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Name of the Scholar: Pankaj Kumar Chauhan

Name of the Supervisor: Dr. Sabah Khan

Name of the Department/ Centre: Mech. Engg. Department/ Faculty of Engg. & Tech. JMI

Topic of Research

Analysis and Simulation of Functionally Graded Materials Based on Mechanical Behavior using FEA

FINDING

The present work is focused on the fabrication and characterization of metal-metal (Al-Cu) FGM. The FGM samples are developed using powder metallurgy technique. Fine Al (200 mesh size, 99% pure) and Cu powder (325 mesh size, 99.5% pure) is used for the fabrication of FGM samples. The proposed gradation consists of multilayers of various Cu compositions (100, 90, 80, 70, 60, 50, 40, 30, 20, 10, 0 weight %) on Al substrate.

Characterizations of the prepared FGM samples areconducted to discuss the morphological characteristics. Optical microscopy, in addition to scanning electron microscopic analysis (SEM), is conducted to validate the microstructure and gradation plan in developed FGM samples. Energy dispersive spectroscopy (EDS) is also performed to verify the elemental composition of the constituent elements throughout the FGM specimens along the gradation axis. In addition, Fourier transform infrared spectroscopy is conducted to identify the elemental composition based on transmittance versus wavenumber variation. X-ray diffraction analysis is also done to trace out the chemical reaction between constituent elements and to identify the various phases formed during sintering process.

In this work, based on various gradation laws that are reported in literature, theoretical estimation of the effective FGM properties is presented in detail. Physical, mechanical and thermal properties such as density, relative density, porosity, hardness, tensile strength and thermal conductivity tests are performed to evaluate the effect of gradation on developed FGM samples. The tensile fracture morphology of the developed FGMis analyzed using SEM. Transient heat transfer apparatus, fitted with fins, is used to estimate the time to attain steady state condition with the developed specimens. Steady state thermal analysis, using FiniteElement Analysis (FEA)technique,is also conducted over the heat sink model to enumerate the associated parameters.

The detailed study of the physical samples revealed that the objective of Al-Cu FGM development is successfully achieved. The microstructural analysis of the samples revealed satisfactory bonding among successive layers and homogeneous dispersion of constituent elements in individual layers. At higher magnification micro pores, clustering of particles and porosity is observed in the SEM micrographs. EDS confirmed the

presence of Cu and Al elements as per the desired gradation plan. XRD micrographs revealed different phases of Al and Cu present in FGM samples. Presence of $CuAl_2$ in XRD spectrum validated the occurrence of chemical reaction which in turn confirms that material is not amorphous in nature. FTIR results of FGM samples revealed that Al and Cu elements are present at the same transmittance percentage and wavelength number range as shown by individual constituent element FTIR results. Based on different gradation laws, it was observed that the theoretical estimation of effective material properties mayprovide an insight to design a tailor made material with variable properties along the gradation axis for any specific application.

Enhancement in density of FGM specimen is observed with the increased percentage of Cu elements in Al substrate. In comparison to bottom and top region, the highest porosity in the middle region of FGM specimen is noticed. Increase in the hardness of FGM samples is witnessed up to 20% reinforcement layers and beyond that a decreasing trend in hardness is observed. Tensile strength of FGM sample is enhanced up to 10.95% compared to pure Cu samples while 22.59% decrease in tensile strength is observed compared to pure Al sample. SEM analysis of fractured surface exhibited plastic deformation with brittle rupture in specific small region. Decrease in thermal conductivity of all the samples is observed with increase in temperature. Thermal conductivity of FGM exhibited increasing drift from bottom to top layer. An increase of 31.18%, compared to pure Al samples, and a decrease of 25.65%, compared to pure Cu sample, in thermal conductivity of FGM is noticed. Transient heat transfer analysis revealed that the temperature at the tip of the developed samples became stable after twenty minutes. The temperature and heat flux profiles were compared using steady state thermal analysismodule of ANSYS (R14.5) software.

Keywords: Functionally graded materials, Gradation laws, Effective material properties, Characterization, Finite element analysis.