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mathematics srm valliammai engineering college kattankulathur chennai tamil nadu 603202 india r c l e n f b r c keywords friction welding based rotating tool penetrates line union previously fixed pressed friction welding piece move along line process joining material low temperature solid state heat source metal melting point heat generated friction tool high rotation dilutes magnesium aluminium base material flow towards center tool causing mechanical mixing shoulder modeling cause final stage material already cooled article proposes study influence different parameter fsw welding thermal characteristic weld joint aluminum magnesium alloy numerically simulation result confirmed temperature distribution high shoulder towards border part symmetrical respect middle plane calculated maximum temperature magnesium aluminum 843 7 k 702 k respectively 1 introduction material form weld bead 10 11 pin enters part shoulder contact face part welded tool welding one popular widely used mean begin advance along line weld keeping temperature assembling metal structure without several industrial ap material lower fusion point technology many plication would possible 1 2 welding advantage conventional process indeed absence fusion process constant development since 19th century mean absence solidification recrystallization problem going torch welding arc welding laser welding one le distortion material therefore le residual stress developed relatively recent process friction stir welding 12 13 process also allows assembly alloy difficult commonly known fsw friction stir welding many weld conventional technique represents alternative advantage particularly aeronautics space sector 3 5 welding 14 15 industrial sector require minimal weight structure several research project carried scientific adequate mechanical property ease implementation reliable community better understand characteristic parameter assembly 6 7 influencing fsw welding 16 18 however appropriate numerical fsw process patented early 90 twi welding analysis mkissing accessible literature research institute great britain consists assembling material novelty mainly focused study different influence solid phase pasty range using specific cylindrical tool set parameter fsw thermal characteristic weld joint rotation 8 9 latter consists shoulder used generate aluminum magnesium alloy numerically heat friction pin role mixing plasticized corresponding author e mail address sasigmath83 gmail com g sasikala http doi org 10 1016 j matpr 2023 08 095 received 16 may 2023 received revised form 8 august 2023 accepted 9 august 2023 2214 7853 copyright 2023elsevierltd allrightsreserved selectionandpeer reviewunderresponsibilityofthescientificcommitteeofthe4thinternational conferenceonmaterials manufacturingandmodelling pleasecitethisarticleas c r maheshaetal materialstoday proceeding http doi org 10 1016 j matpr 2023 08 095c r mahesha et al e r l p r c e e ingsxxx xxxx xxx 2 mathematical development work neglecting first third part c compared part b colegrove gave following model heat solve thermal problem fsw welding mainly necessary source 2 31 know amplitude flux absorbed part welded v 2μyπr hv 4f μv cosθ thermal modeling based two thermal source fsw welding q p 2πr phky 3 3 1 p μ 2 r p n πm 3 friction plastic deformation tool part interface subject several study 19 21 present essential step equation 3 becomes understanding transfer heat flow material around tool lh l e fm thic er th etr ru mc atu l r ol dm eo lid ni gfi c wa oti ro kn ff sth iw bel ad e resolution q p 2 μ 3 π 1 r p h μ 2v rp 4 heat conduction equation completed boundary condition average shear stress material rp radius appropriate initial model thermal source 14 tool pin h thickness part welded μ coeffi case chose thermal model 22 resolution friction stir welding problem cient friction fn translational force welding 2 4 initial boundary condition 2 1 general assumption solve heat transfer equation numerically analytically considered thermal problem managed general heat necessary first correctly set initial boundary condition 15 transfer equation 3d therefore consider following simplifying initial calculation condition temperature initial state assumption 23 24 tool part welded system coordinate considered three dimensional x z assumed mobile linked axis tool x z 0 300k 5 physical description therefore eulerian configuration boundary condition shoulder part welded pin regime becomes quasi stationary type conduction convection part welded interface respectively 15 32 tool pin assumed cylindrical conduction loss contact surface part welded lower support assumed convective transfer k n q 6 γ mode specific heat transfer coefficient loss surface part assumed natural convection exchange coefficient h ambient air k n q w 7 γ heat due plastic deformation material welded effect fsw tool assumed negligible comparing q q w heat flow generated shoulder workpiece pin workpiece interface heat transfer contact heat generated friction interface part welded lower support given local temperature exceed melting temperature tf 15 heat transfer radiation negligible 2 2 equation heat transfer part welded k n h cid 0 0 8 γ considering previous assumption 25 heat transfer equa type heat exchange part welded tion room weld positive ox axis welding direction surrounding environment convective modeled thermal convection coefficient h ρct x k x x k z k x z v x ρct 1 k n h cid 0 0 9 γ ρ density material k x z thermal conductivity different direction c heat capacity v due symmetry two part welded either side feed rate tool part temperature vertical plane weld parallel weld bead fig 1 assumed temperature gradient direction transverse weld zero along plane condition applicable het 2 3 heat source model erogeneous welding according bibliography two major source heat heat interface pin part welded heat 0 10 xsym shoulder part welded interface 26 27 heat generated locally shoulder surface part surface 3 numerical simulation element distance ri calculated follows 28 29 ω q 2 π μ fn r 60 2 elemth ene e mqu ea tt hi oo dn mn ea tg hi dg wh icp hh e dn io sm cre en tio zn e tr e pl av td ia lb fh fee r efi nn ti ae l μ coefficient friction varies equation obtaining system algebraic equation iterative fsw process model initially μ assumed 0 4 fn normal numerical method used solve system obtain solution thermal problem 33 34 use comsol software force ri distance axis rotation tool one point interface shoulder ω tool rotational speed part modeling principle fig 2 present step follow model phenomenon heat transfer fsw welding rpm friction surface shoulder different welding case homogeneous al al mg mg het heat generated locally pin part interface consists 3 part erogeneous al mg mg al 29 30 heat generated shearing material b heat generated friction thread surface pin c heat generated friction bottom surface pin 2c r mahesha et al e r l p r c e e ingsxxx xxxx xxx fig 1 diagram showing initial boundary condition fsw welding fig 2 comsol software interface window command menu 3 1 choose type study 3 1 1 define geometry numerical simulation carried sheet aluminum alloy choose dimension space going work al 2024 t4 magnesium az31b 320 mm long 102 mm wide choose type physical phenomenon studied 12 7 mm thick assembled pair different case 1 6 choose type study tool made h 13 steel pin geometry cylindrical introduce parameter phenomenon program height 12 mm radius 6 mm shoulder tool also clicking right cylindrical height 30 mm plate welded globaldefinitions parameter radius 25 mm 10 introduce function defines variation shear stress function temperature clicking right global defi draw two plate welded must click right nitions function interpolation geometry 1 block inject dimension plate define calculation time step right clicking global display select build selected definition function step draw shoulder pin plate except choose cylinder instead block inject correct dimension 3c r mahesha et al e r l p r c e e ingsxxx xxxx xxx complete geometry right click union choose configuration aluminum 2024 t4 magnesium az31b alloy build selected fig 3 two homogeneous al al mg mg two heterogeneous al mg mg al define repeat step tool 3 1 2 define heat source 3 1 4 define mesh define surface heat source equation shoulder create mesh choose free tetrahedral option pin click right definition variable select mesh 1 menu choose extremely fine dimensioning size boundary corresponding equation 6 menu refined mesh around tool order better define initial boundary condition capture thermal gradient area 10 number degree enter initial temperature part expand heat freedom degree freedom solve obtained 109749 transfer solid initial value 1 section define speed translation click right heat 3 1 5 solution transfer solid 1 translational motion case sheet problem quite light solver configuration default moving respect tool software enough solve 6 10 eulerian frame 1 10 configure solver expand menu study 1 solver config top side surface well face shoulder urations solver 1 stationary solver 1 right click direct contact enable launch calculation click right study 1 air convection whose coefficient h_upside ambient choose compute air introduce clicking right heat transfer solid 1 heat flux select corresponding face without 3 1 6 convergence forgetting define t0 external temperature 10 resolution problem took 77 gave decreasing way face bottom enough change convergence curve convergence reached 8 iteration coefficient h_downside table machine error 10 5 fig 7 define boundary condition shoulder workpiece inter face right click heat transfer solid boundry heat source 4 result discussion selecting corresponding face introduce variable describing shoulder workpiece heat source according fig 8 fig 9 temperature distributed similarly define boundary condition pin part gradually shoulder towards border part notice welded interface temperature distribution symmetrical respect downstream transverse face plate limit condition middle plane x z 1 6 calculated maximum temperature imposed clicking right heat transfer solid lower melting temperature material case outflow magnesium tmax 843 7 k 91 tf aluminum tmax 702 upstream transverse face plate initial temperature k 75 tf maximum temperature located t0 imposed clicking right heat transfer mixed zone shift towards rear center tool due solid temperature 1 movement translation rotation tool fig 8 fig 9 show temperature distribution depth 3 1 3 define material plane z shoulder around pin maximum define material part must go material browser temperature decrease shoulder towards lower surface select desired material assign corresponding plate thus creating maximum zone form inverted geometric domain 35 36 quasi cone slight asymmetry 10 result translation movement tool rotation material around tool h13 steel un t20813 solid pin generates two side advance advancing side withdrawal retreating side regarding plate material fig 4 fig 5 fig 6 tested four chemical mc p residue favorable fig 3 complete geometry 4c r mahesha et al e r l p r c e e ingsxxx xxxx xxx fig 4 specific heat constant pressure cp thermal conductivity k function temperature k h13 steel fig 5 specific heat constant pressure cp thermal conductivity k function temperature k 2024 t6 aluminum alloy fig 6 specific heat constant pressure cp thermal conductivity k function temperature k magnesium az31b alloy characteristic use cr residue significant amount processing o alkaline oxide 7 8 alkaline earth oxide 9 0 act heterogeneous welding aluminum alloy magnesium alloy flux cr firing stage flux provide greater formation using tig mig fe electron beam even laser welding process liquid phase consequently help close porosity subject several study hand particle increasing relative density sintered material 1 interested welding using fsw make weld work residue smaller p improve densification cr interested idea studying heat transfer fsw body forming greater amount liquid phase firing welding aluminum 2024 t4 magnesium az31b represents concluded therefore residue processing o first step study weld quality used clayey cr benefit using waste flux cr providing ecological economic destination waste 5c r mahesha et al e r l p r c e e ingsxxx xxxx xxx fig 7 curve evolution convergence according iteration fig 8 temperature distribution xz plane temperature distribution welding al al fig 9 temperature distribution x z plane temperature distribution mg mg welding 5 conclusion mg al main result obtained follows work numerical study performed comsol multi temperature distribution gradual shoulder towards physic software made four configuration case two ho part boundary symmetrical middle plane x z mogeneous al al mg mg two heterogeneous al mg center tool except heterogeneous case clear 6c r mahesha et al e r l p r c e e ingsxxx xxxx xxx dysmetria observed due different thermal property 10 baosheng z xiangdong j jiaqing c zong yq numerical simulation onto material particularly superior thermal conductivity preliminary period friction hydro pillar processing friction stitch welding proceeding international conference mechanic automation aluminum control engineering mace 2010 jun 26 28 wuhan china piscataway ieee two homogeneous case welding isothermal contour conference publication 2010 p 5617 denser weaker value upstream compared downstream 11 r ramesh dinaharan e akinlabi n murugan microstructure mechanical characterization friction stir welded dual phase brass journal widen increase value hand het material engineering performance 2018 27 4 1544 1554 erogeneous case difference isotherm greater 12 r ramesh dinaharan ravi kumar e akinlabi microstructure aluminum plate also notice downstream thermal mechanical characterization friction stir welded high strength low alloy steel material science engineering 2017 687 39 46 distribution reached slightly shifted towards plate due 13 l cui x yang wang x hou j cao w xu 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