INTISARI

Aluminium dan paduannya banyak diminati karena warnanya yang menarik, ringan, kuat dan tahan korosi. Aluminium paduan yang banyak digunakan di industri diantaranya adalah AA2024-O, AA5052-H112 dan AA6061-T6. Ketiga material tersebut memiliki karakteristik berbeda. AA2024-O memiliki kekuatan tinggi dan dapat ditingkatkan melalui proses perlakuan panas. AA5052-H112 memiliki kekuatan moderat, tahan korosi dalam lingkungan air laut dan kekuatannya dapat meningkat melalui proses *strain hardening*. AA6061-T6 memiliki kekuatan sedang dan kekuatannya dapat meningkat dengan proses perlakuan panas. Penyambungan ketiga material tersebut dengan metode *resintance spot welding* (RSW) sulit dan sering mengalami cacat. Kesulitan tersebut dapat diatasi melalui penyambungan dengan metode *friction stir spot welding* (FSSW) yang merupakan jenis las friksi dalam fasa solid. Oleh karena itu penelitian pengelasan aluminium AA2024-O, AA5052-H112 dan AA6061-T6 dengan metode FSSW perlu dilakukan. Penyambungan dilakukan secara *similar* dan *dissimilar* dengan variasi kecepatan putar dan geometri *tool*. Penelitian bertujuan untuk mengkaji karakteristik sambungan lasan FSSW AA2024-O, AA5052-H112 dan AA6061-T6 secara *similar* dan *dissimilar*. Selanjutnya pengaruh kecepatan putar dan geometri *tool* terhadap struktur mikro dan sifat-sifat mekanis sambungan juga dikaji.

Penelitian ini menerapkan metode eksperimen. Bahan yang digunakan adalah lembaran AA2024-O, AA5052-H112 dan AA6061-T6 dengan tebal 3 mm. Proses penyambungan FSSW menggunakan *tool* dari baja alat H13 yang terdiri 3 macam geometri *tool* (silindris, bertingkat, tirus) dengan bantuan mesin *milling* vertikal. Penelitian dilakukan dalam 5 tahap yang meliputi penyambungan dan karakterisasi FSSW *similar* AA2024-O, *similar* AA5052-H112, *similar* AA6061-T6, *dissimilar* AA2024-O - AA5052-H112 dan *dissimilar* AA2024-O - AA6061-T6. Variabel bebas pada penelitian meliputi geometri *tool*, kecepatan putar *tool* dan material yang disambung. Variabel terikat terdiri dari struktur mikro dan sifat mekanis. Struktur mikro meliputi dimensi *hook*, struktur makro dan mikro lasan. Sifat mekanis terdiri dari kekerasan mikro, beban *tensile-shear* (TS) dan *cross-tension* (CT). Selain itu pengukuran temperatur pengelasan, pengamatan patahan dan SEM dilakukan.

Hasil penelitian menunjukkan bahwa pembangkitan panas pada proses FSSW ditentukan oleh geometri dan putaran *tool*. Pembangkitan panas meningkat dengan meningkatnya putaran *tool*. *Tool* bertingkat membangkit panas yang lebih tinggi dari *tool* lainnya. Struktur FSSW memiliki ciri khas terdapatnya keyhole yang membentuk ikatan interface disekelilingnya. Ikatan pada daerah lasan dapat diamati dan dibedakan menjadi *fully bonded region* (FBR), *partially bonded region* (PBR) dan *unbonded region* (UBR). *Hook* terbentuk di daerah sambungan memiliki dimensi lebar (Hw) dan tinggi (Hh). Struktur mikro daerah lasan terdiri dari *stirring zone* (SZ), *thermomechanical affected zone* (TMAZ) dan *heat affected zone* (HAZ). Struktur SZ memiliki butir paling halus. Butir TMAZ lebih kasar dengan ciri adanya perubahan orientasi butir karena deformasi. Struktur HAZ identik dengan material dasar dan butirnya cenderung lebih kasar. Kekerasan di SZ paling tinggi, dan menurun ketika masuk TMAZ dan HAZ. Beban geser dan tarik maksimum masing-masing sambungan berbeda menurut jenis material, kecepatan putar dan geometri *tool* yang digunakan. Beban geser dan tarik sambungan FSSW meningkat dan menurun dengan meningkatnya kecepatan putar *tool*. Beban geser tertinggi terjadi pada sambungan *dissimilar* AA2024-O -AA6061-T6 dan beban tarik tertinggi terjadi pada sambungan *dissimilar* AA2024-O - AA5052-H112. Penggunaan *tool* silindris dan kecepatan putar 1400 rpm menghasilkan beban sambungan FSSW yang optimal. Mode patah sambungan FSSW umumnya terdiri dari *circumferensial* dan *nugget pullout*.

Kata kunci: FSSW, *similar*, *dissimilar*, AA2024, AA5052, AA6061

ABSTRACT

Aluminum and its alloys are in great demand because of their attractive color, light weight, strength and corrosion resistance. Aluminum alloys that are widely used in industry include AA2024-O, AA5052-H112 and AA6061-T6. These three materials have different characteristics. AA2024-O has high strength and can be improved through a heat treatment process. AA5052-H112 has moderate strength, it can resists corrosion in seawater environments and its strength can be increased through a strain hardening process.The three types of aluminum in their engineering aplications often require a joining proceses. On the other hand AA6061-T6 has medium strength and its strength can be increased by heat treatment process. The joining of these materials using the resistance spot welding (RSW) method is difficult and often suffers from defects. To overcome these difficulties, the joining process can be carried out using the friction stir spot welding (FSSW) method which is a type of friction welding in the solid phase. For this reason, research on welding aluminum AA2024-O, AA5052-H112 and AA6061-T6 with the FSSW method was carried out. The welding is done in a similar and dissimilar materials with variations in rotational speed and tool geometry. This research aims to study and examine the characteristics of similar and dissimilar FSSW AA2024-O, AA5052-H112 and AA6061-T6 weld joint. Furthermore, the effect of tool rotational speed and tool geometry on microstructure and mechanical properties of the welds is studied.

In this research, sequence of experimental methods has been conducted as the follows. The materials used were AA2024-O, AA5052-H112 and AA6061-T6 sheets with a thickness of 3 mm. The FSSW joining process used tool of H13 tool steel which consisted of 3 different tool geometries (cylindrical, step and taper) and a vertical milling machine. The research was carried out in 5 stages which included joining and characterizing of FSSW similar AA2024-O, similar AA5052-H112, similar AA6061-T6, dissimilar AA2024-AA5052 and dissimilar AA2024-AA6061. The independent variables in this study included tool geometry, tool rotational speed and materials being joined. The dependent variable included microstructure and mechanical properties. The microstructure properties included the hook dimensions and the macro-micro structure of the weld. Mechanical properties consisted of micro-hardness, tensile-shear (TS) and cross-tension (CT) load. In addition, welding temperature measurements, fracture observations and SEM were carried out.

The results show that the heat generation in the FSSW process is controlled by the tool geometry and rotational speed. Heat generation increases with increasing tool rotational speed. A step tool generates higher heat than other tools. The FSSW structure is characterized by the presence of a keyhole that forms an interface bond around it. Bonds in the weld area can be observed and divided into fully bonded region (FBR), partially bonded region (PBR) and unbonded region (UBR). In the joint area, a hook is formed which has dimensions of width (Hw) and height (Hh). The microstructure regions of the weld consists of stirring zone (SZ), thermomechanical affected zone (TMAZ) and heat affected zone (HAZ). The SZ structure has the most fine grains. TMAZ is characterized by the presence of cross and bent grains as result of a change in grain orientation due to deformation. The HAZ consisted of coarser grains. Hardness in SZ is highest, and decreases when entering TMAZ and HAZ. The maximum shear and tensile loads of each joint differ according to the type of material, tool geometry and rotational speed are used. The shear and tensile loads of the FSSW joint increase and decrease with increasing tool rotational speed. The highest shear load occurs in the AA2024-O - AA6061-T6 dissimilar weld and the highest tensile load occurs in the AA2024-O - AA5052-H112 dissimilar weld. The use of a cylindrical tool and a rotational speed of 1400 rpm results in optimal FSSW joint strength. The fracture mode of the FSSW joint generally consists of circumferential and nugget pullout.

Key word: FSSW, similar, dissimilar, AA2024, AA5052, AA6061