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Simulation and Optimization on Welding Deformation of Big Size Hopper

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Abstract
This paper main focus to reduce the welding deformation of hopper by using experimental methods and Finite Element analysis (FEA) including inherent strain method. Through our finding, that hopper it must be designed and manufactured with high standard to reduce the distortion of metal during the welding process. we have done further study to solve the issue by adding U shape and V shape including the bevel angle on edges of hopper and welding methods, the results has shown that the maximum deformations is reduced, to meet ISO STANDARD. Structure of hopper by using new design as U shape and V shape to absorb the deformation, and heat distribution will affect the surrounding of U or V shape will be the maximum.
Keywords: key words Welding distortion, finite element analysis, experimental, optimize of structure, welding methods.

1. Introduction

The thin plate is easily deformed during welding, which affects the dimensional accuracy of the product, causes difficulty in subsequent assembly and use, and increases costs. Therefore, effectively predicting and controlling the welding deformation of the thin plate structure becomes an important content in welding production. With the development of computer technology and the maturity of finite element theory, more and more people use the finite element method. For large thin-plate welded parts, in order to avoid the computational difficulties caused by the large number of grids, the intrinsic strain method and the linear elastic volumetric shrinkage method are used to efficiently predict the welding distortion. The thickness of the steel plate in the hopper chute is only 6 mm, so controlling the deformation of the feed wipe is extremely important.

In this paper, we have analyzed the way to control the welding deformation by using Finite Element analysis (FEA), based on inherent strain, the thermal elastic plastic analysis theory associated with mechanical properties and strength. In addition, we have done further study to solve the issue by adding U shape and V shape including the bevel angle on edges of hopper and welding methods, the results has shown that the maximum deformations is reduced, to meet ISO standard. And the influences of welding procedure and assembly sequence on the final distortion were examined numerically.

2. The theory of welding deformation

2.1 Inherent strain method

Inherent strain technique its finding by Ueda and Fukuda in 1980 was the first to measurement of residual stress after which be largely used to predict welding distortion [1, 4]. According to the thermal elastic plastic FEA and experiment observations, the total strain ε_{total}(Equation (1-3) includes elastic strain εe, temperature strainεT, plastic strain εp, creep strain εc and segment transformationεph. Inherent strain ε∗ is the supply of welding distortion and residual stress, can be stay within the weld interior. Thus, inherent strain ε∗ can be expressed as the subsequent Equation (1-3) [5]

$$\varepsilon_{total} = \varepsilon_e + \varepsilon_T + \varepsilon_p + \varepsilon_c + \varepsilon_{ph} \quad (1)$$

$$\varepsilon^* = \varepsilon_T + \varepsilon_p + \varepsilon_c + \varepsilon_{ph} \quad (2)$$

In all components of inherent strain, the plastic strain is the domain component [10], and it can be obtained by experiment measurement or Thermal Elastic Plastic FEA simulation. Furthermore, welding deformation induced by inherent strain is also evaluated by the inherent deformation and bending in the longitudinal and the transverse directions.

$$\theta_y^* = \frac{12}{h^3}\iint \left(z - \frac{h}{2}\right)\varepsilon_y^* \, dydz \quad (3)$$

Inherent strain FEA is generally acknowledged by an elastic FEA calculation, and exceptionally appropriate for anticipating welding deformation of the huge scale structures.

2.2 Residual stresses

The encompassing of material not heated, or not heated with a similar intensity, will keep those extensions to a couple of extend and compressive stresses can be formed inside the warmed piece of the material. While distortions and stresses will disappear from the material on the off chance that it is just compacted flexibly, while cooled off to the starting temperature the underlying condition of the material is in region yet again. But, if the rapid heating and expansion could reason plastic distortions of the heated material, i.e. when stresses are exceeding the yield limit, and plastic strains would be given within the material. However, when cooled method begin on the material is going to contract, and at last it will contract to a smaller volume than before the heating or a smallest try to, the materials surrounding prevents this. So, once the material reaches to initial temperature, tensile stresses can stay in the heated element and compressive stresses among the environment. Totally different phenomena happen throughout the heating and cooling as well as part transformation can also have an effect on the expansion/contraction of the material and additionally end in irreversible deformations moving the residual stresses. The result of the part transformations on the residual stresses depend on variety of things, i.e. material, peak temperature etc. These residual stresses can then account for the deformations occurring after welding and depending on the structure and material properties these will be totally different. [6,7]

2.3 Heat transfer property

There is rapid heating of material which reasons it to melt and frequently base and filler material gets combined together. [8] This could elect the material properties once the material has hardened, partially because of the mix and also due to the thermal cycle the material has experienced. Distraction of hopper during a weld outcome from the extension and contraction of the weld metal and adjacent base metal at some stage among the heating and cooling cycle of the welding procedure. Doing all welding on one side of a section will reason significantly extra bending than if the welds are rotated from one side to the next amid this heating and cooling cycle, numerous components influence shrinkage of the metal and prompt distortion, as an example, mechanical and physical properties that variation as heat is connected. When temperature of the weld region increases, yield strength, elasticity, and thermal conductivity of the metal plate decrease, whilst thermal enlargement and specific warmth growth. These changes, in turn, affect warmness flow and uniformity of heat distribution.

Table 1 hopper welding data

Line number.	Welds distance/mm	Current /A	Voltage /V	Speed/mm/s
1	2695	275-296	31-32	5.32
2	1750	275-296	31-32	6.34
3	2695	275-296	31-32	6.57
4	1750	275-296	31-32	5.79
5	2130	170-190	20-21	6.3
6	2430	170-190	20-21	6.07
7	2130	170-190	20-21	5.68
8	2450	170-190	20-21	6.28
9	900	275-296	31-32	6.87
10	900	275-296	31-32	8.65
11	900	275-296	31-32	9.65
12	900	275-296	31-32	8.41

3 . Simulation results and discussions

Follow Fig1(a) shows the meshed entities of the hopper, fine meshed has done on hopper model where 52095 numbers of elements and 126358 nodes formed.

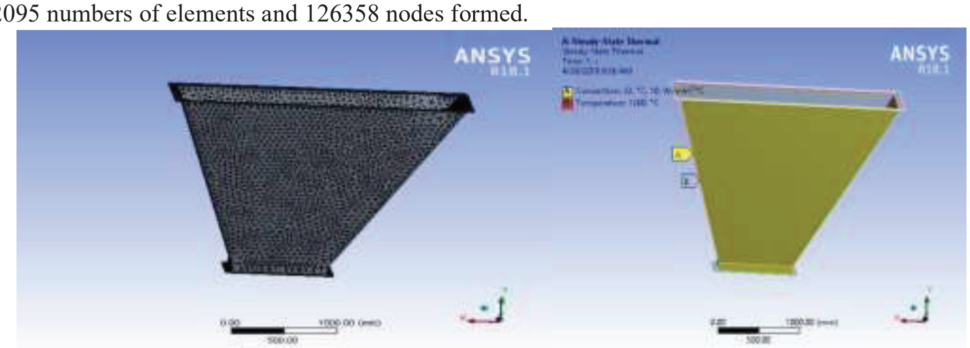

Fig 1 (a), (b) the meshed model and thermal boundary condition

Fig 1 (b) shows thermal boundary conditions where weld parameters are applied in the form of temperature value 1200 ^{0}C. Since during working process of welding, heat generated on hopper body will dissipate by convection process. So the total outer surface of the hopper body has selected for convection value to remove the heat.

3.1 Structural Analysis on Hopper

By this analysis we can easily find the deformations and stresses on the model. Fig 2 shows the total deformation occur at the surface of the hopper. The maximum value is 13.77 mm. maximum deformations are showing by red color area and minimum are by blue colors.

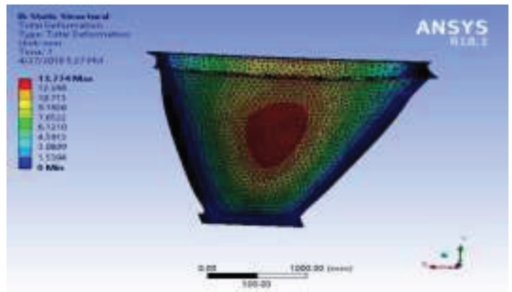

Fig 2 Total deformation (2)

3.2 Optimize structure of hopper [U and V shapes] model

Welding deformation usually occur in thin plate welded structures due to the comparatively low stiffness. To optimize structure of hopper by using U shape that can be absorb the welding deformation that's aim of this project. Optimize groove angle on the edges of hopper plates to reduce the effect of shrinkage force. To proper edge by chamfer, the bevel angle should be 30 degrees, but it's depends on thickness of plate, the importance is space between two corner of plate as 0.794 mm to reduce the volume. Therefore, to selection of the weld preparation is consequently a compromise between maintaining adequate access and minimizing the weld volume**.**

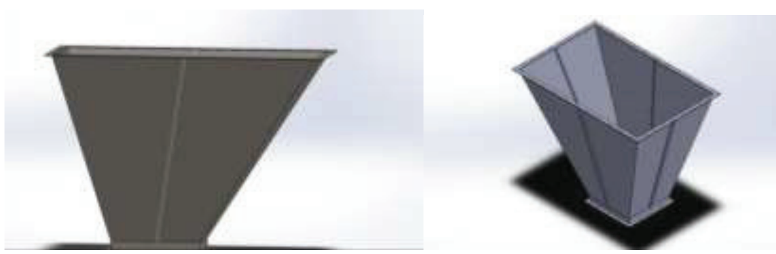

Fig 3 u shape and v shape

3.3 Analysis results on U shape of Hopper

Fig 4 shows thermal boundary conditions where weld parameters are applied at the edges in the form of temperature value 1200 ^{0}C. Since during working process of welding, heat generated on hopper body will dissipate by convection process. So the total outer surface of the hopper body has selected for convection value to remove the heat. Fig5 shows the total deformation occurs at Part 3 surface of the hopper. The maximum value is 7.73 mm. and minimum deformation occurs at part 1 is zero.

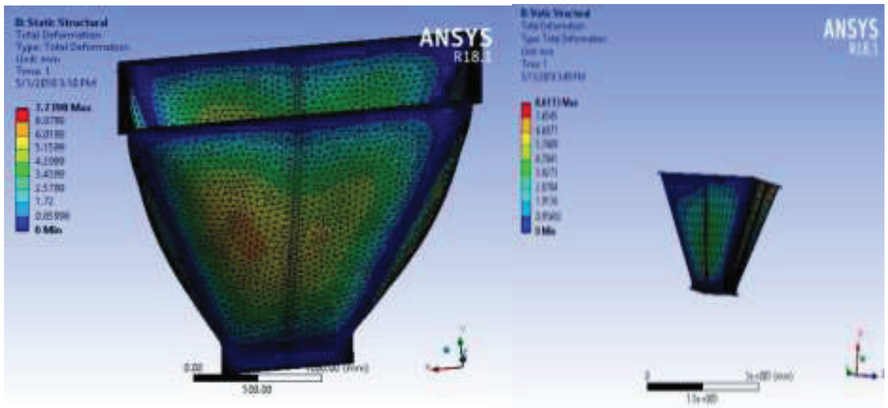

Fig 4 total deformation

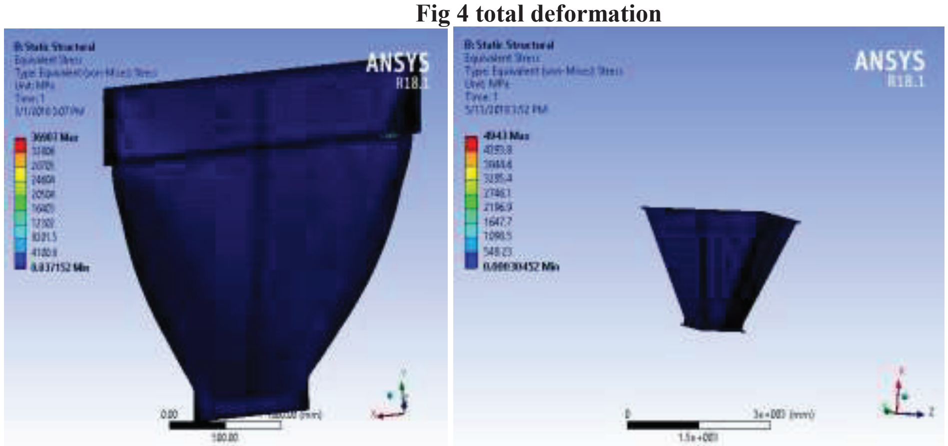

Fig 5 stress

The below figures shows the total stresses & strain are more near to the welding parameters applied area. The max stress found 36907 Mpa at Part 1 and max strain 0.19378 is also at part 1.

3.4 Comparison between FEA results and experimental results

Results are formulated in following table:

Table 2 Analysis result with experiment

EXPERIMENTAL RESULTS		FEA RESULTS
	Total Deformation (mm)	
Hopper without Shape	14	13.7
Hopper with U shape	-	7.73
Hopper with V shape	-	8.61

It observed that experimental calculations are done on primary Hopper where total deformation value is found 14 mm then further we analyzed it by FEA calculations which give the deformation value 13.7 mm. The experimental value and FEA value is approximately same. There is no big difference between them. So we proposed a new model.

The main aim of our work was to reduce the deformation value on Hopper, so we proposed a new model of Hopper with U and V shape on each surface. After FEA calculations on new Hopper with U shape the deformations are reduced from 13.7 mm to 7.73 mm. so our aim is achieved. So optimization with new shape of Hopper does not reduce the strength of primary Hopper so that our model analysis is safe and the values are under allowable stresses.

4. Conclusion

The aim of this paper is to run a simulation using Finite Element analysis (FEA) by using various factors and parameter and boundary condition during the welding method procedure on manufacturing stage as well as on the design stage to reduce the amount of distortion on hopper to meet up ISO standard. Finite Element analysis (FEA) results of U shape and V shape structure of hopper has shown the reduction of welding distortion because the heat input has been distributed to nearly V shape, however U shape it absorbs the heat distribution by forming a central boundary on plate of hopper therefore, the maximum deformation can be occurring on the sounding of V and U shape, however, V shape structure has been shown more deformation than U shape structure the reason of that is the size of U shape mare than V shape so, the size can help full for absorb the deformation.

References

[1] Vishnu V.S et al, "Numerical Analysis of Effect of Process Parameters on Residual Stress in a Double Side TIG Welded Low Carbon Steel Plate", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), eISSN: 2278-1684, p-ISSN: 2320-334X PP 65-68, 2014.

[2] U.Ç. Tapıcı, Fixture design for robotic welding application and analysis of welding distortions, Ms.'s Thesis, Istanbul Technical University, Institute of Science and Technology, 2006.

[3] Deng D, Murakawa H, Liang W. Prediction of welding distortion in a curved plate structure by means of elastic finite element method. J Mater Process Technol. 2008; 203:252–266.

[4] Wang J, Yuan H, Ma N, et al. Recent research on welding distortion prediction in thin plate fabrication by means of elastic FE computation. Mar Struct. 2016;47:42–59..

[5] D. Deng, Theoretical prediction of welding distortion in thin curved structure during assembly considering gap and misalignment, Doctoral Thesis, Osaka University, 2002.

[6] Ueda Y, Fukuda K. A selection method of observing positions for highly accurate measurement of residual stresses (welding mechanics, strength & design). Trans JWRI. 1980;9(1):101–106.

[7] Vishvesha A, Pandey C, Mahapatra MM, et al. On the estimation and control of welding distortion of guide blade carrier for a 660 MW turbine by using inherent strain method. Int J Steel Struct. 2017;17(1): 53–63.

[8] Madhu S Nair,Hidekazu Murakawa , 2002, 'Theoretical study of forming of twisted T- section longitudinal investigation from aspect of inherent strain (1st report)',J.Kansai SOC. N.A, Japan No.237.