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Numerical Prediction of Weld Quality in Friction Stir Welding of Dissimilar Materials

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Abstracts

Objective of this research is to develop a finite element simulation of friction stir welding of Magnesium and Titanium alloys. In the present study, the transient analysis is performed in Ansys to simulate the friction stir welding process of Magnesium and Titanium alloys to predict the time varying temperature across the work piece. From the results of the transient analysis, Aim to find out various temperatures develop between tool and work piece because of friction during the Friction Stir Welding process.

Keywords: FSW, Dissimilar metals, Numerical Prediction, ANSYS.

Introduction

A variety of joining processes for metal parts have been employed in various fields of the manufacturing industry. Depending on the types or combinations of energy, metal welding processes may be divided into two major groups: (1) fusion welding and (2) solid-state welding. Fusion welding processes use intense localized heat source to melt the base metal. Solid-state welding is completed under pressure alone or a combination of heat and pressure. If heat is used, the temperature in the solid-state welding process is below the melting temperature.
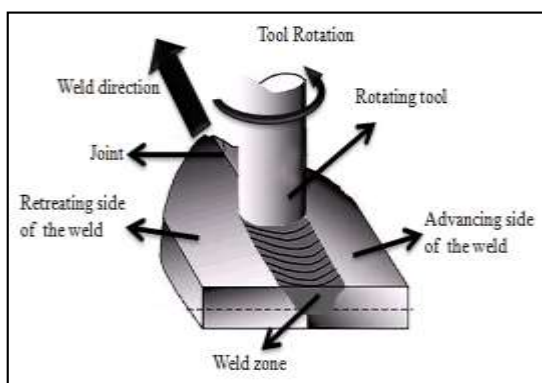

Fig.1 Schematic of Friction Stir Welding

Friction Stir Welding (FSW) falls in the category of solid state welding which was invented by The Welding Institute (TWI) in 1991 for joining low melting temperature alloys like aluminum, magnesium and copper (Thomas et al. 1991). The basic principle of FSW involves plunging a spinning tool that has a specially designed pin and shoulder into the work pieces that are intended for welding. Since melting of materials is avoided; FSW avoids problems such as distortion and metallurgical reactions which typically appear in conventional fusion welding processes. It is reported that the strength of the FSW weld is 30% to 50% greater than those produced by arc welding and resistance spot welding while maintaining the fatigue life comparable to riveted panels (Mendez and Eagar 2001). However, applications with high temperature materials like steel and titanium remain limited. Compared with joining of low temperature materials, FSW of steel requires large plunging and stirring forces, which dictate the use of large FSW equipment. More importantly, the life of a spin tool is significantly reduced in the FSW of high temperature materials. Frequent replacement of worn-out tools leads to high production cost, which results in additional cost due to reduced production rate. Moreover, the use of the damaged tool brings about another problem in terms of welding quality. The tool plays a very important role in successful joints produced by FSW. Tool shape and size will dictate, to some degree, material flow and heat generation in the weld zone, which will, in turn, affect the final weld properties. The shoulder of the tool, which is thought to be the main source of heat generation, is typically concave in shape. This aids in weld consolidation by forcing the softened material to remain in the weld zone as the tool traverses the joint line.

The pin also plays a very important role, joining the work pieces in a through-thickness manner. It is thought that the portion of the heat that is generated by the pin is

considerably smaller than that generated by the shoulder, but an intense region of shearing and flowing material must exist in order for the work piece material to move around the pin and reconsolidate behind it. Although a pin with a smooth surface has proven to be satisfactory for many weld configurations, features are often added to the pin, such as facets, flats, or threads, to increase the ability of the pin to move through the work piece material and to aid in material mixing which can occur in both a horizontal and vertical manner. Temperatures in the tool and work piece are often near the solidus of the work piece and 3-8 kW of mechanical power are converted to heat during each weld. Thus, for a complete understanding of the FSW process, both tool and work piece need to be carefully considered.

Literature review

[1]Yeong-Maw Hwanga et al. explores the thermal histories and temperature distributions in a work piece during a friction stir welding (FSW) process involving the butt joining of aluminum 6061-T6. Different types of thermocouple layout are devised to measure the temperature histories during FSW at different locations on the work piece in the welding direction. Successful welding processes are achieved by appropriately controlling the maximum temperatures during the welding process. [2]W. M. Thomas et al.focussed on the relatively new joining technology friction stir welding (FSW). Like all friction welding variants, the FSW process is carried out in the solid-phase. Generically solid-phase welding is one of the oldest forms of metallurgical joining processes known to man. Friction stir welding is a continuous hot shear autogenous process involving a non-consumable rotating probe of harder material than the substrate itself. In addition, FSW produces solid-phase, low distortion, good appearance welds at relatively low cost. [3]L.M. Marzoli et al.established a friction stir welding (FSW) process parameters envelope for an AA 6061 alloy reinforced with 20% of Al_2O_3 particles, and determines properties of the obtained joints. After a brief description of the FSW technique, and the difficulties in joining MMCs, experimental procedure is illustrated. Microstructure has been observed with optical microscope, and images have been analyzed with image analysis software. Micro hardness and tensile tests have been also carried out. [4]X.K. Zhu et al. analyzed Three-dimensional nonlinear thermal and thermo-mechanical numerical simulations are conducted for the friction stir welding (FSW) of 304L stainless steel. The finite element analysis code—WELDSIM, developed by the authors specifically for welding simulation, was used. Two welding cases with tool rotational speeds of 300 and 500 rpm are analyzed. The objective is to study the variation of transient temperature and residual stress in a friction stir welded plate of 304L stainless steel.[5] Rajesh S.R. et al reported that the heat generation due to plastic work is the dominating term during the steady state friction stir welding (FSW) process. Based on this phenomenon a 3D-analytical model of the stir zone around the FSW tool pin has been developed. In this model, the friction force during steady state FSW process has been neglected as the material in this zone is plasticized and it has undergone plastic deformation rather than inducing friction to the tool pin boundary.

Problem identification

Friction stir welding is a solid state welding technique which can be used to produce sound welds between the different similar and dissimilar materials. Dissimilar welds which include welds between the different series of aluminums to magnesium, steel and titanium has been successfully produced by many researchers. In the present study the transient analysis is performed in Ansys to simulate the friction stir welding process of magnesium and titanium alloys to predict the time varying temperature across the dissimilar work piece. From the result of the transient analysis, the present study aims to find out that at what value of heat which develops between tool and work piece because of friction during the FSW process the good quality of weld is achieved.

Modeling

There is always a need of some assumptions to model any complex geometry. These assumptions are made, keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling we always ignore the things that are of less importance and have little impact on the analysis. The assumptions are always made depending upon the details and accuracy required in modeling. The assumptions which are made while modeling the process are given below: The Work piece material is considered as homogeneous and isotropic. The domain is considered as Axisymmetric for tool and solid for work piece. Inertia and body force effects are negligible during the analysis. The thermal conductivity of the material used for the analysis is uniform throughout.
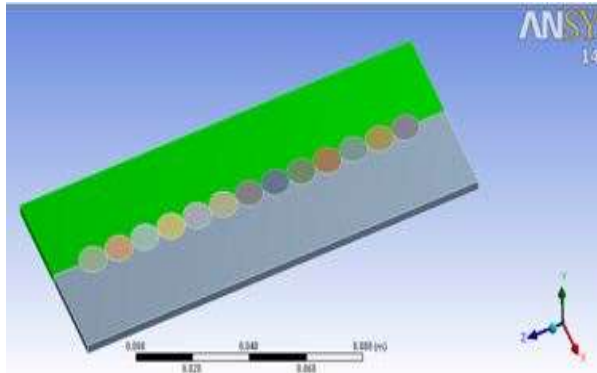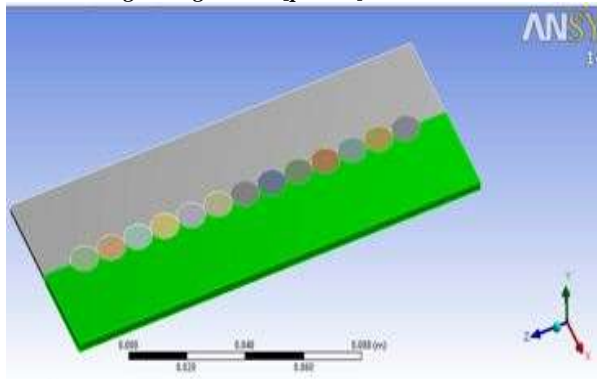
Fig.2 Magnesium [plate 1] and Titanium
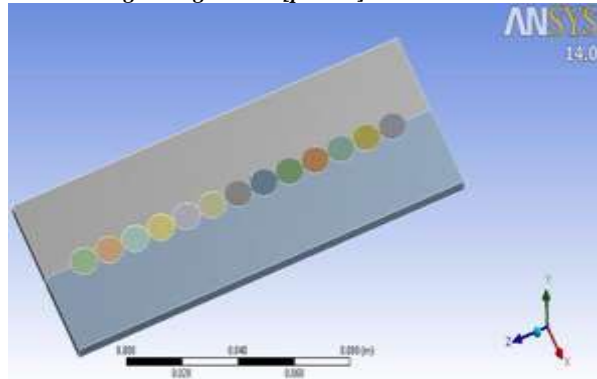

Fig.3 Magnesium [plate 2] and Titanium
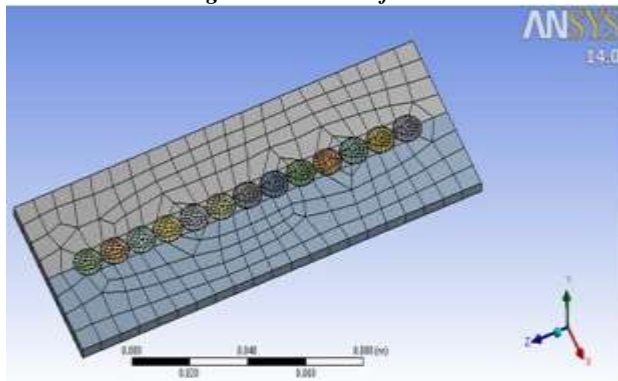

Fig.4 Tool work surface

Fig.5 Mesh geometry

Material properties

The following material properties are taken into account to carry out this analysis.

Table.1 Constants for Magnesium Alloy

Density	6000 kg m^{-3}
Thermal Conductivity	60 W m^-1 C^{-1}
Specific Heat	1000 J kg^-1 C^{-1}
Melting Point	650 °C

Table.2 Constants for Titanium Alloy

Density	6000 kg m^{-3}
Specific Heat	800 J kg^{-1} C^{-1}
Thermal Conductivity	100 W m^{-1} C^{-1}
Melting Point	1668 °C

Table.3 Constants for Structural Steel

Density	7850 kg m^{-3}
Coefficient of Thermal Expansion	1.2e-005 C^{-1}
Specific Heat	434 J kg^{-1} C^{-1}
Thermal Conductivity	60.5 W m^{-1} C^{-1}
Resistivity	1.7e-007 ohm m

Numerical results

The results of transient analysis is given below for two inputs q = 10 J/s and 115 J/s.

Case (a) Q= 10 J/s

Heat Q = 10 J/s, temperature distribution at t = 1 sec, 2 sec, 3 sec, 4 sec up to 13 sec.
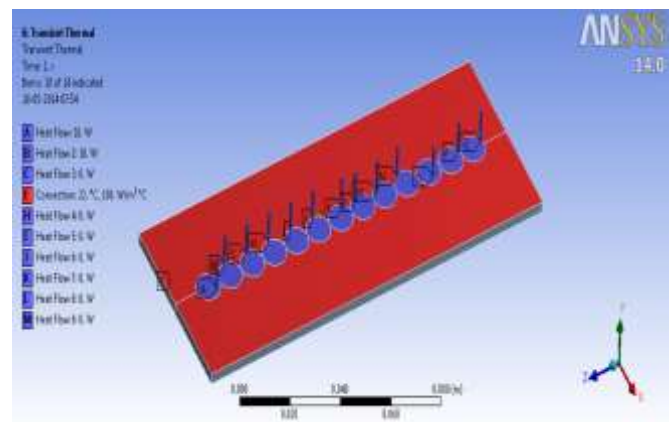
Fig.6 Transient Analysis
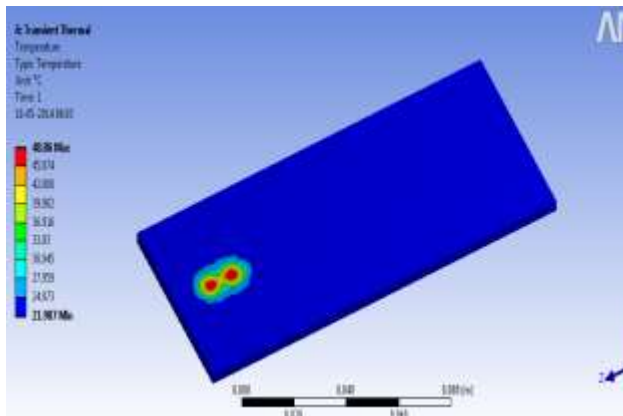
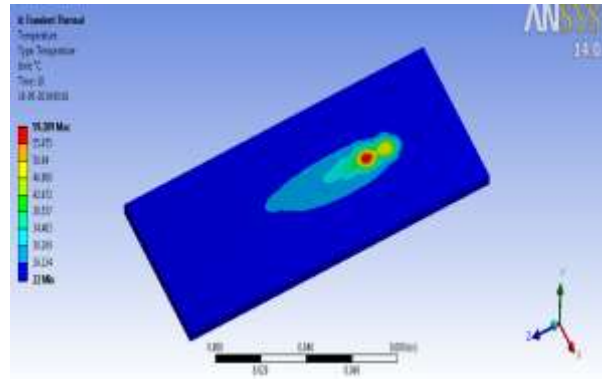*Fig.7 Temperature Distribution at t = 1 sec*

Fig.10 Temperature Distribution at t = 4 sec

Fig.8 Temperature Distribution at t = 2 sec
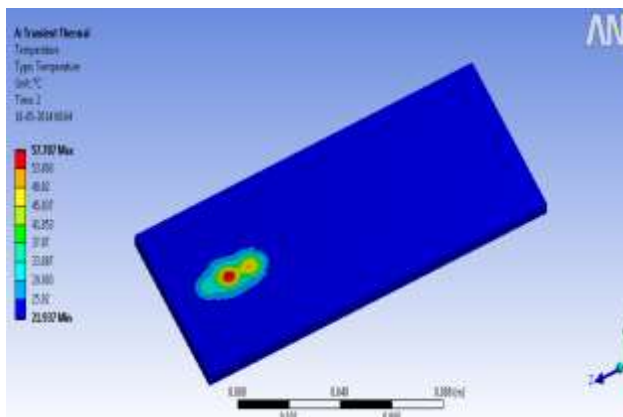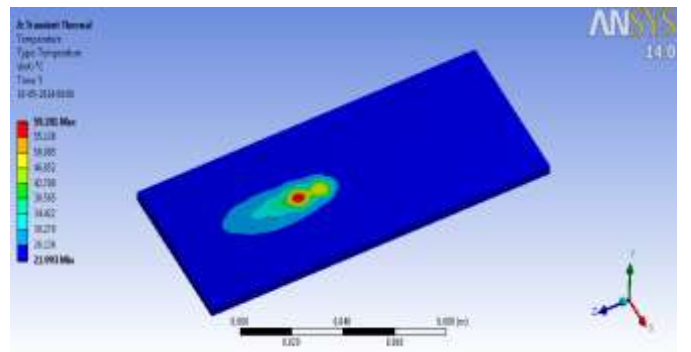
Fig.11 Temperature Distribution at t = 5 sec

Fig.9 Temperature Distribution at t = 3 sec
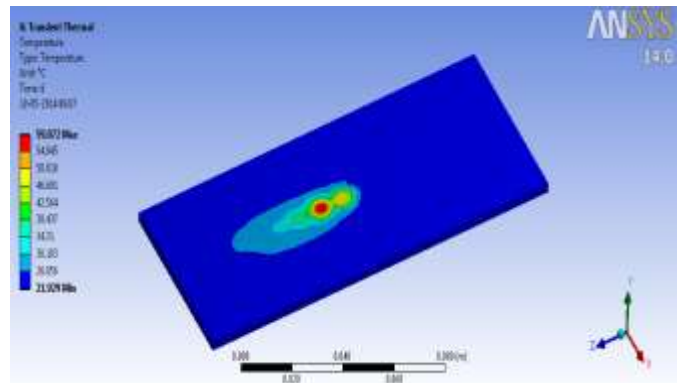
Fig.12 Temperature Distribution at t = 6 sec
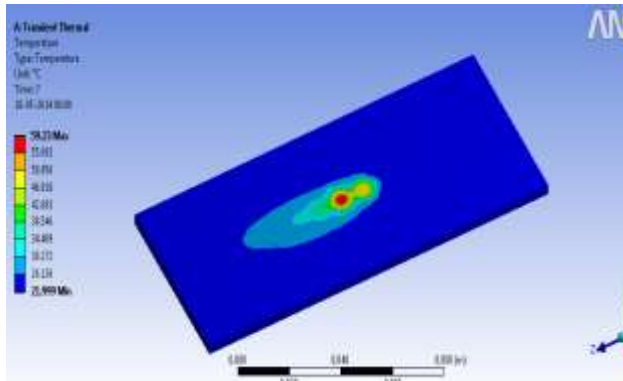
Fig.13 Temperature Distribution at t = 7 sec
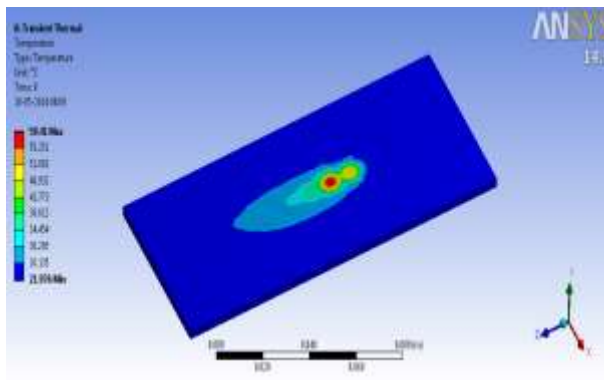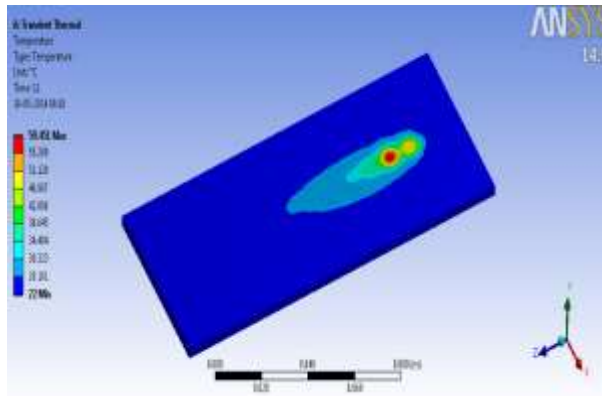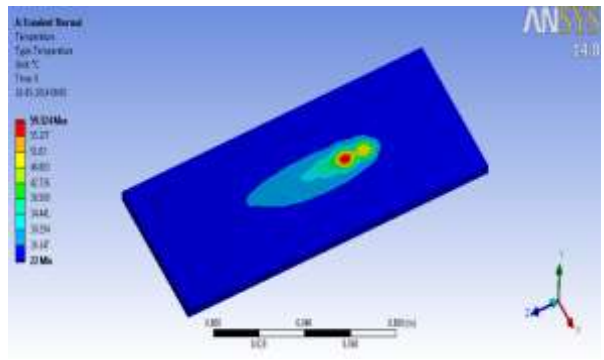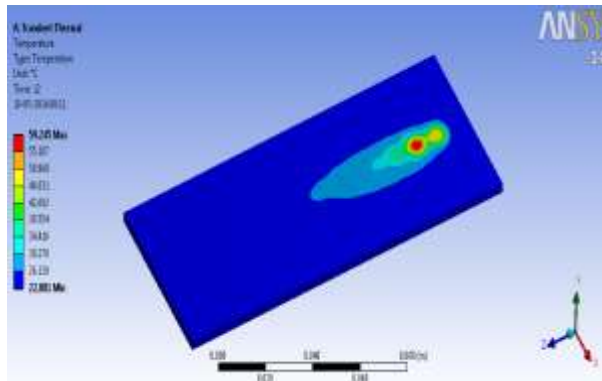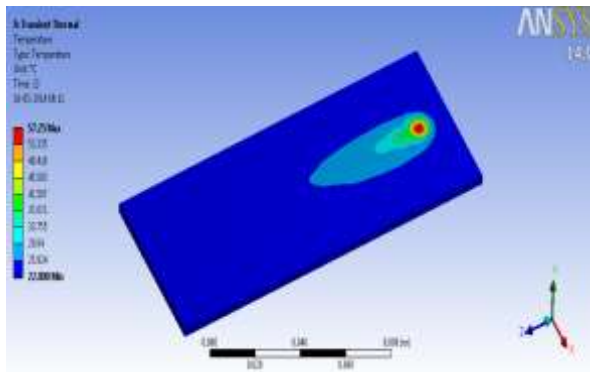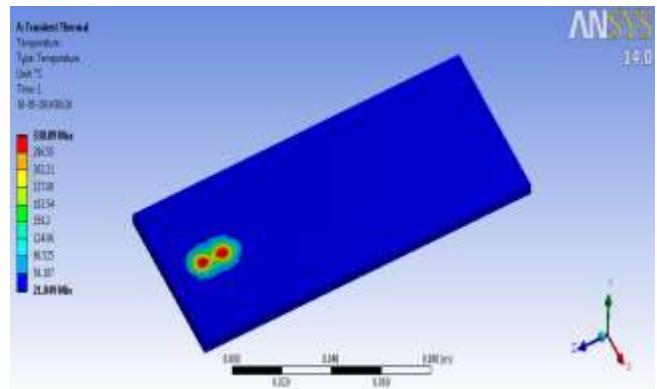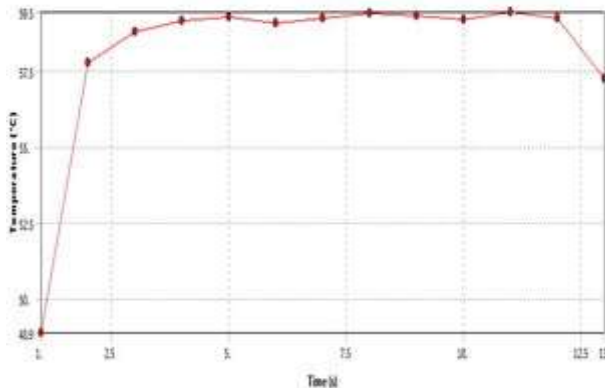

Fig.16 Temperature Distribution at t = 10 sec

Fig.14 Temperature Distribution at t = 8 sec

Fig.17 Temperature Distribution at t = 11 sec

Fig.15 Temperature Distribution at t =9 sec

Fig.18 Temperature Distribution at t = 12 sec

Fig.19 Temperature Distribution at t = 13 sec

Fig.20 Transient Analysis for q = 10 J/s

Case (b) Q= 115 J/s

Heat Q = 115 J/s, temperature distribution at t = 1 sec, 2 sec, 3 sec, 4 sec up to 13 sec.

Fig.21 Transient Analysis

Fig.22 Temperature Distribution at t = 1 sec

Fig.6 to 19 shows that the temperature distribution of two dissimilar metals during FSW with a heat rate of 10 J/s.Fig.20 shows the graphical form of temperature distribution in dissimilar metals during FSW with transient analysis. It shows the temperature distribution have increased with respect to given step by step time period. It also depicts the temperature distribution is increased gradually with respect to increasing time period and it is maintained almost in straight line values.

Fig.23 Temperature Distribution at t = 2 sec
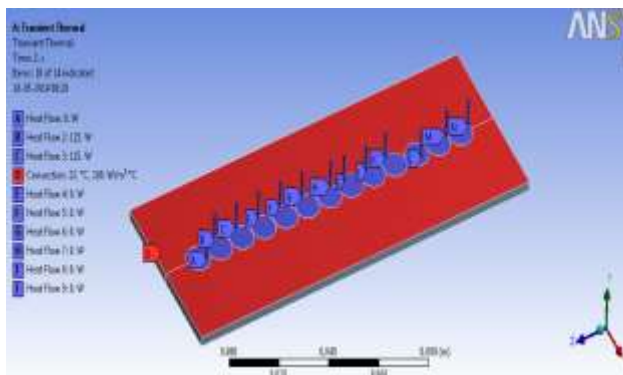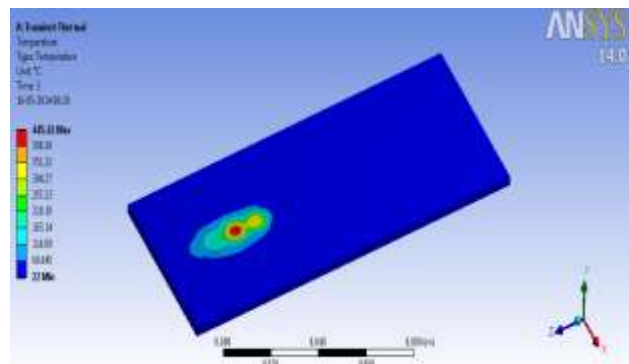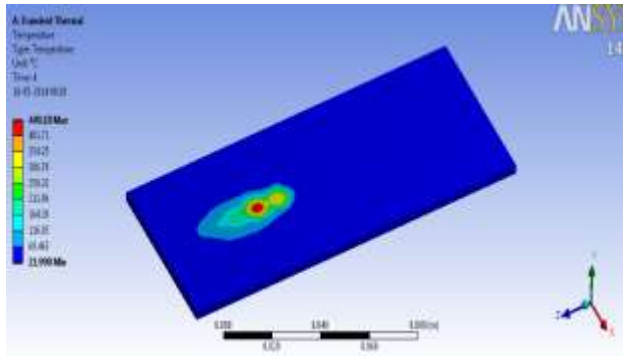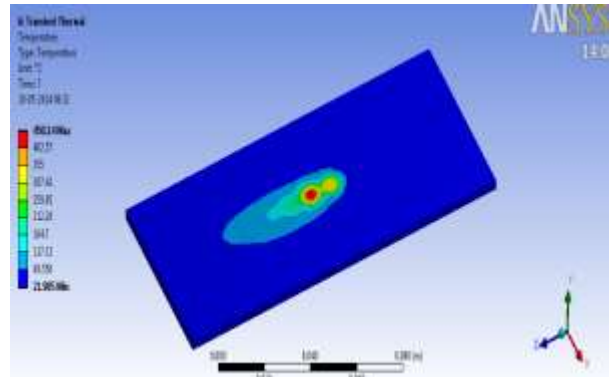

Fig.24 Temperature Distribution at t = 3 sec
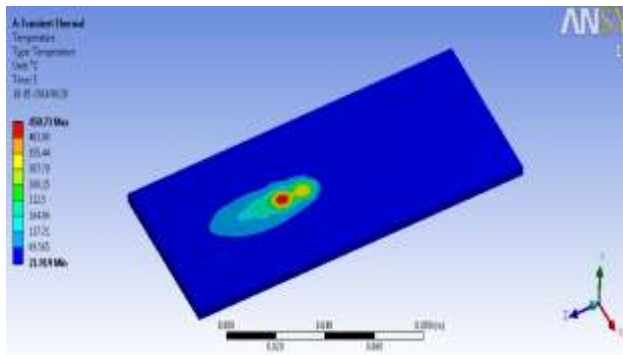
Fig.25 Temperature Distribution at t =4 sec

Fig.26 Temperature Distribution at t =5 sec

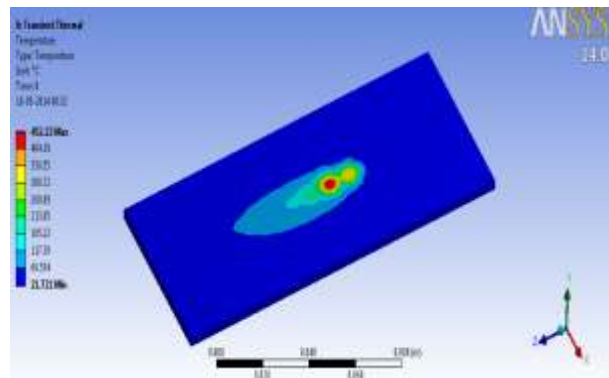*Fig.27 Temperature Distribution at t =6 sec*

Fig.28 Temperature Distribution at t =7 sec
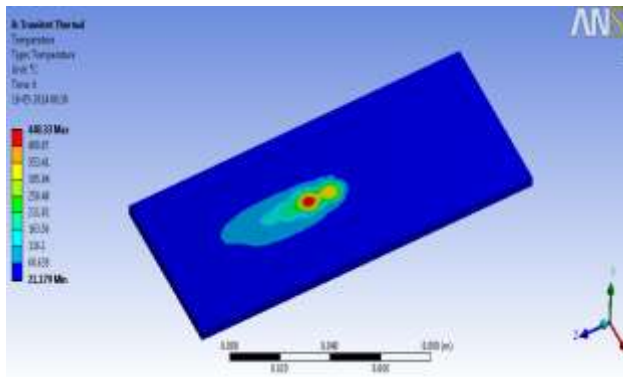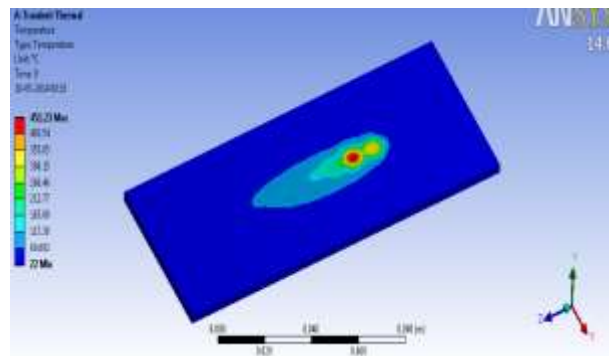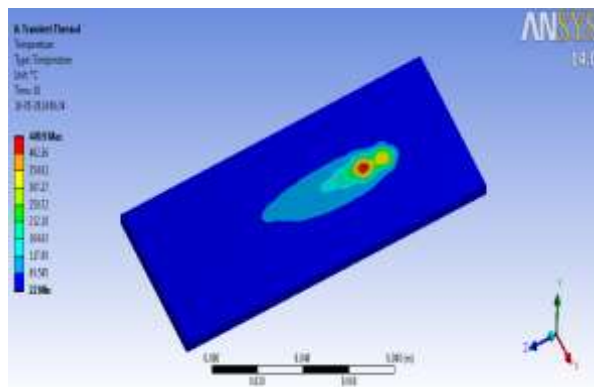

Fig.29 Temperature Distribution at t =8 sec

Fig.30 Temperature Distribution at t =9 sec

Fig.31 Temperature Distribution at t =10 sec

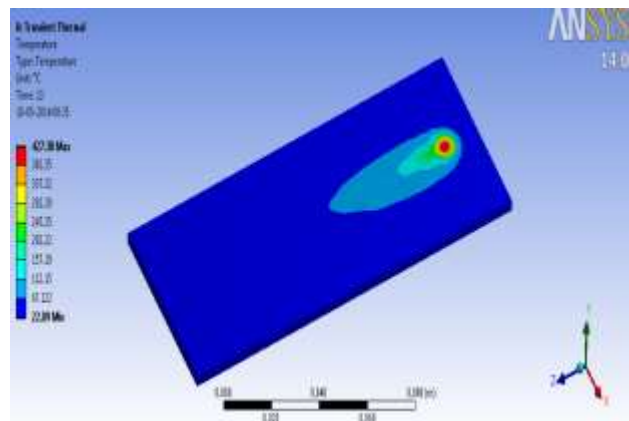*Fig.32 Temperature Distribution at t =11 sec*

Fig.33 Temperature Distribution at t =12 sec
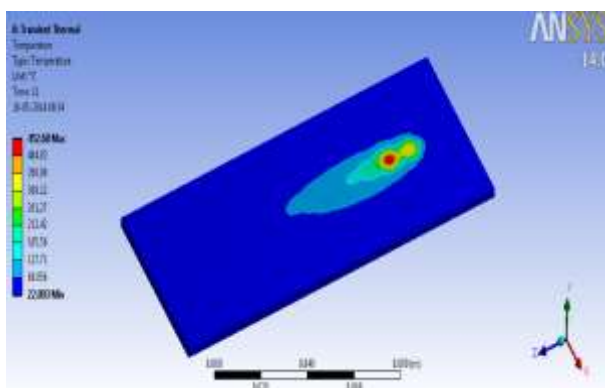

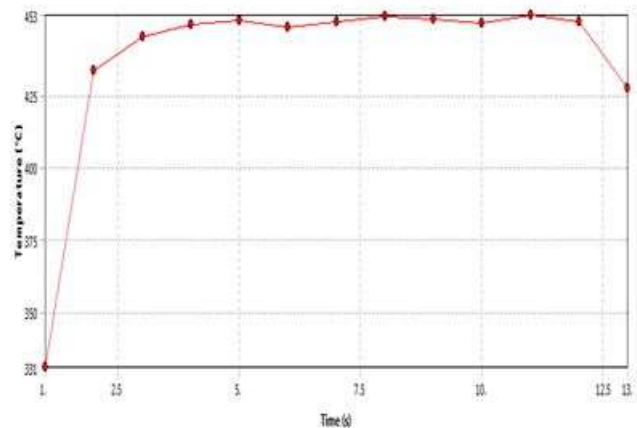*Fig.34 Temperature Distribution at t =13 sec*
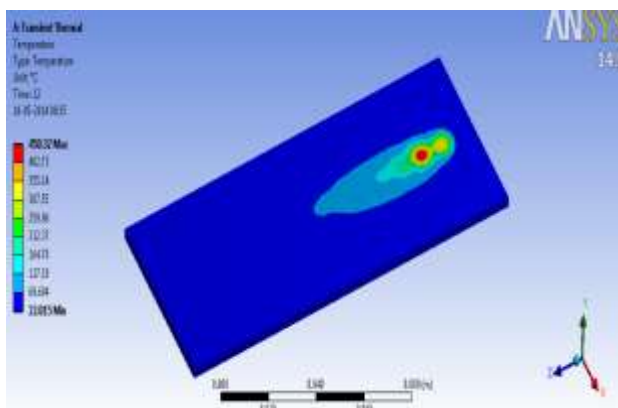

Fig.35 Transient Analysis for q = 115 J/s

Fig.21 to 34 shows that the temperature distribution of two dissimilar metals during FSW with a heat rate of 115 J/s.Fig.35 shows the graphical form of temperature distribution in dissimilar metals during FSW with transient analysis. It shows the temperature distribution have increased with respect to given step by step time period. It also depicts the temperature distribution is increased gradually with respect to increasing time period and it is maintained almost in straight line values.

Conclusions

The present study of transient analysis, in which work piece is subjected to the constant heat flux developed at the surface between tool and the work piece during the welding process due to the friction generated. The developed heat flux is given as the input to the work peace along the joining edge and simulated with respect to time for the tool to travel from one end to other end during welding to plot the temperature distribution across the work piece. From the results of the transient analysis, the maximum temperature at the node near the

heating zone is raising and lowering when the tool is moving away from the node is considered. From the pattern of temperature variation against time at the node considered the welding efficiency could found out. At Heat value 115 watts, the maximum temperature at the weld zone is around 450 ° C which is 70 percent of the melting point of the magnesium alloy. It's been given in the experimental work of many literatures that the welding efficiency is good when the temperature at weld zone is 70 to 75% of the melting point of the welding materials. Here in the present analysis, at 115 watts, good welding efficiency is obtained. It's been concluded finally from the above analysis that ansys can be used effectively to model the whole friction stir welding process to study different parameters during welding process to predict the heat and temperature limit during the FSW process of Magnesium and Titanium alloys.

References

1. Yeong-Maw Hwanga, Zong-Wei Kanga, Yuang-Cherng Chioua, Hung-Hsiou Hsub, 2008.Experimental study on temperature distributions within the work piece during friction stir welding of aluminum alloys.
2. W. M. ThomasU, E. D. Nicholas, 1997, Friction stir welding for the transportation industries.
3. L.M. Marzoli a, A.V. Strombeck a, J.F. Dos Santos a, C. Gambaro b, L.M. Volpone, 2006. Friction stirs welding of an AA6061/Al2O3/20p reinforced alloy.
4. X.K. Zhu, Y.J. Chao, 2011.Numerical simulation of transient temperature and residual stresses in friction stir welding of 304L stainless steel.
5. Rajesh S.R. a,, Han Sur Banga, Woong Seong Changb, Heung Ju Kimb, Hee Seon Banga, Chong In Oha, Jae Seon Chu,2006. Numerical determinations of residual stress in friction stir weld using 3D-analytical model of stir zone.