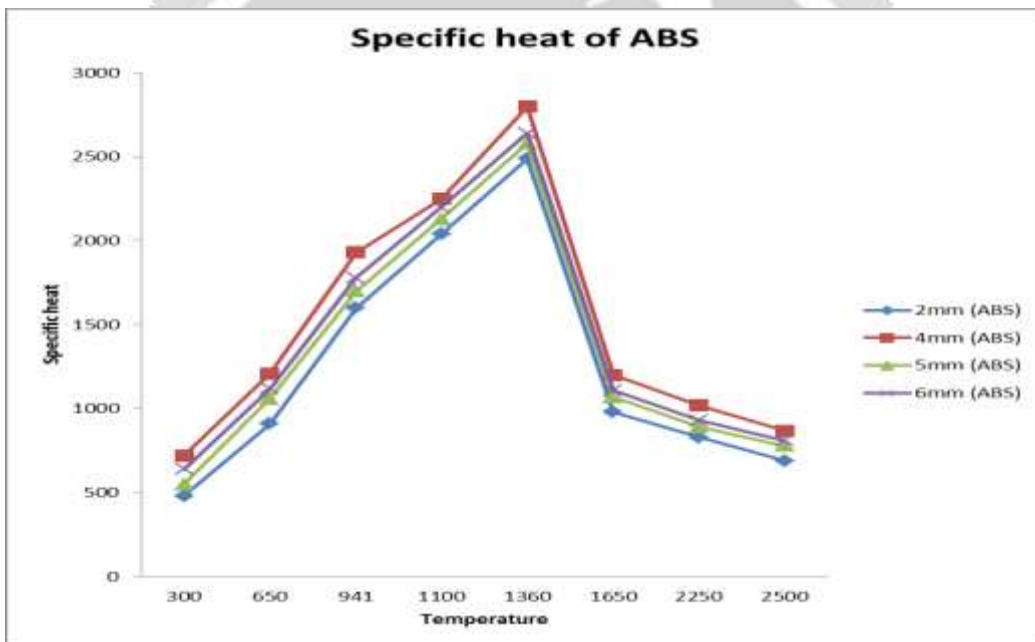


Figure: 5.3 Comparison values of specific heat with different welding temperature

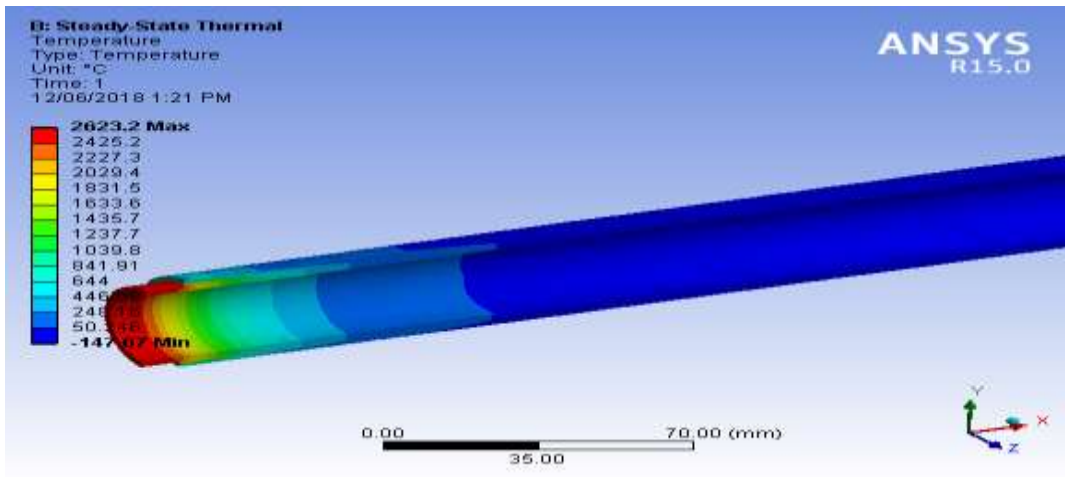


Figure 5.4 Temperature distribution of organic coating on steel pipe with material ABS.

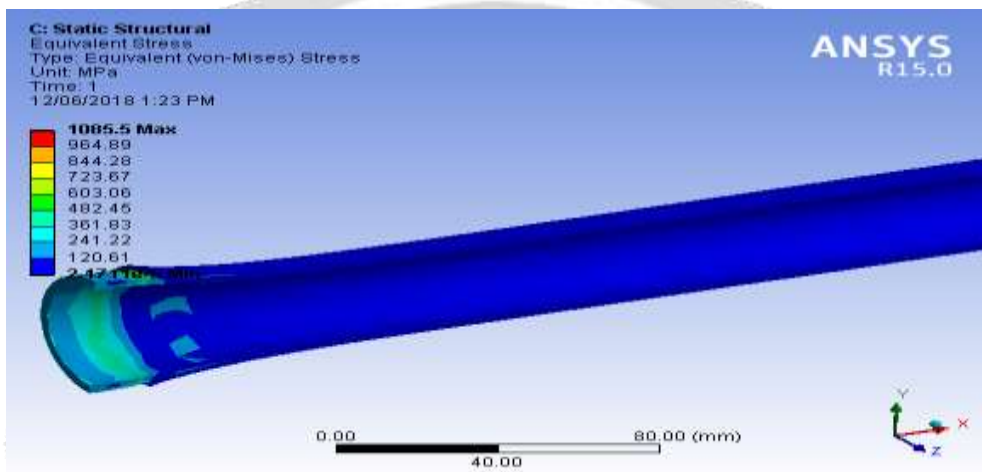


Figure 5.5 Stress distribution of organic coating on steel pipe with material ABS.

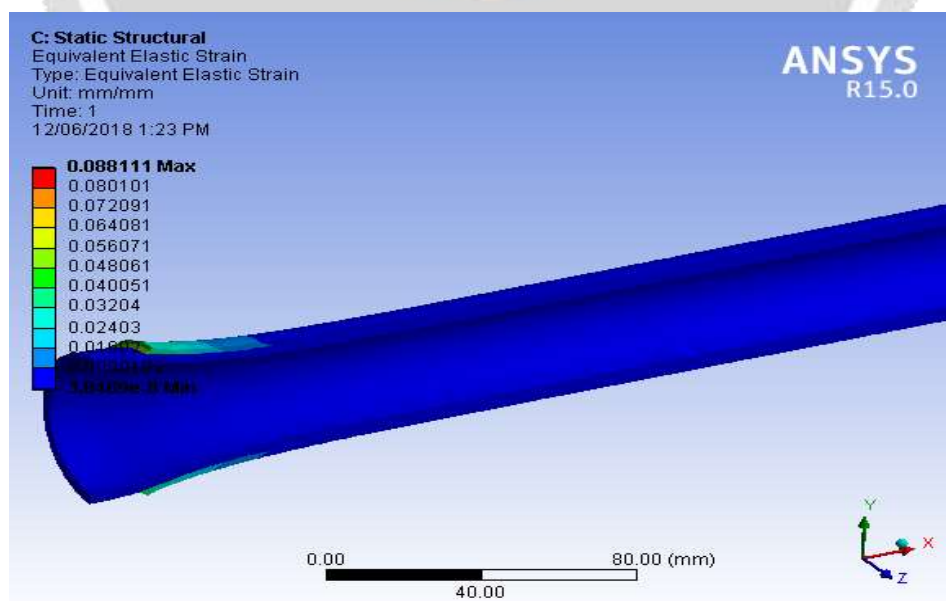


Figure 5.6 Strain distribution of organic coating on steel pipe with material ABS.

VI CONCLUSION

- Average deviation of result obtained from ANSYS in organic coating on steel pipe with thermo plastic layer on welding process, for base model the young's modulus, thermal conductivity, specific heat and temperature distribution lies within the range, temperature is deviate 3.76% for simulation model and thermal conductivity effect is deviate 3.91% as compared to base paper work of the Author.
- Average deviation of results obtained for different layer thickness from ANSYS in temperature is deviated by 17.01 % i.e., temperature decreases for 4 mm layer thickness for ABS and PET.
- Average deviation of result obtained for different welding temperature on organic coating on steel pipe with thermo plastic layer with different layer thickness from ANSYS in thermal conductivity is deviated by 8.15% i.e., thermal conductivity increases for 4mm layer thickness of coated steel pipe in ABS material.
- Thermal stresses decreases for 4mm thickness for different welding temperature and length on organic coating on steel pipe with thermo plastic layer, the average variation is analyze by 5.7% and for young's modulus w.r.t. it is decreased by 18.63%, 24.12%, and 19.35%, 15.97% respectively for different layer.
- This ANSYS analysis clearly indicates that 4mm of layer thickness of ABS decreases the thermal stresses and increases thermal conductivity with different welding temperature and length along steel pipe due to this effect workability of steel pipe coated with thermo plastic material increases

References

- [1] [1] L. Belec, Y. Joliff, "Numerical study on the evaluation of thermal and mechanical stresses during the welding of coated pipelines", *Progress in Organic Coatings* 111 (2017) 336–342.
- [2] Riyadh Salha, Florin V. Tosa, "Looking for Oil-free Building Materials Clay Pipes to Replace Polymer Pipes" *Procedia Technology* 22 (2016) 343 – 350.
- [3] Johanna Rajasarkka, Marek Pernica, Jan Kuta, Jonas Lasnak, Zdeněk Simek, Ludek Blaha, "Drinking water contaminants from epoxy resin-coated pipes: A field study", *Water Research* 103 (2016) 133e140.
- [4] Andrej Stafura, Stefan Nagy, Maria Buckova, Andrea Puskarova, Lucia Krakova, Martin Culík, Nada Beronska, Stefan Nagy, Domenico Pangallo, "The influence of microfilamentous fungi on wooden organ pipes: One year investigation" *International Biodeterioration & Biodegradation* 121 (2017) 139-147.
- [5] Mauricio Latino, Facundo Varela, Maria Forsyth, Yongjun Tan, "Self-validating electrochemical methodology for quantifying ionic currents through pipeline coatings" *Progress in Organic Coatings* 120 (2018) 153–159.
- [6] Lorenzo Fedrizzi, Flavio Deorian, PierLuigi Bonora, "Evaluation of the protective properties of organic coatings on copper pipes for refrigerator cooling circuit" *Electrochimica Acta* 44 (1999) 4251±4258.
- [7] J. Shrestha, J. Li, "Influence of permeate from domestic reverse osmosis filters on lead pipes corrosion and plastic pipes leaching" *Journal of Water Process Engineering* 18 (2017) 126–133.
- [8] K.M. Usher, A.H. Kaksonen, I. Cole, D. Marney, "Critical review: Microbially influenced corrosion of buried carbon steel pipes" *International Biodeterioration & Biodegradation* 93 (2014) 84-105.
- [9] T. Haile, G. Nakhla, E. Allouche, S. Vaidya, "Evaluation of the bactericidal characteristics of nano-copper oxide or functionalized zeolite coating for bio-corrosion control in concrete sewer pipes" *Corrosion Science* 52 (2010) 45–53.
- [10] Ingun Skjevraak, Anne Due, Karl Olav Gjerstad, Hallgeir Herikstad, "Volatile organic components migrating from plastic pipes (HDPE, PEX and PVC) into drinking water" *Water Research* 37 (2003) 1912–1920.

- [11] Flavio Deflorian, Michele Fedel, “Electrochemical analysis of the degradation of lead alloy organ-pipes due to acetic acid” *Journal of Cultural Heritage* 14 (2013) 254–260 .
- [12] Maryam Salehi, Chad T. Jafvert, John A. Howarter, Andrew J. Whelton, “Investigation of the factors that influence lead accumulation on polyethylene: Implication for potable water plumbing pipes” *Journal of Hazardous Materials* 347 (2018) 242–251.
- [13] Jocelyn Tillner, Caroline Hollard, Cristina Bach, Christophe Rosin, Jean-Francois Munoz, Xavier Dauchy, “Simultaneous determination of polycyclic aromatic hydrocarbons and their chlorination by-products in drinking water and the coatings of water pipes by automated solid-phase microextraction followed by gas chromatography–mass spectrometry” *Journal of Chromatography A*, xxx (2013) xxx– xxx.
- [14] Iyad A I-Zaharnah, “Thermal Stresses in Pipes” A Dissertation Dublin City University April 2002.
- [15] S. Ranade, M. Forsyth, M.Y.J. Tan, “The initiation and propagation of coating morphological and structural defects under mechanical strain and their effects on the electrochemical behaviour of pipeline coatings” *Progress in Organic Coatings* 110 (2017) 62–77
- [16] E. Davis, and W. Gill, “The Effects of Axial Conduction in The Wall on Heat Transfer with Laminar Flow”, *Int. J. Heat Mass Transfer*, Vol. 13, pp. 459-470, 1970.
- [17] M. Faghri and E.M. Sparrow, “Simultaneous Wall and Fluid Axial Conduction in Laminar Pipe-Flow Heat Transfer”, *Journal of Heat Transfer*, Vol. 102, pp. 58-63, 1980.
- [18] B. Kraishan, “On Conjugated Heat Transfer in a Fully advanced Flow”, *Int. J. Heat Mass Transfer*, Vol. 25, No.2, pp. 288-289, 1982.
- [19] O.A. Amas, and M.A. Ebadian, “Convective Heat Transfer in A Circular Annulus with Various Wall Heat Flux Distributions and Heat Generation”, *Journal of Heat Transfer*, Vol. 107, pp. 334-337, 1985.
- [20] G.S. Barozzi, and G. Pagliarini, “A Method to Solve Conjugate Heat Transfer Problems: The Case of Fully Developed Laminar Flow in A Pipe”, *Journal of Heat Transfer*, Vol. 107, pp. Seventy seven-eighty three, 1985.
- [21] C. Parakash, and Ye. Liu, “Analysis of Laminar Flow and Heat Transfer in The Entrance Region of An Internally Finned Circular Duct”, *Journal of Heat transfer*, Vol. 107, pp. Eighty four-ninety one, 1985.
- [22] J. Suces, “Analytical Solution for Unsteady Heat Transfer in a Pipe”, *J. Heat transfer*, Vol. One hundred ten, pp. 850-854, 1988.
- [23] S. Olek, E. Elias, E. Wacholder, and S. Kaizwrman, “Unsteady Conjugated Heat Transfer in Laminar Pipe Flow”, *Int. J. Heat Mass Transfer*. Vol. 34, No. 6, pp. 1443-1450, 1991.
- [24] R. Yen and W. Lee, “Conjugate Heat Transfer Analysis in the Entrance location of a Circular Pipe” *Journal of the Chinese Society of Mechanical Engineers*, Vol. 12, No.3, pp. 233-240, 1991.
- [25] Z. Hui ren, and L. Songling, “Numerical Simulation of Traditional Flow and Heat Transfer in A Smooth Pipe”, *Int. J. Heat Mass Transfer*, Vol.34, pp. 2475-2482, 1991.
- [26] R. Yang, R. And S.F. Chang, “A Numerical Study of Fully Developed Laminar Flow and Heat Transfer in A Curved Pipe with Arbitrary Curvature Ratio”, *Int. J. Heat and Fluid Flow*, Vol. 14, No. 2, pp. 138-145, 1993.
- [27] M.A. Al-Nimr, and M.A. Al-Hader, “Transient Conjugated Heat Transfer in Developing Laminar Pipe Flow”, *J. Heat switch*, Vol. 116, pp. 234-236, 1994.
- [28] S. Bilir, “Laminar Heat Transfer in Pipes Including Two - Dimensional Wall and Fluid Axial Conduction” *Int. J. Heat Mass Transfer*, Vol. 38, No. Nine, pp. 1619- 1625, 1995.
- [29] D.J. Schutte, M.M. Rahman, and A. Faghri, “Transient Conjugate Heat Transfer in Thick-Walled Pipe with Developing Laminar Flow”, *Numerical Heat transfer*, Vol. 21, pp. 163-186, 1992.

- [30] B. Shome, and M.K. Jensen, "Mixed Convection Laminar Flow and Heat Transfer of Liquids in Isothermal Horizontal Circular Ducts", *Int. J. Heat Mass Transfer*, Vol. 38, pp. 1945-1956, 1995.
- [31] T. Min, J. Y. Yoo, and H. Choi, "Laminar Convective Heat Transfer of a Bingham plastic in a round pipe-Analytical Approach- thermally Fully Developed Flow and Thermally Developing Flow (the Graetz Problem Extended)", *Int. J. Heat Mass Transfer*, Vol. Forty, No.Thirteen, pp. 3025-3037,1997

